The Thrower's Elbow: Arthroscopic Treatment of Valgus Extension Overload Syndrome

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Abstract Injury to the medial collateral ligament of the elbow (MCL) can be a career-threatening injury for an overhead athlete without appropriate diagnosis and treatment. It has been considered separately from other athletic injuries due to the unique constellation of pathology that results from repetitive overhead throwing. The past decade has witnessed tremendous gains in understanding of the complex interplay between the dynamic and static stabilizers of the athlete's elbow. Likewise, the necessity to treat these problems in a minimally invasive manner has driven the development of sophisticated techniques and instrumentation for elbow arthroscopy.

MCL injuries, ulnar neuritis, valgus extension overload with osteophyte formation and posteromedial impingement, flexor pronator strain, medial epicondyle pathology, and osteochondritis dissecans (OCD) of the capitellum have all been described as sequelae of the overhead throwing motion. In addition, loose body formation, bony spur formation, and capsular contracture can all be present in conjunction with these problems or as isolated entities. Not all pathology in the thrower's elbow is amenable to arthroscopic treatment; however, the clinician must be familiar with all of these problems in order to form a comprehensive differential diagnosis for an athlete presenting with elbow pain, and he or she must be comfortable with the variety of open and arthroscopic treatments available to best serve the patient.

An understanding of the anatomy and biomechanics of the thrower's elbow is critical to the care of this

population. The preoperative evaluation should focus on a thorough history and physical examination, as well as on specific diagnostic imaging modalities. Arthroscopic setup, including anesthesia, patient positioning, and portal choices will be discussed. Operative techniques in the anterior and posterior compartments will be reviewed, as well as postoperative rehabilitation and surgical results. Lastly, complications will be reviewed.

Introduction

Injury to the medial collateral ligament of the elbow (MCL) can be a career-threatening injury for an overhead athlete without appropriate diagnosis and treatment. The syndrome of valgus extension overload describes the unique constellation of injuries resulting from repetitive overhead throwing in the face of MCL insufficiency. These injuries classically occur in baseball players, but myriad other sports employ the mechanics of overhead arm motion with the generation of excessive valgus and extension forces, including tennis, softball, football, lacrosse, and many track and field events. Likewise, youth participation in organized sports is on the rise, and the age of onset is progressively earlier. Chen and associates [1] reported that the incidence of upper extremity injury in baseball is related to the number of years of participation and to the age of the athlete; elbow pain was reported in 20% of athletes aged 8–12 years, in 45% of athletes aged 13–14 years old, and in 58% of high school and college athletes.

The last decade has witnessed tremendous gains in understanding of the complex interplay between the dynamic and static stabilizers of the athlete's elbow. Likewise, the necessity to treat these problems in a minimally invasive manner has driven the development of sophisticated techniques and instrumentation, such as elbow arthroscopy. Formal reconstruction of the MCL involves an open surgical procedure, yet arthroscopy is a

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valuable adjunct both diagnostically and therapeutically. Initially considered a procedure fraught with complications and with few definitive indications, arthroscopy of the elbow has evolved to become established as a safe and reliable procedure that forms the mainstay of surgical treatment of many elbow disorders.

Several authors have described the most common injuries seen in the throwing athlete's elbow [1–7]. MCL injuries, ulnar neuritis, valgus extension overload with osteophyte formation and posteromedial impingement, flexor pronator strain, medial epicondyle pathology, and osteochondritis dissecans (OCD) of the capitellum have all been described as sequelae of the overhead throwing motion. In addition, loose body formation, bony spur formation, and capsular contracture can all be present in conjunction with these problems or as isolated entities.

The scope of this discussion will focus on the treatment of MCL injuries in the thrower's elbow. The authors review this topic from the perspective of elbow arthroscopy in a pending publication [52]. The clinician must be familiar with all of the problems mentioned above in order to form a comprehensive differential diagnosis for an athlete presenting with elbow pain, and he or she must be comfortable with the variety of open and arthroscopic treatments available to best serve the patient. Arthroscopy is often an initial procedure preformed before an open procedure, e.g., before MCL reconstruction. In this setting, arthroscopy can be useful for diagnostic and therapeutic purposes to identify, rule out, or treat intra-articular pathology such as cartilage lesions, loose bodies, osteophytes, or capsular contractures. Definitive treatment of MCL insufficiency then follows.

Anatomy and biomechanics

The elbow joint is a ginglymus, or hinge, joint, and the bony ulnohumeral articulation provides stability at the extremes of motion, from 0° to 20° of flexion and beyond 120° of flexion [2]. The intervening 100°, which is the primary arc of motion used in overhead throwing, relies progressively on the static and dynamic soft tissue restraints to provide stability. In full extension, valgus stability is contributed equally by the bony articulation, the medial collateral ligament, and the anterior capsule [3]. Toward 90° of flexion, the MCL assumes a greater relative role as the anterior capsule becomes lax; in this position, it has been shown to provide 54% of the stabilizing force against a valgus stress [3, 8].

The anatomy of the medial collateral ligament has been well described, as well as the relative contribution of its anatomic components to valgus stability [2, 3, 8–10]. The anterior bundle of the MCL is the primary restraint to valgus stress from 20° to 120° of flexion, and tensile stresses approaching the point of failure are generated during the acceleration phase of high velocity throwing [2, 3, 8–13].

The mechanics of high velocity throwing, especially pitching, explain the constellation of elbow injuries seen in

the overhead athlete [2–5]. Valgus forces have been estimated to reach 64 N m during the late cocking and early acceleration phases of throwing, and compressive forces of 500 N have been documented at the lateral radiocapitellar joint [2, 12]. Angular velocity has been estimated to reach 6,000°/s for shoulder internal rotation and 5,000°/s for elbow extension in the acceleration phase of throwing [13]. After the elbow flexes from 90° to 120° in the early and late cocking phases, the acceleration phase initiates: the trunk rotates, the shoulder internally rotates, and the elbow extends to approximately 25° at the time of ball release. This acceleration occurs over 50 ms. As the elbow extends in the face of such tremendous acceleration, the tangentially directed forces produce a valgus and extension moment, with resulting tensile forces across the medial side of the elbow, compressive forces across the lateral aspect of the joint, and shear forces in the posterior compartment [2, 3, 13]. The term valgus extension overload describes this phenomenon [2, 14].

Cain and associates [2] provide an elegant description of the sequelae of this overload syndrome. Repetitive tensile loads experienced by the anterior bundle of the MCL at forces near the point of failure may eventually lead to ligament attenuation or failure. The valgus overload is then accentuated, and excessive valgus moments may lead to stretch of the other medial structures, resulting in ulnar neuritis, flexor-pronator mass tendonopathy, or medial epicondyle apophysitis in the skeletally immature patient. Corresponding overload on the lateral side of the elbow may lead to abnormal compressive forces across the radiocapitellar articulation, resulting in chondromalacia, osteophyte formation, and loose bodies. Finally, at the extremes of extension, posterior shear forces may produce olecranon osteophytes at its posteromedial tip, with a corresponding “kissing lesion” in the olecranon fossa and posteromedial trochlea. The clinician treating this population of patients must possess a high index of suspicion for underlying valgus laxity, resulting from injury to the MCL, as the etiology of many of these disorders.

Preoperative evaluation

A thorough discussion of the history, physical examination, and diagnostic imaging is beyond the scope of this review. Some key points, however, warrant mention as they relate to arthroscopy and MCL reconstruction.

History

Several key points should be pursued in a thorough patient history of the overhead athlete. The nature, mechanism, acuity of onset, chronicity, and symptoms associated with the pain or injury are important features to elucidate, as with any presenting chief complaint. Specific to an overhead athlete, however, are features that relate to training and performance. Were there any changes in training regimens or was there a history of prior injuries? Changes in performance, such as pitch speed, accuracy, and stamina, are

important. Do the symptoms arise in a consistent phase of the throwing cycle, such as the late cocking phase or the acceleration phase? Conway et al [15] reported that 85% of overhead athletes with medial elbow instability experienced their symptoms during the acceleration phase.

A history of mechanical symptoms, such as locking or catching, is important, as well as posterior pain, exacerbated by forced extension. These symptoms may represent loose bodies, chondral flaps, or posteromedial impingement.

The ulnar nerve is a critical source of pathology and of potential arthroscopic complications. A history of ulnar neuritis is suggested by paresthesias or dysesthesias in the distribution of the ulnar nerve, often radiating from the medial elbow into the ulnar two digits. Intrinsic muscle hand weakness or clumsiness with fine motor movements may also belie ulnar neuropathy. Of the utmost importance in all patients undergoing elbow arthroscopy is to evaluate the stability of the ulnar nerve within the cubital tunnel. O'Driscoll and Savoie [16] noted a 16% incidence of ulnar nerve subluxation in the population at large. A subluxating ulnar nerve is at risk for injury when making and utilizing medial portals.

Physical examination

A thorough examination of the entire upper extremity is important when evaluating the overhead athlete. A cervical spine etiology of shoulder pain is well established. Likewise, cervical radiculopathy can certainly mimic local ulnar neuritis or other medial elbow pain. Similarly, the mechanics of throwing rely on a fluid kinetic chain, which includes the shoulder. Primary shoulder pathology can affect pitching mechanics, which can create excessive stress on the elbow. As with any orthopaedic evaluation of musculoskeletal complaints, identification of proximal and distal sources of pathology will aid the clinician in making an accurate diagnosis.

Inspection of the elbow begins with an assessment of the resting position of the elbow and its carrying angle. An increase in the carrying angle from the normal of 11° of valgus in men and 13° of valgus in women to an angle of further valgus may indicate an adaptation to the repetitive stress of valgus instability [2]. Angles of greater than 15° in professional pitchers have been documented [17]. The presence of an effusion, scars, developmental abnormalities, or signs of previous trauma is important to identify.

Range of motion (ROM) is important to assess for flexion/extension and supination/pronation, as well as the nature of the endpoints of extension and flexion. Cain et al [2] describe the “end-feel” at the extremes of motion in the physical examination of the throwing athlete. Normal extension terminates in the firm sensation of the posterior bony articulation making contact in the olecranon fossa, and normal flexion terminates in the abutment of the soft tissues of the distal humerus and the proximal forearm. Elbow flexion contractures are seen in up to half of professional pitchers [17], and are not necessarily indicative of injury. A soft end feel in extension may indicate a soft tissue contracture, and a bony end-feel in terminal

flexion often indicates anterior bony osteophytes or loose bodies.

Evaluation of medial stability is the cornerstone of the assessment of the overhead athlete with valgus extension overload. This is covered thoroughly in the aforementioned reviews, with techniques described in detail for the optimal assessment of medial elbow stability, including the “milking maneuver” and the moving valgus stress test [1–7, 10, 14, 15]. *The moving valgus stress test:* Starting with the arm in full flexion, the examiner applies a constant valgus force to the elbow and then quickly extends the elbow. The patient experiences reproduction of his painful symptoms with an apprehension-like response in an arc as the elbow passes from 120° of flexion to 70° of extension. *The milking maneuver* is performed by having the patient reach under his injured arm with the opposite hand and grab the thumb of the injured arm. Continued pulling will place a valgus stress on the elbow under examination. Of note, the clinician should palpate the MCL in approximately 60° of flexion, to move the flexor pronator mass anterior to the fibers of the anterior band. As noted, examination of the ulnar nerve for subluxation is critical, as many patients will be unaware of this “normal” variant.

Diagnostic imaging

In the preoperative evaluation of the elbow, routine radiographs include AP, lateral, and two oblique views in 110° of flexion, to identify posteromedial olecranon osteophytes or evidence of traction injury to the medial epicondyle (Fig. 1) [14]. Bone scan and CT scan can be utilized for the assessment of bony pathology, including stress fractures and avulsion fractures. CT arthrogram has been used with high accuracy in the evaluation of ligament injury [18].

MRI remains the gold standard for the evaluation of the soft tissues about the elbow, including ligamentous injury, tendonopathy, and lesions of the articular cartilage (Fig. 2). Yet the accuracy of MRI in the evaluation of subtle MCL injuries, and the utility and necessity of arthrography and

Fig. 1. AP radiograph of a left elbow demonstrates heterotopic ossification near the medial epicondyle at the flexor-pronator origin, consistent with prior trauma.

Fig. 2. Coronal gradient echo MR image demonstrates chronic injury to the midsubstance and humeral attachment of the MCL

contrast, remain controversial [1, 2, 18–20]. Potter and Gaary et al have demonstrated a high sensitivity and specificity of noncontrast MRI using specially designed sequences [19–21]. This maintains the minimally invasive nature of the test and limits costs. A major additional advantage of these sequences is excellent visualization of the articular cartilage in a highly specific and sensitive manner [22].

Surgical indications and decision making

As opposed to ligamentous injuries about other joints, where instability and dysfunction in activities of daily living are commonplace, insufficiency of the elbow MCL is rarely symptomatic beyond the overhead athlete. Certain specific occupations or avocations might elicit recurrent symptoms, but in general, operative reconstruction of the MCL should be limited to the overhead athlete who wishes to return to the same level of competition and who has failed conservative management.

Arthroscopy is a powerful tool for the diagnosis and treatment of many of the sequelae of valgus extension overload, but careful consideration must be given to choosing the appropriate indications. The specific nature of each problem dictates the relative role of arthroscopy in the treatment algorithm. Elbow arthroscopy can be utilized to diagnose intra-articular pathology, to debride osteophytes and otherwise treat cartilage injuries, and to release capsular contracture.

Utilized in conjunction with cartilage-specific MRI sequences in evaluating intra-articular pathology including articular cartilage lesions [22], arthroscopy remains the gold standard in most institutions for the thorough evaluation of the elbow joint before MCL reconstruction. Subtle articular cartilage lesions, including mild chondromalacia, can be identified. The precise geometry of larger defects, including the quality of the surrounding “shoulder” of cartilage, can be accurately determined (Fig. 3). Loose bodies, including those not ossified, can be identified and

Fig. 3. Articular cartilage lesions can be accurately assessed at the time of arthroscopy, with determination of the precise size and location of the defect, as well as the quality of the surrounding “shoulder” of cartilage

removed (Fig. 4). Finally, instability of the elbow can be evaluated arthroscopically by applying a valgus or varus load and measuring the amount of medial or lateral joint opening, respectively. A valgus force is applied across the joint and a probe with known dimensions can be used to estimate opening. In a normal elbow, a maximum of 1–2 mm of opening will be seen in the medial compartment upon valgus stressing in a pronated position (usually, no opening is observed). In MCL insufficiency, an opening of 3 mm or greater will be observed (Fig. 5) [23, 24, 33]. Determination of the degree of instability is critical before reconstruction, and often arthroscopic visualization will provide the most accurate assessment.

As soon as a diagnosis is made or confirmed, the primary utility of arthroscopy is the treatment of the pathologic condition. Loose bodies should be removed, impinging osteophytes debrided back to a normal contour, and articular cartilage lesions addressed. Loose, unstable cartilage flaps may be debrided, and depending on the severity and location of the defect, marrow stimulation techniques such as microfracture may be performed.

Fig. 4. Loose bodies can be identified and removed arthroscopically

Fig. 5. **a** Arthroscopic anterior view of the medial elbow, with no external stress applied. **b** Same view, with a valgus stress applied. Note the excessive opening of the medial compartment, indicating MCL insufficiency

Capsular contracture may also be addressed arthroscopically. Several reports discuss the utility of arthroscopic release for arthrofibrosis of the elbow [25, 27], posttraumatic capsular contracture [26], and isolated causes of loss of motion, including loose bodies, osteophytes, and anterior capsular contracture [28, 44]. Although this technique affords a minimally invasive and reliable means to address this difficult problem, it is not without risks [29]. The surgeon should have a comprehensive understanding of the surrounding anatomy, as well as advanced technical experience of arthroscopic technique, before undertaking arthroscopic capsular release.

Operative setup

Anesthesia

Many options exist for regional and general anesthesia, alone or in combination. Regional anesthesia, with or without i.v. sedation, includes interscalene block, axillary (or subcoracoid) block, or Bier block. Regional anesthesia

optimizes postoperative pain control, minimizes postoperative nausea associated with general anesthesia, and facilitates positioning via the cooperation of the patient. Disadvantages include limitations in patient tolerance of certain positions and the inability to perform a thorough postoperative neurological examination of the involved extremity.

The advantages of general anesthesia include more options for patient positioning, including the prone and lateral decubitus positions, and total muscle relaxation, including the shoulder girdle and trunk musculature. Disadvantages include postoperative tolerance and potentially a longer stay in the postsurgical recovery unit.

We prefer axillary block anesthesia with i.v. sedation. Patient tolerance is maximized, positioning in the supine position is a simple process, as noted below, and postoperative comfort is maximized.

Patient positioning

The supine position, originally described by Andrews and Carson [30], positions the shoulder in 90° of abduction, with the elbow flexed 90° and the forearm suspended by a mechanical traction device. We prefer a modification of this position, with the shoulder flexed 90° in addition, such that the forearm is suspended over the chest (Fig. 6). This position requires a mechanical arm holder, as it stably positions the arm in space and eliminates the need for an additional assistant. Several options exist, including the McConnell arm holder (McConnell Orthopaedic Manufacturing Company, Greenville, TX) and the Spider hydraulic arm holder (Spider® Limb Positioner, Tenet Medical Engineering, Calgary, Canada), which more rigidly suspends the arm in space and can be easily adjusted to accommodate any changes in position.

This modified supine position (as described) is preferred, utilizing the hydraulic arm holder. Advantages of this supine position include the ease of patient positioning and airway access for the anesthesiologist. The arm may

Fig. 6. The modified supine position, with the arm suspended over the chest, facilitates patient positioning and conversion to an open position, but also allows for manipulation of the arm and easy access to the posterior compartment

easily be positioned to facilitate arthroscopic work. By adjusting the position of the arm in space, the anterior and posterior compartments can both be accessed with the relative advantages of the standard supine and prone positions, respectively. Particularly for the throwing athlete, osteophyte debridement or microfracture needs to be done in the posterior compartment to address posteromedial impingement, and this work is performed most simply through this position. In addition, with the arm flexed over the chest, the anterior neurovascular structures drop away from the anterior capsule with gravity, thus making anterior compartment work safer. Finally, the conversion to an open procedure, such as medial or lateral ligament reconstruction, ulnar nerve transposition, or the treatment of medial apophyseal injury can be easily performed. The arm is removed from the holder and placed on an arm board, where the seated surgeon may progress.

Disadvantages of the supine position have historically been reported to include limited access to the posterior compartment and the difficulty of manipulating the elbow if in a traction device [31]. With the modifications as noted above, including flexing the shoulder to bring the forearm over the chest and using an arm holder in which the arm can be removed, these concerns are minimized.

Portal placement

Several portals have been described for elbow arthroscopy, and all have been utilized by different authors with facility [16, 30–32, 34]. Some of the most popular portals include the proximal medial, proximal lateral, anterolateral, midlateral, anteromedial, posterolateral, and the straight posterior (or transtriceps) portals, as well as many slight variations on a theme [31]. The anatomic locations, indications, and potential complications of these portals are discussed thoroughly in these reviews. For arthroscopy of the athlete's elbow and treatment of the sequelae of valgus extension overload, our most commonly used portals will be described (Fig. 7).

Midlateral portal

The midlateral portal has also been referred to as the soft spot portal and the direct lateral portal. It is located in the center of the triangle formed by the lateral epicondyle, the tip of the olecranon, and the radial head. The anconeus is penetrated in this portal, and the nearest neurovascular structure is the posterior antebrachial cutaneous nerve [35]. It is most often used to inject fluid at the beginning of the case to distend the capsule, but it can also be utilized to remove loose bodies stuck in the lateral gutter.

Proximal lateral portal

This portal, originally described independently by Field et al [36] and by Stothers and colleagues [34], is located 2 cm proximal to the lateral epicondyle and lies directly on

Fig. 7. **a** Our most commonly used portals are the midlateral, the proximal lateral, the posterolateral, and the transtriceps portals. **b** An intraoperative photograph demonstrating the most commonly used portals

the anterior surface of the humerus. The trocar pierces the brachioradialis and distal brachialis before penetrating the lateral elbow capsule. Stothers et al [34] demonstrated that the posterior antebrachial cutaneous nerve is on average 6.1 mm away (range 0–14 mm), but lies in direct contact with the cannula 29% of the time. The radial nerve lies 4.9 mm away in extension and 9.9 mm away in flexion, which is approximately twice as far as the more hazardous anterolateral portal. The authors note that the capsular attachments are such that, in flexion, the radial nerve is carried away from the portal when the joint is distended. Excellent visualization is possible of the medial and lateral sides of the joint, the anterior and lateral aspect of the radial head and capitellum, and the lateral gutter.

Proximal medial portal

For arthroscopy of the athlete's elbow and treatment of the sequelae of valgus extension overload, the previously described portals usually suffice, and a medial portal is not usually necessary. When mandated by the presence of a loose body or areas of cartilage wear in the anterior

compartment, especially medially, a proximal medial portal as described by Poehling and colleagues [32] is favored. It is located 2 cm proximal to the medial epicondyle and 1–2 cm anterior, taking care to stay anterior to the medial intermuscular septum. The elbow must be maintained at 90° of flexion during placement of this portal, and subluxation of the ulnar nerve or a history of transposition is a contraindication [31]. The structure most at risk is the medial antebrachial cutaneous nerve, located at an average of 2.3 mm from the cannula; the ulnar nerve is on average 12–23 mm from the portal, and the median nerve is 12.4–22.3 mm away [31, 34]. This portal provides full visualization of the entire anterior compartment.

Anterolateral portal

The anterolateral portal was originally described by Andrews and Carson [30]. It is located 3 cm distal and 1 cm anterior to the lateral epicondyle. It has been subsequently shown in anatomic studies that this portal places the radial nerve at an unacceptable risk, with the closest reported distance of 2.8 mm from the trocar [31, 34, 36]. Alternative entry points have been offered. The superficial nerves at risk are the lateral antebrachial cutaneous and the anterior branch of the posterior antebrachial cutaneous nerves. Due to the safety issue described, we prefer the proximal lateral portal.

Posterolateral portal

The posterolateral portal is located 3 cm proximal to the tip of the olecranon and immediately lateral to the triceps tendon. This portal has been described as having one of the largest areas of safety of any portal, with the posterior brachial cutaneous and posterior antebrachial cutaneous nerves as the nearest neurovascular structures [31]. It provides excellent visualization of the entire posterior compartment. Caution is advised when evaluating the medial gutter, as the ulnar nerve is immediately superficial to the capsule.

Transticeps portal

This straight posterior portal is located in the midline, 3 cm proximal to the tip of the olecranon. It is largely used as a working portal in conjunction with the posterolateral portal to debride the posteromedial olecranon of osteophytes and the corresponding olecranon fossa of chondral lesions, and to remove loose bodies.

Operative techniques

After appropriate anesthesia and supine positioning as described above, the elbow is distended with 20–30 mL of saline, injected through the soft spot in the midlateral portal. Joint distention facilitates the introduction of instruments, and it shifts the neurovascular structures

further away from the penetrating instruments. Care should be taken, however, to avoid overdistention to the point of brisement and capsular rupture, as the joint would then be unable to effectively maintain adequate fluid pressure for the ensuing arthroscopy. We prefer the Spider hydraulic arm holder and the patient in the supine position for the reasons described above.

Anterior arthroscopy

The arthroscope is introduced through the proximal lateral portal into the anterior compartment. A diagnostic arthroscopy is performed anteriorly to evaluate the articular cartilage and synovium, as well as to look for loose bodies. The coronoid is examined for the presence of a spur, and the anterior trochlea and coronoid fossa are examined for corresponding cartilage lesions. The anterior radiocapitellar joint is evaluated, especially for osteochondral lesions of the capitellum and matching pathology of the radial head. The radial nerve lies on, or at the least within a few millimeters of, the anterolateral joint capsule, so debridement in this area requires careful consideration. The anterior capsule is evaluated for thickening or contracture in the context of a loss of passive extension. To confirm the diagnosis of MCL insufficiency, the *arthroscopic valgus stress test* is performed as described above. With the arthroscope in the proximal lateral portal and visualizing the medial compartment, a valgus stress is applied manually to the elbow. If work needs to be done in the anterior compartment, such as debridement, synovectomy, capsular release, or removal of loose bodies, a proximal medial portal is established under direct visualization, localized by a spinal needle (Fig. 8). A probe of known dimensions may be inserted through this portal to aid in measurement of medial ulnohumeral opening. If such a portal is not necessary, then valgus opening can be visualized and appropriately estimated (Fig. 5). In either event, a gap of 3 mm or more will appear between the coronoid process and the medial trochlea. It is the senior author's experience that when using the Spider hydraulic arm holder, which is stiffer and provides less "play" than does the Tenet arm holder, the arthroscopic valgus opening produced by the arthroscopic stress test can be dampened.

Posterior arthroscopy

After completion of the anterior arthroscopy, the cannula with its camera is retained, with fluid inflow attached to maintain distention of the joint. A posterolateral portal is then established and the camera is then removed from the anterior cannula and inserted through this portal; however, the cannula in the anterior portal is retained statically, with its trocar replaced, to facilitate reentry into the anterior compartment if necessary and to ultimately drain the elbow of fluid at the conclusion of the case. If work needs to be done posteriorly, a transtriceps portal is established as a working portal.

Fig. 8. **a** Arthroscopy of the anterior compartment can demonstrate pathology such as capsular thickening and synovial inflammation. **b** A large, irregular osteophyte of the posteromedial olecranon is observed

The medial, lateral, and central olecranon are evaluated for the presence of an osteophyte. The corresponding olecranon fossa and posterior medial aspect of the humeral condyle are evaluated for matching chondral defects. The posterior radiocapitellar joint is evaluated by advancing the arthroscope down the lateral gutter. One of the most common errors made in elbow arthroscopy is to miss a loose body that is caught in the posterior radiocapitellar joint [33]. When such a loose body is present, an accessory midlateral portal through the soft spot will often be necessary for removal.

In the throwing athlete, the most common problem encountered is a fragmented spur on the posteromedial olecranon as a result of posterior shear stresses seen in valgus extension overload, as described above. Such spurs can be evident in the radiographs and MRI preoperatively and should be anticipated. With the camera in the posterolateral portal and the shaver in the transtriceps portal, the extent and dimensions of the osteophyte should be evaluated. Excess soft tissue, including synovial

reflections, is removed from the olecranon tip using a radiofrequency device. The osteophyte is removed from the posteromedial olecranon using a gentle medial-to-lateral movement. It is important to remember the position of the ulnar nerve just superficial to the capsule in the posteromedial gutter. Avoid the use of suction when the shaver is near this area of the capsule, and use the radiofrequency device with caution. Once the osteophyte is removed, the humeral chondral surface can be visualized more completely, and the “kissing lesion” of chondral abrasion opposite the osteophyte will be in direct view. If a chondral injury is present, standard principles apply. Loose chondral flaps should be debrided, and if necessary, microfracture can be performed.

The optimal amount of olecranon to be debrided has been a matter of debate, and common surgical practice involves debridement of the osteophyte along with a variable amount of native olecranon bone. Although no single critical value is reported in the literature, two recent studies recommend limiting resection to the osteophyte only, and to preserve as much normal olecranon bone as possible, given the potential for elbow instability and MCL strain in the throwing athlete [48, 49].

Once the arthroscopy in the posterior compartment is completed, the fluid is evacuated from the anterior and posterior cannulas, and the portals closed. If MCL reconstruction is needed, then the forearm is easily removed from the arm holder and the arm is placed onto the table extension, previously attached and draped into the field.

MCL reconstruction

The “Docking Technique” of MCL reconstruction, as described by the senior author (D.W.A.), has been well described [23, 33]. The reader is encouraged to review this technique through these articles.

Postoperative rehabilitation

Specific physical therapy regimens vary depending on the procedure performed, and a thorough discussion of the most commonly performed procedures and their protocols is beyond the scope of this discussion. Certain general principles apply, however, and the following description refers to rehabilitation following elbow arthroscopy.

Postoperatively, we prefer a compressive dressing for 48 h, cryotherapy, and routine arthroscopic wound care. Sling immobilization is minimal and is for comfort only. A comprehensive review of nonoperative and postoperative rehabilitation of the athlete’s elbow was written by Wilk and Levinson [51], serving as an excellent guide for the physician and the therapist. The fundamental goal of physical therapy in the postarthroscopic period is the restoration of joint ROM and flexibility within the healing parameters of the structures involved. Rehabilitation progresses through a multiphasic approach that is progressive, with each phase beginning only after the major goals of the previous phase has been successfully met. The authors

outline the following criteria to enable an athlete to safely return to sports: painless and full range of motion, no elbow pain or tenderness, satisfactory isokinetic muscular strength testing, and a satisfactory clinical examination. Overall, rehabilitation following elbow arthroscopy can be somewhat aggressive, as the procedure causes minimal postoperative morbidity. A three-phase program is outlined, which allows the surgeon and therapist to tailor the program to the individual patient's needs [51].

Phase 1 is the immediate motion phase, with the goals to reestablish motion, to diminish pain and inflammation, and to retard muscle atrophy. This phase routinely spans the first 1–2 postoperative weeks. Early wrist and elbow motion is begun, including passive and active-assisted flexion–extension and supination–pronation of the elbow. The reestablishment of full elbow extension is a primary goal of this phase, as a flexion contracture can develop and can be a particularly devastating complication in the overhead athlete. Joint contracture has been postulated to occur more commonly in the elbow for several reasons, including the high degree of conformity of the ulnohumeral articulation, the relatively low compliance of the capsule, and the thin anterior capsule that may be more prone to injury and thus to scarring [51]. Gentle joint mobilization, combined with various modalities such as ice, aqua therapy, pulsed galvanic stimulation, ultrasound, and transcutaneous neuromuscular stimulation, has been utilized to decrease pain and inflammation, although peer-reviewed evidence of several modalities is sparse. Lastly, gentle submaximal isometric strengthening exercises of the wrist and elbow flexors and extensors, as well as the forearm supinators and pronators, are initiated to minimize atrophy and to facilitate transition to a formal strengthening regimen.

Phase 2 is the intermediate phase and emphasizes maintaining mobility, improving strength and endurance, and resuming neuromuscular control of the elbow. As mentioned, in a progressive rehabilitation program, certain criteria must be met before progression to the next phase. Full ROM, minimal pain and tenderness, and at least grade 4/5 manual muscle testing must all be present, or the patient must continue with phase 1 exercises [51]. Most patients are ready to begin this second phase by postoperative week 2. Muscular strengthening exercises are advanced using isotonic contractions. Dumbbell progressive resistive exercises and elastic band exercises are performed, involving muscle groups of the entire upper extremity. A critical component of successful rehabilitation of the athlete's elbow is recognition of deconditioning and loss of motion in the shoulder. Weakness in the periscapular muscles and in the rotator cuff must be addressed, emphasizing the concept of total arm strength to ensure proximal stability, which enables distal mobility. In addition, neuromuscular exercises are begun to enhance dynamic stability and proprioception.

Loss of glenohumeral motion must also be restored. Specifically, internal rotation is lost, as the thrower's arc of motion is shifted to accommodate the increased external rotation that is demanded by repetitive throwing, particularly pitching. The absolute range of motion is usually not

diminished, but rather gains in external rotation are matched by progressive losses in internal rotation. In a successful therapy program, these internal rotation deficits are addressed, and ideally the forces seen across the elbow are normalized.

Phase 3, the advanced strengthening phase, is initiated as soon as patients have a full, painless ROM, no pain or tenderness in the elbow, and strength that is 70% of the opposite side [51]. This phase is focused on progressively increasing activities to prepare the athlete to return to sport, and it usually commences 3 or 4 weeks postoperatively and continues until approximately week 8. The goals are to increase total arm strength, power, endurance, and neuromuscular control. Advanced strengthening exercises such as plyometrics are initiated.

An interval throwing program is usually initiated at some point from 3 to 6 weeks postoperatively. Before full return to competitive sport, an athlete must demonstrate full ROM, no pain or tenderness, an isokinetic strength test that fulfills established criteria, and a satisfactory clinical examination [51].

Results

Elbow arthroscopy has been shown to be a safe, reliable, and powerful tool in the treatment of elbow pathology in the throwing athlete [1–7, 16, 23, 24, 30–36, 40–47]. Results have been reported for many different applications, including osteophyte debridement for posteromedial impingement, loose body removal, capsular release, treatment of osteochondritis dissecans, and debridement for lateral epicondylitis, as well as debridement for degenerative joint disease and other problems not directly related to the athlete's elbow [40–48].

Andrews and Carson [42] published one of the earliest reports for elbow arthroscopy in 1985. Using patient-derived subjective and objective measures of outcome, they reported objective improvements from preoperative scores of 50% to postoperative scores of 83%. Subjective criteria improved similarly, from 17% preoperatively to 58% after arthroscopy. The most successful procedure performed was the removal of loose bodies.

Andrews and Timmerman [50] reviewed their results of arthroscopic and open elbow surgery in 72 professional baseball players. The most common diagnoses were posteromedial olecranon osteophytes (65%), intra-articular loose bodies (54%), MCL injury (25%), and ulnar neuritis (15%). The patients with posteromedial olecranon osteophytes had the highest rate of reoperation, and patients who underwent MCL reconstruction had a higher rate of return to play. They cautioned the clinician that the incidence of MCL injuries was most likely underestimated, and that procedures aimed at treating the secondary effects of MCL insufficiency (such as posteromedial impingement) without addressing the underlying MCL often had an unsatisfactory outcome.

Reddy and colleagues [40] reported a large series in 2000, in which the results of 187 arthroscopies were

reviewed. The most common diagnoses were posterior impingement (51%), loose bodies (31%), and degenerative joint disease (22%). The average Figgie score improved from 27.7 points to 45.4 points, with the largest increases occurring in the pain score. Fifty-one percent of patients achieved an excellent result, 36% a good result, 11% a fair result, and 4% were classified as poor. Forty-seven of 55 baseball players (85%) were able to return to the same level of competition. The complication rate was 1.6%.

The results of MCL reconstruction are quite favorable. Altchek et al [33] reported that 39 of 40 athletes with minimum 2-year follow-up returned to their previous level of sports competition. Rohrbough et al [23] reported similar findings, with 30 of 31 patients returning to their previous competition level.

Complications

The safety of elbow arthroscopy has dramatically improved as clinical and cadaveric study has increased our understanding of portal placement and the relative positions of surrounding neurovascular structures. However, the procedure is nevertheless fraught with complications for the inexperienced arthroscopist. Nerve injury is the most commonly reported complication of elbow arthroscopy [16, 29–31, 37–39, 43]. Injury can be caused by direct laceration from a knife penetrated deep to the skin or from the cannula trocar. In addition, compression from a cannula, from fluid extravasation, or from the use of local anesthetics has been reported as a causative factor [31]. The majority of these injuries are transient [43], but devastating neurological injury can occur. Haapaniemi and colleagues [29] reported on a case of complete transection of the median and radial nerves during arthroscopic release of a posttraumatic elbow contracture. Some of the portals described in the literature place the neurovascular structures at a higher relative risk than other portals; for this reason, we have chosen the portals as outlined above to minimize the inherent risks involved in this procedure.

Other complications are similar to those reported for arthroscopy in general. These include infection, articular cartilage injury, synovial fistula formation, instrument breakage, and tourniquet-related complications [31].

Conclusion

Elbow arthroscopy is a powerful tool in the diagnosis and management of injuries to the throwing athlete. As noted, MCL injuries, ulnar neuritis, valgus extension overload with osteophyte formation and posteromedial impingement, flexor pronator strain, medial epicondyle pathology, and osteochondritis dissecans of the capitellum have all been described as sequelae of the overhead throwing motion. The preoperative evaluation should focus on a thorough history and physical examination, as well as on specific diagnostic imaging modalities. We prefer regional anesthesia, the use of a hydraulic arm holder, and the

modified supine position as described above. The most commonly used portals are the midlateral, proximal lateral, proximal medial, posterolateral, and the transtriceps portals. Elbow arthroscopy can be safely performed anteriorly, posteriorly, and in the gutters. Appropriate rehabilitation focuses on a graduated progression of advancing to one functional step once the preceding the step had been satisfactorily achieved.

References

1. Chen A, Youm T, Ong B et al (2003) Imaging of the elbow in the overhead throwing athlete. *Am J Sports Med* 31:466–473
2. Cain E, Dugas J, Wolf R, Andrews J (2003) Elbow injuries in throwing athletes: a current concepts review. *Am J Sports Med* 31:621–635
3. Schickendantz M (2002) Diagnosis and treatment of elbow disorders in the overhead athlete. *Hand Clin* 18:65–75
4. Ball C, Galatz L, Yamaguchi K (2002) Elbow instability: treatment strategies and emerging concepts. *Instr Course Lect* 51:53–61
5. Rizio L, Uribe J (2001) Overuse injuries of the upper extremity in baseball. *Clin Sports Med* 20(3):453–468
6. Miller C, Savoie F, III (1994 Oct) Valgus extension injuries of the elbow in the throwing athlete. *J Am Acad Orthop Surg* 2(5):261–269
7. Chen F, Rokito A, Jobe F (2001 Mar–Apr) Medial elbow problems in the overhead throwing athlete. *J Am Acad Orthop Surg* 9(2):99–113
8. Morrey BF, An KN (1983) Articular and ligamentous contributions to the stability of the elbow joint. *Am J Sports Med* 11:315–319
9. Morrey BF (1986) Applied anatomy and biomechanics of the elbow joint. *Instr Course Lect* 35:59–68
10. Morrey BF, An KN (1985) Functional anatomy of the ligaments of the elbow. *Clin Orthop* 201:84–90
11. Dillman CJ, Fleisig GS, Andrews JR (1993) Biomechanics of pitching with emphasis upon shoulder kinematics. *J Orthop Sports Phys Ther* 18:402–408
12. Fleisig GS, Andrews JR, Dillman CJ et al (1995) Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med* 23:233–239
13. Pappas A, Zawacki R, Sullivan T (1985) Biomechanics of baseball pitching: a preliminary report. *Am J Sports Med* 13:216–222
14. Wilson FD, Andrews JR, Blackburn TA et al (1983) Valgus extension overload in the pitching elbow. *Am J Sports Med* 11:83–88
15. Conway JE, Jobe FW, Glousman RE et al (1992) Medial instability of the elbow in throwing athletes. Treatment by repair or reconstruction of the ulnar collateral ligament. *J Bone Jt Surg* 74A:67–83
16. O'Driscoll S, Savoie F: Arthroscopy of the elbow, in ...
17. King JW, Brelsford HJ, Tullos HS (1969) Analysis of the pitching arm of the professional baseball pitcher. *Clin Orthop* 67:116–123
18. Timmerman LA, Schwartz ML, Andrews JR (1994) Preoperative evaluation of the ulnar collateral ligament by magnetic resonance imaging and computed tomography arthrography. Evaluation in 25 baseball players with surgical confirmation. *Am J Sports Med* 22:26–32
19. Potter HG (2000) Imaging of posttraumatic and soft tissue dysfunction of the elbow. *Clin Orthop* 370:9–18
20. Gaary EA, Potter HG, Altchek DW (1997) Medial elbow pain in the throwing athlete: MR imaging evaluation. *AJR Am J Roentgenol* 168:795–800
21. Potter HG, Ho ST, Altchek DW (2004 Mar) Magnetic resonance imaging of the elbow. *Semin Musculoskelet Radiol* 8(1):5–16
22. Potter HG, Linklater JM, Allen AA, Hannafin JA, Haas SB (1998

- Sep) Magnetic resonance imaging of articular cartilage in the knee. An evaluation with use of fast-spin-echo imaging. *J Bone Jt Surg Am* 80(9):1276–1284
23. Rohrbough JT, Altchek DW, Hyman J, Williams RJ III, Botts JD (2002 Jul–Aug) Medial collateral ligament reconstruction of the elbow using the docking technique. *Am J Sports Med* 30(4):541–548
 24. Field LD, Altchek DW (1996) Evaluation of the arthroscopic valgus instability test of the elbow. *Am J Sports Med* 24:177–181
 25. Jupiter JB, O'Driscoll SW, Cohen MS (2003) The assessment and management of the stiff elbow. *Instr Course Lect* 52:93–111
 26. Ball CM, Meunier M, Galatz LM, Calfee R, Yamaguchi K (2002 Nov–Dec) Arthroscopic treatment of post-traumatic elbow contracture. *J Shoulder Elb Surg* 11(6):624–629
 27. Phillips BB, Strasburger S (1998 Jan–Feb) Arthroscopic treatment of arthrofibrosis of the elbow joint. *Arthroscopy* 14(1):38–44
 28. Kim SJ, Kim HK, Lee JW (1995 Dec) Arthroscopy for limitation of motion of the elbow. *Arthroscopy* 11(6):680–683
 29. Haapaniemi T, Berggren M, Adolfsson L (1999 Oct) Complete transection of the median and radial nerves during arthroscopic release of post-traumatic elbow contracture. *Arthroscopy* 15(7):784–787
 30. Andrews JR, Carson WG (1985) Arthroscopy of the elbow. *Arthroscopy* 1:97–107
 31. Walcott GD, Savoie FH, Field LD (2001) Arthroscopy of the elbow: setup, portals, and diagnostic technique. In: Altchek DW, Andrews JR (eds) *The athlete's elbow*, Lippincott, Williams & Wilkins. Philadelphia, PA, pp. 249–273 pp 209–217.
 32. Poehling GG, Whipple TL, Sisco L et al (1989) Elbow arthroscopy: a new technique. *Arthroscopy* 5:222–224
 33. Altchek DW, Hyman J, Williams R et al (2000) Management of MCL injuries of the elbow in throwers. *Tech Shoulder Elb Surg* 1(2):73–81
 34. Stothers K, Day BD, Regan WR (1995) Arthroscopy of the elbow: anatomy, portal sites, and a description of the proximal lateral portal. *Arthroscopy* 11(4):449–457
 35. Adolfsson L (1994) Arthroscopy of the elbow joint: a cadaveric study of portal placement. *J Shoulder Elb Surg* 3:53–61
 36. Field LD, Altchek DW, Warren RF (1994) Arthroscopic anatomy of the lateral elbow: a comparison of three portals. *Arthroscopy* 10:602–607
 37. Papilion JD, Neff RS, Shall LM (1988) Compression neuropathy of the radial nerve as a complication of elbow arthroscopy: a case report and review of the literature. *Arthroscopy* 4:284–286
 38. Ruch DS, Poehling GG (1997) Anterior interosseous nerve injury following elbow arthroscopy. *Arthroscopy* 13:756–758
 39. Thomas MA, Fast A, Shapiro D (1987) Radial Nerve damage as a complication of elbow arthroscopy. *Clin Orthop* 215:130–131
 40. Reddy AS, Kvitne RS, Yocum LA, Elattrache NS, Glousman RE, Jobe FW (2000 Sep) Arthroscopy of the elbow: a long-term clinical review. *Arthroscopy* 16(6):588–594
 41. O'Driscoll SW, Morrey BF (1992 Jan) Arthroscopy of the elbow. Diagnostic and therapeutic benefits and hazards. *J Bone Jt Surg Am* 74(1):84–94
 42. Andrews JR, Carson WG (1985) Arthroscopy of the elbow. *Arthroscopy* 1(2):97–107
 43. Morrey BF. Complications of elbow arthroscopy. In...pp. 519–522.
 44. Kim SJ, Shin SJ (2000 Jun) Arthroscopic treatment for limitation of motion of the elbow. *Clin Orthop* (375):140–148
 45. Kuklo TR, Taylor KF, Murphy KP et al (1999) Arthroscopic release for lateral epicondylitis: a cadaver model. *Arthroscopy* 15:259–264
 46. Owens BD, Murphy KP, Kuklo TR (2001) Arthroscopic release for lateral epicondylitis. *Arthroscopy* 17:582–587
 47. Krijnen MR, Lim L, Willems WJ (2003) Arthroscopic treatment of osteochondritis dissecans of the capitellum: report of 5 female athletes. *Arthroscopy* 19:210–214
 48. Kamineni S, Hirahara H, Pomianowski S, Neale PG, O'Driscoll SW, ElAttrache N, An KN, Morrey BF (2003 Jun) Partial posteromedial olecranon resection: a kinematic study. *J Bone Jt Surg Am* 85-A(6):1005–1011
 49. Kamineni S, ElAttrache NS, O'Driscoll SW, Ahmad CS, Hirohara H, Neale PG, An KN, Morrey BF (2004 Nov) Medial collateral ligament strain with partial posteromedial olecranon resection. A biomechanical study. *J Bone Jt Surg Am* 86-A(11):2424–2430
 50. Andrews JR, Timmerman LA (1995) Outcome of elbow surgery in professional baseball players. *Am J Sports Med* 23(4):407–413
 51. Wilk KE, Levinson M (2001) Rehabilitation of the athlete's elbow. In: Altchek DW, Andrews JR (eds) *The athlete's elbow*, Lippincott, Williams & Wilkins. Philadelphia, PA, pp. 249–273.
 52. O'Holleran JD, Altchek DW (2005) Elbow arthroscopy: treatment of the thrower's elbow. *Instr Course Lect* 55, in press.