Operative Strategies for Ulnar Collateral Ligament Insufficiency

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Background

History of Ulnar Collateral Ligament Injury and Reconstruction

The first report in the literature of a medial ulnar collateral ligament (UCL) injury was provided in 1946 by Waris, describing medial elbow pain and instability in a cohort of javelin throwers [1]. Since that time, reports of UCL injury have been described in a variety of athletes, most notably overhead throwing athletes. Within this population, UCL injury was frequently noted in baseball pitchers, where repetitive valgus forces can lead to chronic attenuation or acute injury to the medial ligamentous structures of the elbow. Prior to modern diagnostic and therapeutic techniques, UCL injury was almost certainly a career-ending injury for professional baseball pitchers. While attempts at UCL repair were described, the results in the baseball pitcher were less than satisfying [2]. The first described UCL reconstruction was performed in 1974 by Dr. Frank Jobe on Los Angeles Dodgers pitcher Tommy John. The first operation was generally accepted as a success, as Tommy John returned to pitching and made several All-Star game appearances after the procedure. The results of Dr. Jobe's initial UCL reconstruction technique were published in 1986 [3], setting the stage for multiple technique and rehabilitation modifications to be made to his original description of UCL reconstruction, now popularly referred to as Tommy John surgery in reference to Jobe's first patient.

Epidemiology

As most UCL injuries in non-throwing athletes are managed conservatively without surgical intervention, the true prevalence of UCL injury is unknown. Within the general population, UCL injury requiring surgical intervention is rare, with as few as 4 in 100,000 individuals undergoing surgical intervention. The incidence of UCL reconstruction procedures appears to be highest in young patients, aged 15–19 years, where the incidence of reconstruction approaches 22 in 100,000 patients [4]. The majority of today's UCL reconstruction procedures are performed in baseball players, where as many as 10 % of minor league and professional players have undergone UCL reconstruction [5]. The prevalence is even

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higher in professional baseball pitchers, where nearly 25 % of current professional pitchers describe a history of UCL reconstruction. Over the last decade, there has been an estimated annual increase in UCL reconstruction procedures of 4 %, with annual growth rates approaching 10 % for patients aged 15–19 years [4]. Given the high prevalence of UCL reconstruction procedures in elite baseball players as well as the increasing incidence in young patients over the last decade, it is safe to assume that team physicians, athletic trainers, and rehabilitation specialists will be managing a record number of post-UCL reconstruction athletes in the coming years. Fortunately, while primary UCL reconstruction procedures continue to increase, the incidence of revision UCL reconstructions is decreasing, presumably secondary to improved techniques and rehabilitation protocols [6]. If recent trends continue to hold true, preventative strategies, including throwing programs and pitch limits for youth baseball players [7], will be important to implement in order to protect our young athletes in future years.

Relevant Anatomy

The UCL is comprised of three components, including the anterior, posterior and transverse bundles [8]. The anterior bundle of the ligament originates at the anteroinferior portion of the medial epicondyle of the humerus. Moving distally from its relatively broad-based origin, the anterior bundle narrows in the sagittal plane prior to inserting on the sublime tubercle of the ulna and fanning out along the medial ulnar collateral ridge [9]. The anterior bundle of the UCL can be identified as a distinct structure from the underlying elbow joint capsule [10], which distinguishes it from the other bundles of the UCL. The anterior bundle of the UCL provides the primary restraint to valgus force between 20° and 120° [11–14]. Outside of this range, the osseous anatomy of the elbow serves as the primary restraint to valgus laxity. The posterior bundle is essentially a fan-shaped thickening of the elbow joint capsule, coursing between the medial epicondyle of the humerus and the semilunar notch of the ulna. The fan-shaped posterior bundle has been found to have a relatively insignificant role, described as a secondary or tertiary restraint in mid-flexion, with respect to elbow stability [12, 13]. The transverse bundle both originates and inserts on the ulna. It connects the medial olecranon to the inferomedial coronoid process. As it does not cross the ulnohumeral joint, it does not act as a valgus restraint. As the anterior bundle of the UCL has been shown to be the primary static stabilizer to resist valgus stress, the majority of UCL reconstruction procedures have aimed to reproduce this anatomy.

Evaluation

History

Obtaining a detailed history is the first step toward diagnosis of UCL. The presentation almost invariably includes medial sided elbow pain that is aggravated by activity. A patient's age, activity, sport, and level of competition are all important to ascertain during the initial history and may help narrow the diagnosis. UCL injuries are frequently described in baseball players, particularly pitchers, javelin throwers, tennis players, and volleyball players but may occur during a variety of other sporting and nonsporting activities. A prior history of elbow injury or surgery should be elucidated, as should any previous upper extremity injury, surgery, or cervical spine pathology. Determining whether or not a patient's symptoms resolved with appropriate treatment in the setting of prior injury or surgery is important, as surgical failure, reinjury, underlying concomitant injury, or missed diagnosis should all be considered.

The duration and context of the pain is also important to note. With UCL injury, presentations often fit two classic scenarios. The first and most common presentation is an acute onset of pain [15], which is frequently described as a popping sensation. In the competitive overhead athlete, this presentation may coincide with a specific throw or pitch followed by the inability to continue with competition. This scenario likely represents an acute rupture or acute on chronic presentation in the setting of a previously attenuated ligament. The second scenario is also described as medial elbow pain, but in a more chronic setting with more ambiguous symptoms which may be accompanied by a gradual decline in performance, such as decreased throwing velocity, control, or endurance in a pitcher, as well as a noticeable or perceived change in mechanics to accommodate for underlying symptoms. In this type of presentation, it is important to note the timing of the symptoms relative to training regimens and pitch counts.

In the case of baseball pitchers, pain is often noted most during the late cocking and early acceleration phases of throwing when the most stress is placed on the UCL [16]. Despite the complexity of the overhead throwing motion, overhead athletes can fairly reliably describe the location of their symptoms as well as the phase of throwing that those symptoms occur during. Both the location of the pain as well as phase of the throwing motion are important components of the history, with medial-sided symptoms occurring during the late cocking or early acceleration phase frequently described by patients who ultimately are determined to have a UCL injury at the conclusion of their diagnostic workup [2].

While the history is the first step toward diagnosis of a UCL injury, UCL pathology can occur independently or concomitantly with several other diagnoses not limited to valgus extension overload [17], osteochondral defects with or without loose bodies, ulnar neuritis or subluxation [18], olecranon stress fracture [19], and flexor–pronator mass strains or tendonitis which need to be identified for appropriate treatment. These diagnoses as well as other diagnoses, including medial epicondylitis, little leaguer's elbow, or a variety of nerve entrapment syndromes, may also occur independent of UCL injury, further confounding the diagnosis. In this setting, additional questions including the presence or absence of radiating symptoms or paresthesias, loss of hand intrinsic strength, or vascular complaints [20] are all important to note. Additional clinical testing and diagnostic imaging can help clarify the diagnosis when in question or when concomitant pathology is a significant concern.

Physical Examination

A thorough understanding of the bony anatomy as well as the active and passive soft tissue stabilizers of the elbow is a prerequisite to completing a systematic exam of the elbow when there is suspicion of UCL injury. Physical examination begins with visual inspection of the elbow. Comparison of muscle mass and distribution as well as gross alignment should be made to the contralateral limb and should not be limited to the region of the elbow alone but should include the shoulder and hand, where intrinsic muscle wasting may be indicative of underlying ulnar nerve or systemic pathology. Depending on the nature and timing of the injury, visible swelling or ecchymosis may be seen along the medial aspect of the elbow. Additionally, the posture of the elbow should be noted, as an effusion will often lead to the patient holding the elbow in flexion to accommodate increased intracapsular volume [21]. The natural carrying angle of the elbow is in slight valgus, approximately 10° in males [22], which may be increased in the dominant arm of the throwing athlete and should not be confused with pathology in this population [23]. Also noted should be any prior surgical scars along the elbow, which may provide clues to previous injuries if the patient is unable to provide sufficient detail. In cases where UCL reconstruction is likely, inspection of the wrist and determination of the presence or absence of a palmaris longus tendon may influence graft choice.

Following inspection of the elbow, palpation of the elbow can be performed. The most prominent structure on the medial aspect of the elbow is the medial epicondyle, serving as the origin of the flexor–pronator mass. The UCL sits deep to the proximal flexor–pronator mass and it may be tender along its entire course. The ligament should be palpated from its origin at the medial epicondyle, along the mid-substance of the ligament, all the way to the insertion on the sublime tubercle of the ulna. Flexing the elbow to 50–70° of flexion moves the bulk of the flexor–pronator mass anteriorly, making the underlying UCL more accessible [24]. As the medial epicondyle is the common origin for many structures about the elbow, tenderness to palpation is a relatively nonspecific finding [25]. Palpation of other bony landmarks, including the posteromedial aspect of the ulna, lateral epicondyle, posterolateral soft triangle, and radiocapitellar joint may help identify concomitant pathology, such as valgus extension overload [17] or olecranon stress fracture. Additionally, the ulnar nerve assumes a relatively subcutaneous position at the elbow and should be palpated throughout an entire range of motion in order to assess the stability of the ulnar nerve. Anterior subluxation, or less commonly anterior dislocation, of the nerve may be identified, contributing to symptoms and potentially altering management at the time of surgical intervention if indicated. The ulnar nerve can also be lightly percussed or gently compressed within the cubital tunnel in order to provoke paresthesias or abnormal sensation in the ring and small finger of the affected extremity, which may indicate underlying ulnar neuritis.

Following inspection and palpation of the elbow, assessment of both active and passive range of motion is important. As a ginglymoid joint, the ulnohumeral articulation acts as a simple hinge with varus and valgus motion limited by a combination of bony and soft tissue restraints. In the sagittal plane, the elbow typically has 0–140° of motion [21]. The radiocapitellar joint accommodates pronation and supination at the level of the elbow, and should also be assessed. The contralateral elbow can serve as a readily available comparison when any concerns arise. Additionally, pain, crepitus, or mechanical symptoms should be noted during range of motion testing. In the throwing athlete, it is not uncommon to have a loss of motion [23], particularly terminal extension, which may not represent injury in this population. Assessment of elbow stability has been described previously through the use of several special tests. Assessing valgus stability of the elbow is best done in the supine position, allowing stabilization of the scapula and humerus. Valgus stress can be applied to the elbow at a variety of elbow flexion and shoulder abduction angles, with flexion of the arm to approximately 70° while maintaining neutral forearm rotation has been found to result in the greatest valgus laxity [26]. Valgus stress testing that is asymmetric compared to the contralateral elbow, painful, or lacks a firm endpoint is concerning for a UCL injury. Pain is often the most important indicator, as clinically unperceivable valgus opening can be associated with a partial or complete tear of the UCL [27, 28]. Alternatively, where available and technically an option, stress ultrasonography can provide a dynamic evaluation of the UCL [29]. Other tests, including the milking maneuver [24] and modified milking maneuver [30], can be performed with the patient in the seated position and 90° of shoulder abduction while a valgus load is applied by the patient themselves or the examiner (Fig. 12.1). O'Driscoll and colleagues have

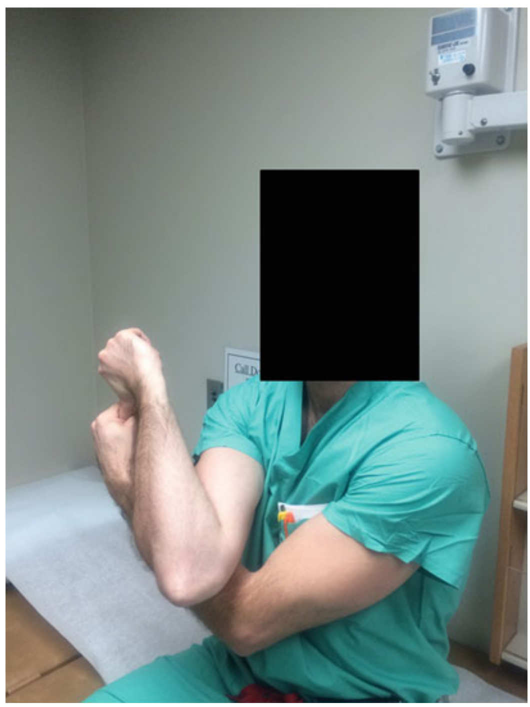

Fig. 12.1 The milking maneuver can be performed by the patient or examiner. Valgus stress is applied while maintaining the forearm in supination. A positive test elicits pain at the medial elbow

described the moving valgus stress test, which places the elbow in full flexion and the shoulder in 90° of abduction followed by rapid extension of the elbow while a valgus load is applied [31]. This was originally described in the seated position, but can also reliably be performed in the supine position (Fig. 12.2), which is preferred by the authors. Supine positioning allows the examining table to stabilize the shoulder and arm while stressing the elbow. Using this test, pain or apprehension as the elbow is extended from 120° to 70° of flexion while a valgus load is applied is concerning for UCL injury with good sensitivity and specificity reported.

In addition to examination of the elbow, examination of the adjacent shoulder and wrist should also be performed. For example, pain at the medial elbow with resisted flexion of the wrist may represent flexor–pronator strain or tendonitis. Additionally, UCL injuries have been associated with decreased shoulder motion including deficits in total shoulder range of motion as well as glenohumeral internal rotation deficit. These deficits in motion may be secondary to adaptive changes in the throwing shoulder and are common among throwing athletes [32, 33]. As such, these findings may be less of a diagnostic clue when attempting to diagnosis UCL injury, but rather serve as a potential therapeutic intervention either prophylactically or as part of nonoperative or post-surgical management in the throwing athlete to prevent subsequent injury or reinjury, respectively.

Fig. 12.2 The moving valgus stress test performed in the supine position. The arm is extended from 120° to 70° of flexion while a valgus force is applied. Pain in this range of motion is consistent with a positive test

Diagnostic Imaging

Imaging of the painful elbow is indicated with persistent pain or concern for acute injury. Standard anteroposterior and lateral radiographs of the elbow are useful as they may identify avulsion at the sublime tubercle in acute cases [34] or heterotopic ossification adjacent to the ligamentous insertion in more chronic cases of UCL insufficiency [35]. Additionally, radiographs can help identify concomitant pathology including loose bodies, osteochondral defects, or posteromedial olecranon osteophytes associated with valgus extension overload [17]. Additional radiographs, include internal and external oblique views as well as oblique axial views can be obtained depending on the concern for concomitant pathology. Historically, valgus stress radiographs have also been described. However, increased valgus laxity may be a normal finding in some overhead athletes [36], and the absolute amount of medial opening that indicates pathology is unclear. Because of this, the reported benefit of stress radiographs are inconsistent throughout the literature [15, 37], and their role in practice is limited, particularly given the improvement and widespread availability of advanced imaging techniques.

With widespread availability and improved quality, magnetic resonance imaging (MRI) of the elbow has become the study of choice for evaluation of UCL injury. MRI without contrast has been shown to have both sensitivity and specificity approaching 100 % in detecting full-thickness UCL injuries with good interrater reliability [38], but may be limited in detecting partial-thickness tears. Sensitivity and specificity are both improved with the addition of intraarticular gadolinium contrast in the form of a magnetic resonance arthrogram (MRA). MRA is particularly useful given the spectrum of pathology that can exist within the UCL, ranging from degenerative changes, partial-thickness tears, and full-thickness tears that may be difficult to distinguish with standard MRI sequences [25, 39–41]. With MRA, the undersurface of the UCL can be better visualized, improving sensitivity for partial thickness tears [38, 40], and any contrast extravasation from the joint is indicative of a UCL injury. With the widespread availability of MRI, the role for computed tomography (CT) either alone or with intraarticular contrast has become limited. However, in patients who cannot undergo MRI due to implanted medical devices or severe claustrophobia, or those with significant osteophytes or loose bodies, CT arthrography remains an option.

The use of ultrasound in imaging the UCL continues to evolve. Ultrasound provides the benefit of a dynamic, real-time evaluation, but may be limited by operator experience and availability. In the competitive throwing athlete, the UCL is often thickened [42], and areas of heterogeneity within the ligament must be distinguished from pathology. Dynamic ultrasound in the form of valgus stress ultrasound is limited by many of the same factors that limit interpretation of stress radiographs, namely increased laxity in the throwing elbow of the asymptomatic thrower [36, 43] and the lack of a definitive amount of medial opening to indicate a tear. Ultrasound remains an evolving technology, and its diagnostic and therapeutic uses in the setting of UCL injury will require further evaluation in years to come.

Treatment Algorithm

Injury Prevention

With the increased rate of UCL reconstruction over the last decade [4], efforts to reduce injuries have been made, particularly at the level of youth baseball. Efforts to reduce injury in young pitchers have primarily focused on reducing pitch quantity, as the amount of pitching has been shown to correlate with the risk of subsequent elbow injury [44, 45]. Additionally, injuries are more likely to occur in baseball pitchers who express symptoms of fatigue or overuse. Fatigue has been shown to alter pitching kinematics, potentially setting the stage for future injury [46]. Based on these findings, pitch count recommendations for youth baseball players have been made at the national level as well as local and regional levels. Despite these efforts, a lack of knowledge and compliance with pitch count recommendations has been noted, with both youth baseball players and coaches deficient in this area, suggesting that further education on this topic is necessary [47, 48]. Further hindering compliance is the fact that players frequently play in multiple leagues with multiple coaches, which has also been shown to be a risk factor for injury, likely serving as a surrogate for overall pitch volume [45]. While pitch choice has often been implicated as a risk factor for elbow injury in youth pitchers, there is little solid evidence to support that throwing curveballs or sliders increases the risk of injury, although it may increase the incidence of arm pain [45, 49]. However, increased pitch velocity has been associated with an increased risk of elbow injury [44]. In light of these findings, several recommendations have been made to reduce the risk of elbow injury in youth pitchers and include responding to fatigue and pain with rest, avoid pitching more than 100 innings in a calendar year, encourage non-pitching activities for at least 4 months of the year, teach and reinforce proper mechanics, and encourage compliance with pitch count regulations [7, 49]. In order to address the increased rates of shoulder and elbow injuries in youth baseball pitchers, several organizations guided by expert panels, including Little League® and USA Baseball, have provided age-specific pitch count and rest recommendations for young pitchers [50, 51] (Table 12.1). Additionally, optimizing shoulder and elbow health in the throwing athlete with a dedicated program focused on range of motion, core and lower extremity strengthening, and scapular stabilization can help correct kinematic abnormalities and prevent deficits, such as glenohumeral internal rotation deficits [52], which may reduce the risk of UCL injury.

Table 12.1 Age-based daily pitch count recommendations and rest recommendations [50, 51]

Pitch count recommendations	
Age	Pitches per day
7–8	50
9–10	75
11–12	85
13–16	95
17–18	105
19–22	120
Rest recommendations	
Pitches per day	
<14 years of age	Rest days required
1–20	0
21–35	1
36–50	2
51–65	3
≥66	4
15–18 years of age	
1–30	0
31–45	1
46–60	2
61–75	3
≥76	4
19–22 years of age	
1–30	0
31–45	1
46–60	2
61–75	3
76–105	4
≥106	5

Nonoperative Management

Nonoperative management of UCL injuries remains the treatment of choice for non-throwing athletes. Nonoperative management in the non-throwing athlete includes rest for 4–6 weeks, activity modification, physical therapy, pain control with nonsteroidal anti-inflammatory medications, and possible hinged bracing as athletes return to play depending on their level of competition, sport, and position. Using this protocol, nonoperative management has even been shown to be effective in some throwing populations, including professional quarterbacks, where 90 % were able to return to sport without surgical intervention [53]. While the vast majority of the current literature has focused on failures of nonoperative management in baseball players, specifically pitchers, nonoperative management remains the treatment of choice for non-throwing and even some throwing athletes.

Nonoperative management of UCL injuries in baseball players have historically produced less than satisfying results. However, the literature frequently fails to distinguish between partial-thickness and full-thickness tears, limiting the applicability of findings. In one of the largest case series detailing the results of nonoperative treatment in the throwing athlete, Rettig et al. found that only 42 % of athletes were able to return to sport at a preinjury level [54]. The nonoperative protocol utilized in their study included two stages. The first stage consisted of complete rest from throwing for 2–3 months, pain control with anti-inflammatory medications, ice, and active and passive elbow range of motion with bracing at night. The second stage of the protocol was initiated after the athlete was pain free and included upper extremity strengthening, a progressive throwing program, and an elbow hyperextension brace. While their overall results would be considered poor, the inability to distinguish athletes with partial-thickness and full-thickness tears limits conclusions.

While nonoperative management of full-thickness tears is unlikely to produce satisfying results, nonoperative management of partial-thickness tears remains a viable option. Nonoperative protocols for partial-thickness UCL strains typically include a minimum of 3 months of no throwing activity, with immediate initiation of non-painful active and passive range of motion, progressing toward exercises to increase strength, power, and endurance while incorporating a thrower's ten program [55]. A brace can be used during range of motion exercises to prevent valgus loading and restrict motion to a non-painful arc. Progression to throwing activities at 3 months only occurs if the athlete has non-painful and full range of motion and no increased valgus laxity on exam. With these requirements satisfied, the throwing athlete can initiate an interval throwing program while still focusing on the thrower's ten program, core strengthening, and plyometric exercises [56]. If symptoms persist or reoccur at any point during the throwing program, surgical intervention can be considered.

In the era of biologic augmentation, the effectiveness of biologic agents in the treatment of patients with partial-thickness UCL injuries has been considered. One such biologic agent, platelet-rich plasma (PRP), has been extensively studied in the orthopedic literature with variable results depending on the pathology and anatomic site in question [57]. To date, a single study has evaluated the effectiveness of PRP in the treatment of partial-thickness UCL injury. In this study, Podesta and colleagues evaluated the effectiveness of PRP injections for throwers that had previously failed 2 months of nonoperative treatment, which included an interval throwing program. In their study, 88 % of athletes were able to return to throwing at an average of 12 weeks following PRP injection [58]. While these findings are promising, further studies specifically evaluating nonoperative management of partial-thickness injuries with or without biologic augmentation are necessary.

Surgical Indications

Surgical management of UCL injury is reserved for throwing athletes with full-thickness UCL tears who wish to return to competition or individuals with partial-thickness tears that have persistent medial elbow pain or valgus laxity following an appropriate nonoperative treatment course.

Surgical Techniques

Prior to Jobe's original description of UCL reconstruction [3], surgical intervention for UCL injury was limited to primary repair. While primary repair for acute avulsion injuries with suture anchor fixation or bone tunnels remains an option, the results for this technique are limited in the literature [59–61]. Early comparative studies revealed inferior results with repair as compared to reconstruction [2, 15], although those studies did not distinguish repair in acute injuries from repair in the more chronic setting where ligament attenuation is a known issue and reconstruction is preferable. In our experience, direct repair remains an option for acute proximal or distal avulsion injuries. Direct repair is particularly suitable for non-pitching athletes, such as baseball position players or non-throwing athletes that participate in football or wrestling. If repair is considered, it is important to carefully inspect the UCL at the time of surgery in order to rule out intrasubstance ligament injury or attenuation. If intrasubstance ligament injury or attenuation is noted, then a UCL reconstruction is performed. However, if the UCL injury appears to be a true avulsion injury, suture anchor methods have been described with good-to-excellent outcomes in young athletes [61].

The original UCL reconstruction as described by Jobe included a medial approach to the elbow with mobilization of the ulnar nerve for later transposition. Access to the UCL was gained by transecting the flexor–pronator mass off of the epicondyle, leaving a cuff of tendon attached to bone for later repair. With the flexor–pronator mass reflected distally, the UCL could be visualized from its origin at the medial epicondyle to its insertion on the sublime tubercle of the ulna. Tunnels were drilled at the sublime tubercle and medial epicondyle to allow passage of a palmaris autograft in a figure-of-eight fashion, which was then sutured again at its midpoint under appropriate tension. The mobilized ulnar nerve was then placed under the reflected flexor–pronator mass and the flexor–pronator mass repaired back to the cuff of tendon at medial epicondyle, resulting in a submuscular transposition of the ulnar nerve [3]. In the original series reported by Jobe et al. as well as the later comparative study by Conway et al. [2, 3], ulnar neuritis was a relatively common complication, contributing at least in part to low return to play numbers. In order to reduce this complication, the modified Jobe technique was described, which utilized a muscle splitting approach through the posterior aspect of the flexor–pronator mass in order to gain access to the underlying UCL [15, 62, 63]. Additionally, the humeral tunnels were oriented more anteriorly in order to prevent injury to the ulnar nerve [62]. While management of the ulnar nerve varied between authors, ranging from transposition with a flexor–pronator fascial sling to in situ decompression, the modified Jobe technique significantly reduced postoperative complications and allowed improved return to sport as compared to the original description [62].

In 2002, Rohrbough and colleagues described UCL reconstruction using the docking technique, which was the first major technique modification that addressed graft fixation, tensioning, and iatrogenic fracture concerns while also utilizing a flexor–pronator splitting approach [64]. Tunnels were created at the sublime tubercle and connected with a curette to maintain an approximately 1 cm bone bridge. A single dead-end humeral tunnel was made in the anterior portion of the medial epicondyle at the origin of the anterior band of the UCL, and two small holes were made with a dental drill or small burr to communicate with the humeral tunnel and allow suture passage. A palmaris or gracilis autograft was then passed through the ulnar tunnel and the sutured end of the graft pulled through one of the small communicating drill holes, effectively docking one limb of the graft. The free limb of the graft was then measured while maintaining the elbow in varus in order to estimate its length in the tunnel. A Krackow stitch was then placed in the remaining free limb of the graft and passed through the other small drill hole in the medial epicondyle to dock the free end in the humeral tunnel. With varus maintained at the elbow, the two free suture ends were tensioned and tied over the bone bridge at the medial epicondyle. Minor modification to the docking technique, including use of a doubled palmaris autograft, has also been described and referred to as the modified docking procedure [65]. The docking and modified docking technique provide greater control of graft tensioning while yielding equivalent or even improved biomechanical properties as compared to the Jobe technique [66–69].

More recent modifications to the Jobe and docking techniques have primarily focused on alternative or hybrid fixation at the ulna, humerus, or both. One popular modification is the eponymously named DANE TJ (David Altcheck, Neal ElAttrache, Tommy John) technique, which uses interference screw fixation at the UCL insertion on the ulna [70, 71]. As hypothesized by the authors, interference screw fixation better replicates the native anatomy of the UCL as it narrows at the ulnar footprint. Additionally, interference screw fixation eliminates the need for two bone tunnels, theoretically reducing the risk of iatrogenic fracture. Biomechanical comparisons of the different fixation techniques have been explored with variable results throughout the literature [66, 69, 72]. A clear limitation of these cadaveric biomechanical studies is that the in vivo dynamic stabilizers are rarely accounted for during testing and that healing is not considered, with each biomechanical study essentially serving as a time zero analysis of the construct strength.

As implant designs and fixation techniques continue to evolve, modifications to UCL reconstruction techniques will continue to be described. Suspensory and interference screw ulnar and humeral fixation using manufacturer-specific devices are frequently reported in the literature with little biomechanical superiority or inferiority noted with these subtle technique variations [73–76]. Similarly, a variety of graft choices have been described, including palmaris, gracilis, toe extensor, plantaris, and Achilles autograft as well as hamstring allograft [3, 77, 78], all of which have provided satisfying results in the literature when coupled with modern techniques. When carefully evaluating the literature, major technique advances since Jobe's original technique description include the use of the flexor–pronator splitting approach as well as patient-specific management of the ulnar nerve depending on preoperative symptoms and intraoperative evaluation. In general, these advances have reduced postoperative complications and led to lower rates of revision surgery despite the increased rate of primary reconstructions being performed [6].

Postoperative Management

Patients are typically placed in a posterior splint for 1–2 weeks postoperatively with the elbow immobilized in 90° of flexion. Finger and wrist range of motion protocols vary while immobilized at the elbow, but with the flexor–pronator splitting approach, can typically be started as pain allows postoperatively as compared to the original Jobe description which took down the origin of the flexor–pronator mass [79]. After this short period of immobilization, patients are transitioned to a hinged elbow brace, with initial range of motion limited to 45–90° of motion, increasing range of motion by approximately 15° per week with the goal or reaching full passive range of motion by 6 weeks postoperatively. As elbow flexion contractures are common even in the throwing arm of uninjured athletes, gentle stretching exercises to reduce flexion contractures can be used but should be carefully guided by a patient's symptoms. At 6 weeks postoperatively, the hinged elbow brace can be discontinued and light strengthening exercises can commence. In addition to the elbow, shoulder and wrist strengthening and range of motion should also be addressed. At 12 weeks postoperatively, more vigorous strengthening exercises can begin, and an organized throwing program, such as the thrower's ten program [55], can begin at 14–16 weeks postoperatively. Progression through an organized throwing program should include careful monitoring of symptoms, including medial elbow pain. Throwing off a mound can be expected at 6–9 months postoperatively, with return to competition at 9–12 months in most throwing athletes. For non-throwing athletes, postoperative protocols are less well defined but similarly should focus on obtaining full range of motion by 6 weeks with gradual strengthening beginning at this time as well. More aggressive strengthening can begin at 12 weeks postoperatively, with the goal of achieving normal strength and pain free range of motion prior to returning to sport.

Surgical Outcomes

Since the first published outcomes of UCL reconstruction using Jobe's original figure-of-eight technique were reported in 1986 [3], the technique, perioperative management, and outcome measures of interest for medial ulnar ligament reconstruction have continued to evolve. While initial outcomes focused simply on return to sport and complications with the use of a single technique, today's outcomes cover an array of techniques [80] with outcomes that extend beyond return to sport, focusing on the quality of return to sport in a variety of patients [2, 81–87]. Given the ongoing changes both technically and with outcomes reporting, direct comparisons between studies and comparative study designs are limited. However, careful analysis of the reported outcomes provides useful information for the practicing surgeon and patient following UCL reconstruction.

Medial Ulnar Collateral Ligament Repair

Reporting of results for primary repair of UCL injuries is limited in the literature, and is primarily reserved for acute avulsion type injuries [34, 60] or in the setting of traumatic elbow dislocation with persistent instability [88]. Jobe and colleagues compared the results of primary UCL repair with their initial figure-of-eight reconstruction technique and found that 50 % of patients with direct repair returned to sport as opposed to 68 % of patients who had reconstruction. Results for repair were even less satisfying when evaluating professional baseball players as a subset [2]. Other comparative studies revealed similar results, with reconstruction providing superior results as compared to primary repair [15]. These early findings potentially set the stage for limited reporting of primary repair results. More recently, Richard and colleagues reported 90 % return to sport for collegiate athletes with acute UCL injuries. In their series, all three overhead athletes were able to return to sport [60]. Similarly, return to sport rates above 90 % have been reported for primary repair of acute, UCL injuries in patients younger than 22 years of age and in competitive female athletes [59, 61]. The more promising recent results for primary repair are likely secondary to improved indications, namely limiting repair to acute avulsion type injuries, whereas older studies likely included primary repair for more chronic injuries with attenuation of the ligament. In light of these findings and limited high level evidence, primary ligament repair may provide satisfactory surgical results in the appropriately indicated patient, although reconstruction remains the treatment of choice for the majority of throwing athletes or those who fail nonoperative treatment.

Medial Ulnar Collateral Ligament Reconstruction

UCL reconstruction is typically reserved for overhead athletes with full-thickness tears or athletes with partial-thickness tears that have failed a period of nonoperative treatment due to persistent medial elbow pain. Since Jobe's original description [3], a variety of technique modifications have been made. Some of the technique changes altered the original approach, the so-called modified Jobe technique, which was performed through a flexor–pronator muscle-splitting approach [62], while others altered graft fixation at the sublime tubercle and medial epicondyle [64, 66, 70, 89]. Other changes to the original technique, including graft choice modifications, have also been described in the literature [65, 78]. With multiple technique descriptions, direct comparisons are limited. However, several general trends can be elucidated from the literature since the original technique descriptions.

Several recent systematic reviews have helped consolidate the results of the available Level 3 and 4 data with respect to UCL reconstruction [77, 80, 90]. The original outcomes reported by Jobe et al. noted a 62.5 % return to sport with nearly one-third of patients report ulnar nerve for at least some period of time postoperatively [3]. Over the next several decades, operative techniques were modified to improve upon these results. More recent studies have reported excellent results in over 90 % of patients with a return to sport rate of 90 % for docking and modified docking techniques [77, 80]. Additionally, while the most common complication postoperatively remained ulnar nerve neuritis or neuropraxia, the complication rate for this dropped to nearly 2 % for modern techniques using a muscle-splitting approach [80]. Other commonly reported complications included reconstruction failure, infection, tunnel fracture, and heterotopic ossification. Today, UCL reconstruction is most frequently performed through a muscle-splitting approach using either palmaris or gracilis autograft. While the aggregate numbers in the literature predominantly describe the modified Jobe technique, there has been a trend toward increased use of the docking or modified docking technique, which is the technique of choice for the senior author given its consistent ability to allow return to sport while avoiding significant complications.

While return to sport data has been consistently reported, other outcomes of interest have recently been investigated, particularly in high demand athletes, including collegiate and professional pitchers. Despite the optimistic return to sport results with new and improving techniques, there is some evidence to suggest that pitchers who underwent UCL reconstruction frequently return to the disabled list for ipsilateral throwing arm injuries with a decline in common pitching performance metrics compared to preinjury including earned run average, innings pitched, and average fastball velocity [84, 87]. Although less frequently reported, this information is important to convey to elite athletes as their goals often extend beyond simply returning to sport, but frequently include goals that allow them excel in a competitive environment.

Revision Medial Ulnar Collateral Ligament Reconstruction

Despite the recent increased incidence of UCL reconstructions, the rate of reconstructions requiring revision has decreased, possibly secondary to improved surgical technique and postoperative rehabilitation efforts [6]. However, when reconstructions do fail and revision reconstruction is required, the return to sport rate for professional baseball pitchers is significantly lower than for primary reconstruction [91–93]. Additionally, complications are more frequently noted in revision surgery as compared to more recently described primary reconstruction techniques [93]. Revision reconstruction procedures pose several technical challenges, including difficulty with fixation depending on the location and mode of failure, as well as obvious limitations with graft choice depending on the primary surgical technique. Given these less than satisfactory results and notable technical challenges with revision reconstruction procedures, future efforts should aim to continue to improve upon primary reconstruction techniques in order to decrease the revision rate, while also aiming to improve upon revision reconstruction techniques and rehabilitation protocols given the increasing number of at risk patients with a history of UCL reconstruction.

Authors Preferred Technique

While a variety of reconstruction options exist, the authors prefer the docking technique for UCL reconstruction. One of the first decisions to be made when considering reconstruction is to determine whether arthroscopic evaluation is warranted. Arthroscopic evaluation of the elbow allows for assessment and treatment of posteromedial impingement, osteochondral defects, or loose bodies that may be suspected based on preoperative imaging or physical exam. An arthroscopic valgus stress exam can also be performed during arthroscopic evaluation, demonstrating gapping across the medial ulnohumeral joint with significant UCL injury (Fig. 12.3). The authors do no routinely perform elbow arthroscopy prior to every UCL reconstruction. Rather, arthroscopy is done when intraarticular pathology is suspected or identified based on preoperative physical exam and imaging.

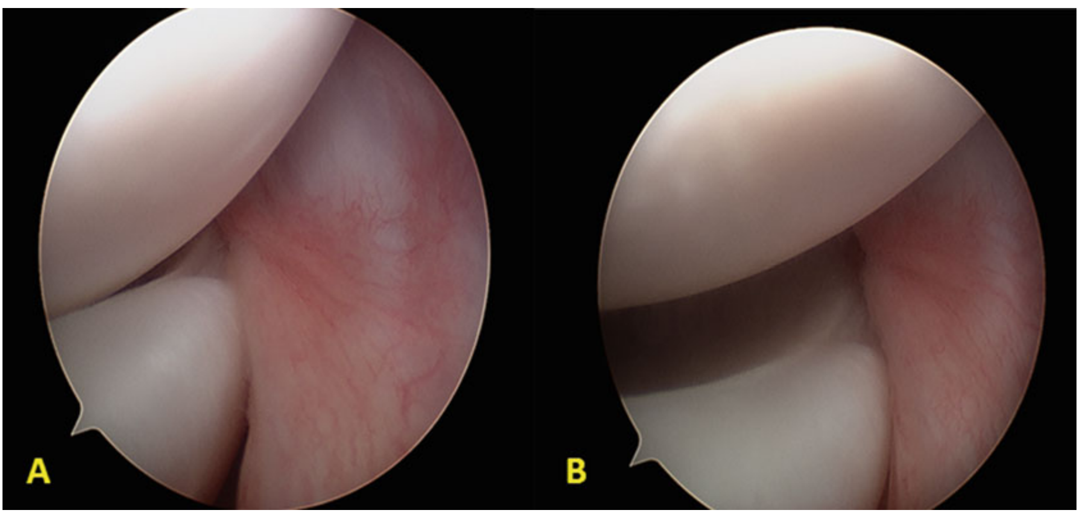

Fig. 12.3 Elbow arthroscopy visualizing the medial ulnohumeral joint (**a**) without and (**b**) with valgus stress applied. Notable gapping with valgus stress is consistent with ulnar collateral ligament insufficiency

Patient Positioning

Patient positioning is an important consideration and may be dictated by concomitant pathology requiring additional procedures at the time of UCL reconstruction. Supine positioning with an arm board and the shoulder externally rotated to allow access to the medial side of the elbow is frequently described. It is the authors' preference to perform surgery with the patient positioned prone with the arm placed in an arthroscopic arm holder. For one, this positioning allows easy transition if arthroscopic evaluation precedes UCL reconstruction. The arm can then be internally rotated at the shoulder with the forearm placed on a well-padded Mayo stand (Fig. 12.4). This position maintains the elbow in varus throughout the procedure while still allowing range of motion at the elbow.

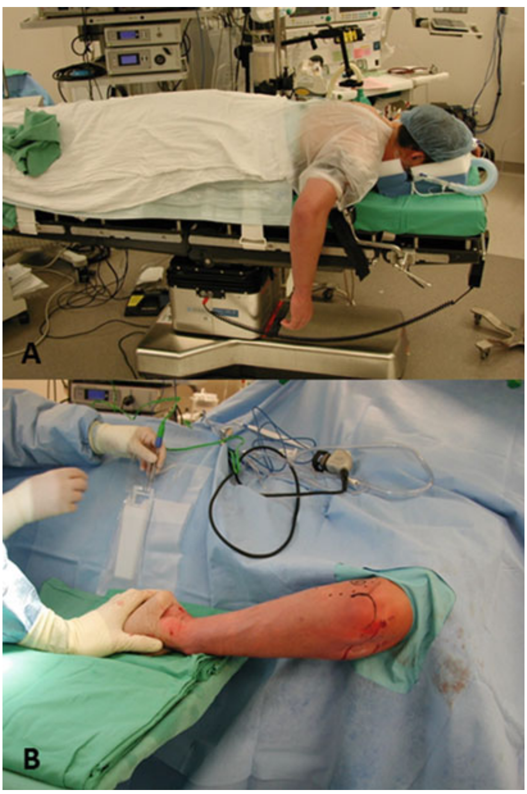

Fig. 12.4 (**a**) The patient is positioned prone with the arm in an arm holder for arthroscopic evaluation. (**b**) Following arthroscopic evaluation, the shoulder is internally rotated and the forearm placed on a well-padded Mayo stand to access the medial elbow

Surgical Technique

Several graft options exist for UCL reconstruction including autograft gracilis or palmaris as well as allograft. It is the author's preference to use ipsilateral palmaris autograft when present. The palmaris borders can be marked in the preoperative holding area while the patient is able to perform active thumb opposition to the small finger with wrist flexion for easy identification of the palmaris during surgery. We typically make a small, transverse incision at the flexion crease of the wrist over the identified palmaris tendon. The tendon is freed from any underlying adhesions, and a size 0 braided suture is placed in a Krackow fashion along the distal 15–20 mm of the tendon and any residual tendon amputated distal to the sutures. A small tendon harvester is then used to obtain the graft. Residual muscle belly is dissected of the proximal aspect of the harvested tendon in preparation for later graft passage.

The palpable landmarks at the medial elbow, including the medial epicondyle, medial intermuscular septum, proximal olecranon, and sublime tubercle of the ulna are marked. It also helps to carefully delineate the borders of the cubital tunnel using these landmarks. A 10–12 cm curvilinear incision is made over the medial epicondyle. Branches of the medial antebrachial cutaneous nerve can frequently be identified just superficial to the antebrachial fascia and should be identified and protected throughout the case. The fascia of the flexor–pronator mass is then identified as is the ulnar nerve within the cubital tunnel. In the absence of preoperative ulnar nerve symptoms or instability, the ulnar nerve is left alone. If there are noted ulnar nerve symptoms, instability of the ulnar nerve with elbow range of motion, or subluxation of the nerve onto the epicondyle, we proceed with subcutaneous ulnar nerve transposition. In this setting, the ulnar nerve is exposed and mobilized prior to UCL reconstruction. In addition, a strip of the medial intermuscular septum is prepared and used as a fascial sling to stabilize the nerve after transposition. The septum is amputated as proximal as possible and then a strip of septum is mobilized off the humerus from proximal to distal, keeping the most distal attachment at the epicondyle intact.

After the ulnar nerve is identified, the fascia overlying the flexor–pronator mass is split in line with the underlying muscle fibers at the junction of the anterior two-thirds and posterior one-third of the flexor–pronator mass (Fig. 12.5). The muscle fibers of the underlying flexor carpi ulnaris can then be bluntly split and blunt, deep retractors placed to visualize the UCL. In the majority of cases, the UCL is significantly attenuated. The anterior band of the UCL is identified deep to the muscular layer and is split longitudinally, allowing visualization of the ulnohumeral joint, which aids with ulnar tunnel placement.

We begin with preparation of the ulnar tunnels at the sublime tubercle. With the sublime tubercle identified, approximately 10–15 mm distal to the ulnohumeral joint line, a 3.2 or 3.5 mm drill is used to make anterior and posterior converging drill holes, maintaining a 1 cm bone bridge between the tunnels. This can be done freehand or using a commercially available converging drill guide. A small curette is used to further prepare and connect the converging tunnels. With the tunnels connected, a shuttling suture or suture passing device is passed in preparation for graft passage (Fig. 12.6). Using the shuttling suture, the graft is shuttled through the ulnar tunnels from posterior to anterior.

Attention is then turned to the medial epicondyle and the humeral tunnel. With the medial epicondyle exposed, a 4.5–5.0 mm drill or burr is used to make a tunnel at the origin of the anterior band of the UCL. The origin of the anterior band sits just anterior to the distal most point of the epicondyle in the axial plane. The tunnel is aimed directly proximal, roughly in line with the shaft of the humerus, with an ideal tunnel length measuring 15–20 mm. In order to obtain adequate tunnel length, the tunnel can be angled slightly posterior and lateral compared to the anatomic axis of the medial epicondyle [94]. Commercial guides are available to assist with humeral tunnel drilling as well. The proximal and posterior cortex of the epicondyle should be left intact. Near the proximal aspect of the tunnel, a 1.8–2.0 mm drill is used to drill two tunnels that connect to the 4.5 mm tunnel, leaving a stable bone bridge on the proximal epicondyle between the two small drill holes, which

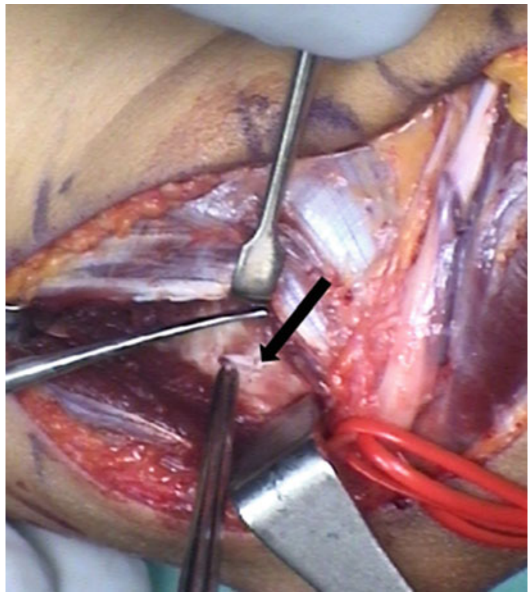

Fig. 12.5 The flexor–pronator fascia and flexor carpi ulnar muscle belly are split an retracted, allowing visualization of the underling medial ulnar collateral ligament (*arrow*)

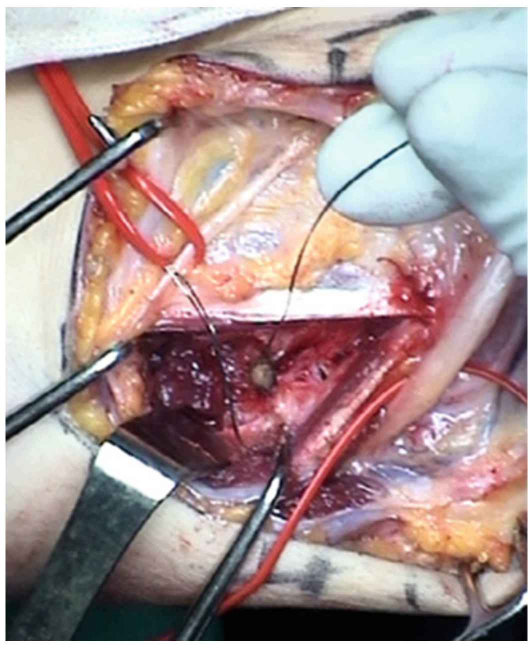

Fig. 12.6 Shuttling wire placed through the ulnar tunnels at the sublime tubercle in preparation for graft passage. A branch of the medial antebrachial cutaneous nerve and ulnar nerve are protected with vessel loops

allows for suture passage. Alternatively, several commercial drill guides exist that allow for targeting of these small suture passage tunnels to the 4.5 mm tunnel. The exit location of these suture tunnels is somewhat dependent on any concurrent ulnar nerve surgery. If the ulnar nerve is transposed, we prefer to place one tunnel anterior to the supracondylar ridge and the other posterior. If the ulnar nerve is left in situ, then we aim to place both suture tunnels anterior to the supracondylar ridge in order to prevent irritation of the ulnar nerve within the cubital tunnel. Using a shuttling suture or device through the more anterior suture passage tunnel, the anterior limb of the prepared graft is pulled into the humeral tunnel. Maintaining the arm in varus, the posterior limb of the graft is pulled into position and measured in order to ensure that there is enough graft length to fill the humeral tunnel without bottoming out within the tunnel, which would prevent tensioning. Typically, we aim to have 10–15 mm of each limb of graft within the humeral tunnel. Using this measurement, the posterior limb is prepared with a braided size 0 Krackow stitch. Final graft length is confirmed and then excess graft is removed. Prior to final graft docking and tensioning, the longitudinal split in the native UCL is repaired using size 0 suture in a running fashion from distal to proximal. Then, using the more posterior suture passage tunnel, the posterior limb of the graft is pulled into the humeral tunnel (Fig. 12.7). Graft tension is checked to ensure that it is appropriate through a full range of motion. The arm is maintained in varus with the forearm supinated and elbow positioned at approximately 45–60° of flexion and the sutures are tied over the bone bridge at the proximal epicondyle (see Video 12.1). With the graft in place, we routinely close the split in the flexor–pronator fascia with a running absorbable size 0 suture. The ulnar nerve is addressed with final transposition using soft-tissue sling stabilization, if warranted, prior to skin closure.

Fig. 12.7 Both limbs of the graft are pulled into the humeral tunnel and docked prior to positioning in varus, manual tensioning, and tying suture over the humeral bone bridge

Postoperative Management

The patient is placed in a hinged elbow brace to allow range of motion between 60° and 90° for the first 10–14 days postoperatively. After 2 weeks, the brace is opened to allow range of motion from 45° to 90°, thereafter increasing both flexion and extension over the next 4 weeks with the goal of achieving full elbow range of motion at 6 weeks after surgery. The elbow brace is discontinued at 6 weeks at which time shoulder range of motion and strengthening is emphasized. At 12 weeks, vigorous elbow and shoulder strengthening exercises commence. In throwing athletes, a throwing program is typically initiated at 14–16 weeks postoperatively. Position players are typically finished with their throwing rehabilitation program by 6–8 months postoperatively, while pitchers are typically fully rehabilitated by 9–14 months postoperatively and can return to competition.

Conclusions

Since its first description over four decades ago, the management of UCL injuries and UCL reconstruction procedures has continued to evolve. UCL reconstruction has provided consistent outcomes for overhead athletes who have failed a trial of conservative management, which typically includes rest and a graduated throwing program. While our surgical techniques and outcomes continue to improve, there remains significant concern with the increasing incidence of elbow injuries in adolescent athletes which has been accompanied by an increase in UCL reconstruction procedures in this age group. Injury prevention remains the greatest area for improvement when it comes to UCL injuries, and future studies that investigate the efficacy and adherence to specific throwing guidelines, including pitch counts and rest, are warranted as many of our current guidelines and recommendations are based on anecdotal evidence and expert opinion. While injury prevention requires a collaborative effort from surgeons, coaches, parents, and players, it provides the best opportunity to reverse the concerning trends seen in recent years.

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