Outcome of Ulnar Collateral Ligament Reconstruction of the Elbow in 1281 Athletes

Results in 743 Athletes With Minimum 2-Year Follow-up

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Background: The anterior bundle of the ulnar collateral ligament (UCL) is the primary anatomical structure providing elbow stability in overhead sports, particularly baseball. Injury to the UCL in overhead athletes often leads to symptomatic valgus instability that requires surgical treatment.

Hypothesis: Ulnar collateral ligament reconstruction with a free tendon graft, known as *Tommy John surgery*, will allow return to the same competitive level of sports participation in the majority of athletes.

Study Design: Case series; Level of evidence, 4.

Methods: Ulnar collateral reconstruction (1266) or repair (15) was performed in 1281 patients over a 19-year period (1988−2006) using a modification of the Jobe technique. Data were collected prospectively and patients were surveyed retrospectively with a telephone questionnaire to determine outcomes and return to performance at a minimum of 2 years after surgery.

Results: Nine hundred forty-two patients were available for a minimum 2-year follow-up (average, 38.4 months; range, 24-130 months). Seven hundred forty-three patients (79%) were contacted for follow-up evaluation and/or completed a questionnaire at an average of 37 months postoperatively. Six hundred seventeen patients (83%) returned to the previous level of competition or higher, including 610 (83%) after reconstruction. The average time from surgery to the initiation of throwing was 4.4 months (range, 2.8-12 months) and the average time to full competition was 11.6 months (range, 3-72 months) after reconstruction. Complications occurred in 148 patients (20%), including 16% considered minor and 4% considered major.

Conclusion: Ulnar collateral ligament reconstruction with subcutaneous ulnar nerve transposition was found to be effective in correcting valgus elbow instability in the overhead athlete and allowed most athletes (83%) to return to previous or higher level of competition in less than 1 year.

Keywords: ulnar collateral ligament; elbow; baseball pitcher; Tommy John surgery

The anterior bundle of the ulnar collateral ligament (UCL) is the primary restraint to valgus stress at the elbow during functional range of motion between 20° and 120° of flexion.[14,18-21,24,26,34] Injury to the UCL occurs most often in overhead athletes, especially baseball pitchers, but is seen less commonly in other sports including javelin throwers, tennis, gymnastics, football, and wrestling.[2,5,15,16,22,27,33,35] The UCL may also be injured in acute upper extremity trauma outside athletic participation, and is usually torn in cases of acute elbow dislocation. Injury to the UCL in overhead athletes often leads to symptomatic valgus instability and often requires surgical treatment for return to overhead sports. Dr Frank Jobe pioneered surgical reconstruction of the UCL in 1974, often referred to as *Tommy John surgery* in reference to the first recipient of the reconstruction procedure.

The purpose of this study was to evaluate the results of UCL reconstruction performed by a single surgeon in a large group of patients at a minimum 2-year follow-up.

Our hypothesis was that UCL reconstruction with a free tendon graft, the Tommy John surgery, would allow return to the same competitive level of sports participation in the majority of athletes.

MATERIALS AND METHODS

Ulnar collateral reconstruction (1266) or repair (15) was performed in 1281 patients over a 19-year period (1988–2006) by the senior author (J.R.A.). There were 1253 male and 28 female patients between the ages of 14 and 59 years (average, 21.5 years). The dominant extremity was involved in 1263 patients (98%). There were 1213 (95%) injuries from participating in baseball; other sports involved in injuries were football, 13; javelin throwing, 15; softball, 9; tennis, 7; wrestling, 2; soccer, 2; gymnastics, 2; cheerleading, 4; and pole vaulting, 1. The remaining 13 injuries were from a wide variety of other sports.

The baseball players (1210) included 1085 pitchers (89%), 18 catchers, 9 infielders, and 18 outfielders, and 80 athletes that played several positions, but did not pitch. Three hundred eighty-six (32%) played professional baseball, including 86 major league and 300 minor league athletes. The remaining baseball players included 583 (48%) who played collegiate baseball and 240 high school and recreational athletes.

Reconstruction was performed with an autologous palmaris longus, gracilis, or plantaris tendon graft, and subcutaneous ulnar nerve transposition was performed in all cases. Additional procedures were done in 437 (34%) patients, primarily excision of a posteromedial olecranon osteophyte.

A standard preoperative clinical assessment including stress radiographs was performed as described in a previous report.[2] All patients reported elbow pain while athletically active (throwing, tennis). Baseball players primarily (96%) complained of pain during the late cocking and acceleration phase of throwing (Figure 1). Five hundred ninety-seven (47%) reported an acute onset of pain at the medial elbow, while 684 (53%) could not identify a single inciting event. For those athletes who could identify the onset of symptoms, 73% reported the onset occurring during a game, 13% during practice, 9% during the preseason, 4% during the off-season, and 1% while playing recreationally. The diagnosis of ulnar collateral insufficiency was made an average of 6.4 months (range, 0-84 months) after symptoms began, and surgical reconstruction was performed at average 7.1 months (range, 0.25-85 months) after the onset of symptoms. For baseball pitchers, 44% reported throwing with the arm angle "overhand," 52% threw 3/4 style, and 4% reported throwing sidearm.

Nonoperative treatment is generally recommended for a minimum of 3 months before considering UCL reconstruction. However, specific seasonal timing (preseason, in-season, or postseason) and level of play often affect the length of nonoperative treatment. During nonoperative treatment, the patient is prescribed an active period of complete rest from throwing, including shoulder and elbow
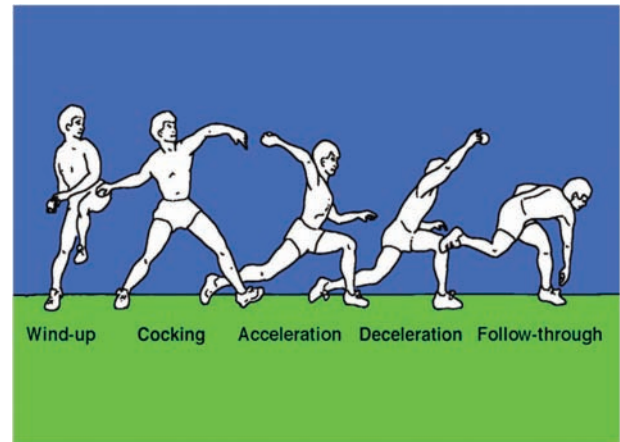

Figure 1. The 5 phases of the overhead throwing motion.

rehabilitation exercises, nonsteroidal anti-inflammatory medications, and avoidance of any activities causing valgus stress across the elbow (eg, tennis, racquetball, weight lifting). When symptoms resolve, the athlete is allowed to progress to an interval throwing program and, in some cases, a biomechanical throwing evaluation. Failure to progress through a rehabilitation program after 3 months, depending on sport-specific seasonal factors, led to consideration of surgical reconstruction.

Preoperatively 292 (23%) athletes reported neurologic symptoms, most commonly intermittent paresthesia in the ulnar nerve distribution (ring and small fingers) during throwing. Two hundred (16%) had a history of previous surgery on the same elbow, most commonly open or arthroscopic excision of a posteromedial olecranon osteophyte for valgus extension overload syndrome.

The average preoperative range of motion was from 5° to 136° of flexion, with 84° and 85° of pronation and supination, respectively. Only 281 (22%) patients demonstrated valgus instability to manual testing at 30° of elbow flexion. Valgus instability was determined to be present subjectively on physical examination if the laxity or end-feel to valgus stressing was significantly more (or softer) than the contralateral elbow, usually believed to represent more than 2 mm difference. Tinel test was positive for ulnar nerve sensitivity in 271 (21%) patients, but only 34 (3%) had persistent ulnar nerve symptoms (while not throwing) at the time of surgery. Palmaris longus tendon was present in at least 1 forearm in 84% of patients and was absent in 16%.

Radiographic examination revealed normal findings in 437 (43%) patients, while 577 (57%) patients were found to have assorted radiographic abnormalities, most commonly olecranon osteophyte formation (148) and ectopic calcification within the UCL substance (94) (Figure 2). Eight hundred seventy-one (68%) patients underwent MRI, most with intra-articular contrast. Many patients had obtained a noncontrast MRI before arrival at our tertiary referral center. If the findings on the outside study were conclusive, no repeat MRI was ordered. However, all MRI examinations done at our center were performed

Figure 2. An AP radiograph of the elbow with ectopic calcification within the ulnar collateral ligament at the ulnar attachment.

Figure 3. Schematic of ulnar collateral ligament reconstruction with free autologous graft and subcutaneous ulnar nerve transposition.

with intra-articular contrast. The MRI findings indicated a complete UCL tear in 459 (53%) patients and a partial tear or insufficient ligament in 275 (31%). Other MRI findings included olecranon osteophytes, ectopic UCL calcification, flexor muscle tendinopathy or edema, medial epicondylitis, and an olecranon stress fracture. Magnetic resonance imaging was not always diagnostic for UCL insufficiency, but was used as additional data along with the history, examination, stress radiographs, and rehabilitation course to determine the overall health of the ligament and potential for return to play without surgical reconstruction. The MRI was only considered diagnostic if it revealed a complete tear with contrast extravasation.

Ulnar collateral ligament reconstruction was performed with the modified Jobe technique as described previously by Azar and colleagues[2] and Jobe and colleagues[15] (Figure 3). Elbow arthroscopy was performed in all cases during this study period to help confirm the presence of valgus instability. A single anterolateral viewing portal was placed, and the elbow was tested in valgus stress at approximately 70° of flexion to determine medial joint space opening. An opening of greater than 2 mm was considered a positive sign of instability. Although the arthroscopic examination was helpful in some cases of questionable UCL insufficiency, it rarely changed our preoperative plan; therefore, we no longer perform routine arthroscopic examination before reconstruction. Because olecranon osteophytes are excised through an open arthrotomy, only the presence of anterior pathologic findings (loose bodies) requires concomitant arthroscopy with our current technique.

Palmaris longus tendon graft was used in 935 (73%) surgeries, including 825 (88%) grafts harvested from the ipsilateral extremity and 110 (12%) from the contralateral
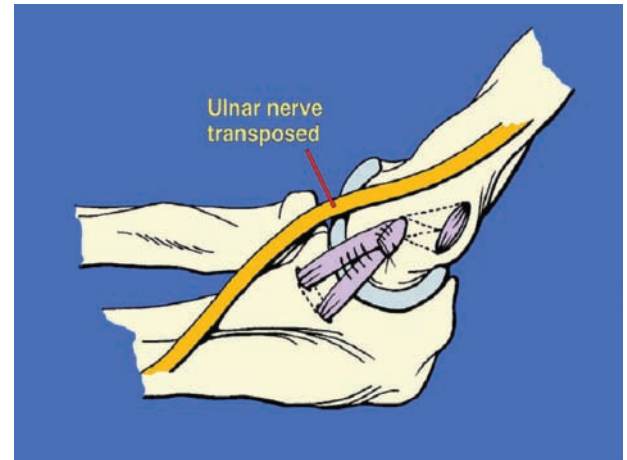
forearm. The contralateral palmaris longus tendon was used only in cases where the tendon was absent or insufficient (small caliber) on the operative extremity, but present on the contralateral arm. Toe extensor tendon from the ipsilateral extremity, the second graft choice early in the series, was used in 30 (3%) patients. Gracilis tendon from the contralateral extremity, the current alternative graft source, was used in 294 (23%) patients with insufficient or absent palmaris longus tendons (Table 1). The change from toe extensor to gracilis tendon occurred early in the study period, primarily because of the authors' surgical experience with harvest of the more robust hamstring graft for ACL reconstruction. Other grafts used include plantaris (23) and ipsilateral patellar tendon (1). Plantaris tendon was unreliable in caliber, and the patellar tendon was difficult to tension because of improper length of the tendinous portion (longer than the length of the native UCL).

Subcutaneous ulnar nerve transposition stabilized with flexor muscle fascial slings was performed in all cases. The nerve is held by a fascial sling in a subcutaneous tract after complete release from the Arcade of Struthers proximal to the deep portion of the 2 heads of the flexor carpi ulnaris distally. Early in the series, 2 fascial slings were used to stabilize the nerve; however, current surgical technique includes a single fascial sling or a strip of the medial intermuscular septum that is released proximally and remains attached to the medial epicondyle distally. These modifications were made in response to the relatively high rate of postoperative ulnar nerve symptoms (20%), although the neurapraxia was temporary in all cases. The rate of ulnar nerve symptoms has decreased with the current transposition technique.

Additional procedures were done in 437 patients (34%); including 337 cases with excision of a posteromedial olecranon osteophyte. Other procedures included debridement of flexor tendinitis (15), capsular release (2), loose body removal (64), lateral collateral ligament repair (3), and screw fixation of an olecranon stress fracture (4). The study methods and data collection received institutional review board approval.

TABLE 1
Operative Findings and Graft Source by Athlete Level

	Major	Minor	High School	College	Recreational	Other	Total
Instability	25	85	39	126	2	15	292
+1	18	58	30	95	1	4	206
+2	7	25	8	28		8	76
+3		2	1	3	1	3	10
UCL							
Attenuated	29	118	86	225		20	478
Complete tear	25	70	38	105	1	22	261
Partial tear	5	26	18	58	2	5	114
Other		12		3			15
Graft							
Palmaris longus	42	202	118	296	3	22	935
Gracilis	20	41	39	98		18	294
Other	3	7	1	13		3	27

Postoperative Rehabilitation

A standardized postoperative 4-phase rehabilitation program for ulnar collateral reconstruction as described by Wilk and colleagues[38-40] was followed (see online Appendix for this article at http://ajs.sagepub.com/supplemental/). The first phase begins immediately after surgery and continues for 3 weeks. During surgery, the patient's elbow is placed in a compression dressing with a posterior splint to immobilize the elbow in 90° of elbow flexion for 1 week to allow initial healing. Full range of motion of the elbow joint is restored by the end of the fifth to sixth week after surgery. During phase II (weeks 4-10), a progressive isotonic strengthening program is initiated. Exercises are focused on scapular, rotator cuff, deltoid, and arm musculature. Shoulder range of motion and stretching exercises are performed during this phase and the Thrower's Ten Exercise Program is initiated.[40] During the advanced strengthening phase (phase III), from weeks 10 to 16, a sport-specific exercise/rehabilitation program is initiated. During this phase, stretching and flexibility exercises are performed to restore full shoulder internal and external rotation as well as elbow and wrist range of motion. Isotonic strengthening exercises are progressed, and at week 12, the athlete is allowed to begin an isotonic lifting program including bench press, seated rowing, latissimus dorsi pull downs, triceps push downs, and biceps curls. In addition, the athlete performs specific exercises to emphasize sport-specific movements. At week 12, overhead athletes begin a 2-hand plyometric throwing program, and at 14 weeks a 1-hand plyometric throwing program. Furthermore, endurance exercises, core stability, and leg strengthening are emphasized during phase III. Phase IV, the return to activity phase, (week 16 and beyond) is characterized by the initiation of an interval throwing program.

RESULTS

Nine hundred forty-two patients with prospectively collected surgical data were eligible for a minimum 2-year follow-up (average, 38.4 months; range, 24-130 months). Eight hundred ninety-one (94.5%) patients were baseball players: 320 professional (35.9%), 413 collegiate (46.3%), 158 high school or recreational (17.7%). Forty-one were involved in track, football, or other sports. Seven hundred forty-three (79%) patients were contacted for follow-up evaluation: 596 (80%) by phone interview and 147 (20%) were examined and completed a questionnaire during an office visit at an average of 37 months postoperatively. The remaining 199 patients were not able to be located for follow-up despite multiple attempts at contact by search vehicles, private investigation, and emergency contact telephone numbers.

Six hundred seventeen (83%) patients returned to the previous level of competition or higher, including 610 (83%) after reconstruction and 7 of 10 after repair (70%). Thirty-four of 45 (75.5%) major league baseball players returned to the same level, 7 returned to the minor league level, and 4 have not returned to sport (Table 2). One-hundred thirty-eight of 188 (73%) minor league baseball players returned to the same level or higher, 61 (32%) at the same level, and 77 (41%) at a higher level, including 35 (19%) who advanced to the major league. Twenty-four (13%) minor league baseball players returned to play professional baseball at a lower level (ie, from AAA to AA), while 21 (11%) did not return to professional baseball (Table 3). Five (1.5%) of 346 collegiate players progressed to the major league, 66 (19%) to the minor league, 233 (67%) returned to collegiate level, and 10 (3%) to a lower recreational level; 26 (7%) did not return to sport. One hundred eight (83%) of 131 high school athletes returned to the same or higher level, including 8 (6%) who progressed to professional baseball and 65 (50%) to the college level, but none of the high school athletes in this group had reached the major leagues at the time of this report. Seven (5%) returned to a lower recreational level and 13 (10%) did not return to sport (Table 4). The average time from surgery to the initiation of throwing was 4.4 months (range, 2.8-12 months), and the average time to full competition was 11.6 months (range, 3-72 months) after reconstruction. No

TABLE 2
Major League Return to Play Data[a]

	Higher	Lower (Returned to Minor)	Did Not Return	Same
Major	NA	7	4	34

[a]NA, not available.

TABLE 3
Minor League Return to Play Data[a]

Minor Group	Higher (to Minor)	Lower (to Minor)	Did Not Return	Same	Higher (to Majors)	Lower (Recreational)	Total
A	19	0	4	25	9	3	60
AA	9	6	2	8	11	0	36
AAA	NA	13	3	17	10	0	43
Independent	2	NA	2	3	2	0	9
Rookie	12	NA	1	0	1	0	14
Unknown	NA	5	9	8	2	2	26
Total	42	24	21	61	35	5	188

[a]NA, not available.

TABLE 4
Collegiate, High School, Recreational, and Other Athletes Return to Play Data[a]

	Higher (to Minors)	Did Not Return	Same	Higher (to Majors)	Higher (to College)	Lower (Recreational)	Unknown Return
High school	8	13	35	0	65	7	3
College	66	26	233	5	NA	10	6
Recreational	0	0	2	0	0	NA	1
Other	0	2	29	0	7	0	3

[a]NA, not available.

specific elbow outcomes score validated for throwing athletes was available during the study period; therefore, return to play at the same or higher level of competition was considered a positive result.

No significant statistical difference in outcome was found for different graft choices. Return rates were as follows: ipsilateral palmaris longus, 85% (435 of 512); contralateral palmaris longus, 88% (35 of 40); gracilis, 88% (154 of 175); and plantaris 88% (14 of 16) (P = .30). Return to play for patients with concomitant olecranon osteophyte excision during the index UCL reconstruction was 86% compared with 82% for athletes without olecranon osteophyte excision (P = .21). Return to play for patients with any prior elbow surgery was 81% compared with 86% for patients with no prior elbow surgery (virgin elbows) (P = .22). None of these differences reached statistical significance (P < .05).

Complications occurred in 148 patients (20%). Most commonly, minor postoperative ulnar nerve neurapraxia was reported in 121 (16%) patients. Most (99 of 121) involved only sensory paresthesias in the ring and small fingers and resolved within 6 weeks. Twenty-two patients developed ulnar nerve sensory disturbances that resolved between 3 months and 1 year. One patient developed complete ulnar nerve motor and sensory dysfunction postoperatively. After 2 ulnar nerve neurolysis procedures, motor

function returned at 10 months, but sensory paresthesias were persistent at 48 months. Postoperative ulnar nerve dysfunction did not significantly affect outcome. One hundred three of 121 patients (85%) with postoperative ulnar nerve symptoms and 514 of 622 (83%) of patients with no postoperative neurologic complications returned to the same level of play or higher. Twenty-seven (4%) patients reported graft site complications, most commonly superficial wound infections that resolved with oral antibiotics.

Fifty-five patients underwent 62 subsequent elbow surgeries during the study period from 6 months to 7 years after reconstruction. The most common reason for additional surgery was arthroscopic debridement of an olecranon osteophyte (53), although 9 patients (1%) required revision UCL reconstruction. Ten of 53 (19%) patients who required subsequent osteophyte excision had an olecranon osteophyte excised at the index UCL reconstruction. The average time from index UCL surgery to subsequent olecranon osteophyte excision was 25.4 months (range, 4.5-72.4). Return to play for those who required subsequent osteophyte excision was 71% (38 of 53). Five patients (0.5%) developed avulsion fractures of the medial epicondyle at the tunnel site at 6, 8, 12, 14, and 18 months after surgery. Four were treated with open reduction and internal fixation, and 1 was treated with immobilization alone. Twenty patients (3%) underwent subsequent shoulder

TABLE 5
Preoperative and Intraoperative Physical Examination Findings by Athlete Level

	Major	Minor	High School	College	Recreational	Other
Age, y	28.2 ± 4.1	24.9 ± 3.9	17.8 ± 2.1	20.5 ± 2.1	33 ± 9.9	23.4 ± 9.6
Preop flexion (deg)	132.2 ± 7.7	136.3 ± 2.9	137.5 ± 13.4	141.4 ± 72.3	140 ± 0	132.6 ± 17.3
Preop extension (deg)	4.5 ± 9.3	3.3 ± 11.7	3.3 ± 14.9	1.86 ± 9.6	7.5 ± 3.5	0.7 ± 11.5
Preop supination (deg)	83 ± 8.9	84.7 ± 5.1	84.2 ± 5.1	84.4 ± 5.8	80 ± 0	83.8 ± 5.5
Preop pronation (deg)	82.4 ± 5.5	83.5 ± 5.5	84.2 ± 4.9	83.6 ± 5.9	80 ± 0	82.3 ± 6.2
Intraop flexion (deg)	134.9 ± 5.1	137.7 ± 6.8	139.5 ± 13	138.7 ± 5.7	142.5 ± 3.5	135.5 ± 15.4
Intraop extension (deg)	4.4 ± 5.6	3.3 ± 7	0.984 ± 4.5	1.7 ± 6.7	5 ± 0	2.5 ± 6.5
Intraop supination (deg)	82 ± 7.6	83.6 ± 5.7	84.9 ± 5.2	84.7 ± 5.7	80 ± 0	83.7 ± 4.8
Intraop pronation (deg)	80.2 ± 6.0	79.6 ± 17.2	84.6 ± 5.5	82.9 ± 12.6	80 ± 0	82.3 ± 5.6

surgery for labral or rotator cuff repair after return from UCL reconstruction.

DISCUSSION

This study represents a continuation and subsequent follow-up of the patient database of UCL reconstructions performed by one surgeon (J.R.A.).[2] The additional patients reported here provide confirmation of some of the findings of the previous study as well as new insight into this "epidemic" of medial elbow injuries in overhead athletes, particularly baseball players. The principal finding of this study was that UCL reconstruction allows a high percentage (83%) return to the previous level of competition for athletes at all skill levels in multiple sports, despite a relatively high (20%) minor complication rate.

Six hundred seventeen (83%) patients returned to the same or higher level of competition, including 83% of those with reconstructions and 70% of patients with UCL repair without augmentation. This represents an improvement compared with the previous report of Azar et al[2] (79% total return: 81% reconstruction, 63% repair). We attribute this improvement primarily to greater experience in surgical technique and rehabilitation. Table 5 shows preoperative and postoperative overall results. Patient expectations have also changed during the study period. Most patients expect to return to competition after UCL reconstruction today, and this positive outlook may have some influence on the ultimate outcome.

We rarely perform UCL repair alone for symptomatic valgus instability. After early experience demonstrated higher failure with UCL repair alone in high-demand athletes, the senior author has advocated surgical reconstruction with an autologous palmaris longus, gracilis, or plantaris tendon graft, except in the rare case of an acute ligament avulsion with healthy remaining tissue. As a result, only 2 repairs (rather than reconstruction) have been performed since 1993, while 13 UCL repairs were performed between 1988 and 1993.

Mechanical stability in the overhead athlete's elbow is provided by both bony and soft tissue restraints. The bony articulating surfaces of the distal humerus, radius, and ulna provide primary stability to valgus stress from full extension to 20° of flexion, and from 120° to full flexion. The soft tissue restraints, especially the anterior band of the UCL, are responsible for primary stability to valgus stress from 20° to 120° of flexion, the functional arc of motion for most athletic activities.[19-21,26,34]

The majority of patients in our treatment group were baseball players, especially pitchers. Baseball pitching generates high valgus and extension forces across the elbow during the late cocking and acceleration phases of throwing. The valgus load produced during throwing has been estimated to approach the ultimate tensile strength of the UCL.[6,9,36] Forty-seven percent of patients reported an acute onset of pain at the medial elbow, while 53% complained only of persistent medial elbow pain and inability to perform at overhead sport. The throwing elbow encounters repetitive near-failure stresses during high-level sports that may cause UCL microtrauma with eventual complete failure or gradual attenuation. Therefore, most UCL tears in baseball are either an acute injury to a chronically attenuated ligament (52%) or an insufficient ligament that produces associated elbow symptoms (48%) within the spectrum of valgus extension overload syndrome.[5,37] Attenuation of the UCL may increase the stress on associated restraints, including the radiocapitellar joint and the olecranon tip. As a result, olecranon osteophytes, ulnar nerve neurapraxia, and radiocapitellar chondral damage are the most common lesions seen in the throwing elbow.[1] Based on biomechanical measurements and calculations of the forces generated in the throwing elbow, one would expect UCL failure to occur even more frequently than is currently encountered. Additional research is needed to determine the physiologic and mechanical factors responsible for UCL injury in a minority of overhead athletes.

The clinical examination of the elbow and subsequent diagnosis of UCL insufficiency is based on a combination of symptoms and findings. All patients complained of medial elbow pain with overhead activities, but only 22% of patients demonstrated valgus instability to manual testing at 30° of elbow flexion. This is because of the inherent difficulty of evaluating the small amount of laxity that indicates UCL insufficiency. Field and Altchek[8] performed sequential cutting studies of the anterior bundle during arthroscopic evaluation and found no visible joint laxity before complete sectioning. Even complete release of the

anterior bundle of the UCL increased valgus laxity by only 1 to 2 mm. Similar cutting studies by Sojbjerg and colleagues[29] and Callaway and colleagues[3] have demonstrated that the greatest amount of valgus laxity occurs between 70° and 90° of flexion after anterior bundle sectioning. The elbow is difficult to stabilize and examine at 70° or 90° of flexion; therefore, examination is generally performed at 30° of flexion. The small expected amount of measurable laxity needed to identify UCL insufficiency with physical examination is often beyond the sensitivity of the examiner's hands. Partial tearing of the UCL or attenuation without complete tear is most likely indistinguishable from normal elbow laxity on examination. The clinician must therefore rely on a thorough history, physical examination, and a compilation of available testing to reach the proper diagnosis. We typically rely primarily on a combination of findings to diagnose UCL insufficiency: symptoms during the late cocking phase of throwing, tenderness to palpation along the ligament, positive milking maneuver, and evidence of injury to the ligament on magnetic resonance arthrography with intra-articular gadolinium injection (MRA). The difficulty in diagnosis is demonstrated by the relatively long duration of symptoms before diagnosis of UCL insufficiency (5.8 months) in our patient population.

For those athletes who could identify the onset of symptoms, more than half (73%) reported the onset occurring during a game, perhaps indicating the contribution of "overthrowing" (extra effort in competition) or fatigue. Additional data concerning the number of pitches thrown during the game and season before injury may help determine the relationship, but is not available at this time.

Ulnar nerve sensitivity (positive Tinel test) was present in about one third of patients, and 3% had persistent ulnar nerve paresthesias at the time of surgery. Ulnar nerve injury or sensitivity may be secondary to increased stretching around the medial epicondyle with excess valgus laxity.[4,12,37] The degree of laxity necessary to cause stretch injury (neurapraxia) to the ulnar nerve is not known, but all patients with preoperative nerve symptoms had resolution of ulnar paresthesias after UCL reconstruction and subcutaneous ulnar nerve transposition.

Radiographs revealed abnormalities in half of patients, including olecranon osteophyte formation and ectopic calcification within the UCL substance. The formation of olecranon osteophytes is clearly related to the increased stresses of valgus extension overload in the face of valgus instability.[37] However, the relationship between UCL calcification and injury is not as well understood. Avulsion of the distal UCL insertion at the sublime tubercle of the ulna has been reported in the acute UCL injury, but some athletes demonstrate ectopic calcification without a history of acute injury.[11] Asymptomatic athletes have also been reported to have ectopic calcification present along the medial elbow.[7] Ectopic UCL calcification may represent either a physiologic response to repetitive trauma or evidence of a previous acute avulsion injury. Prospective radiographic evaluation of the throwing elbow may clarify the cause of the calcification and prognostic value of this finding.

Currently, MRA remains our ancillary test of choice for evaluation of the UCL and associated lesions. We perform MRA on all patients before surgical reconstruction, except those who present with a standard noncontrast MRI from an outside facility. The MRA test allows visualization of complete or partial UCL injury indicated by contrast extravasation or contrast presence outside the normal attachment site of the distal UCL on the sublime tubercle of the ulna, the "T sign."[31,32] Also, MRA may demonstrate olecranon osteophytes, loose bodies, chondral injury to the radiocapitellar joint, ectopic UCL calcification, flexor muscle tendinitis or edema, medial epicondylitis, and an olecranon stress fracture. If the diagnosis is uncertain in the individual with an outside MRI, we often repeat the test with our standard MRA protocol. The MRA test was not typically used alone to make the diagnosis of ligament injury, but provided additional data to help determine ligament health and plan a treatment course. Gaary et al[10] and Potter[23] at the Hospital for Special Surgery have reported excellent visualization of the UCL for diagnostic purposes with noncontrast MRI; however, we have found MRA to be of more diagnostic value in our facility.

Each of the patients in this study underwent diagnostic arthroscopy to confirm valgus instability before reconstruction. We have recently abandoned the routine use of diagnostic arthroscopy for preoperative confirmation of instability. Arthroscopy is useful in difficult diagnostic cases to visualize pathologic joint opening of the medial aspect of the ulnohumeral joint and a valgus stress is applied as described by Timmerman et al.[32] Even though arthroscopic evaluation may be a useful adjunct to assessing UCL injuries that have failed nonoperative treatment, we have found that arthroscopy alone rarely alters our diagnosis or the procedure to be performed. Our current indication for concomitant elbow arthroscopy is limited to the difficult diagnostic case or the patient with an intra-articular lesion amenable to arthroscopic treatment (ie, anterior loose bodies). For patients with an olecranon osteophyte, we generally perform open debridement of the olecranon tip through a posteromedial capsulotomy during UCL reconstruction.

Dr Frank Jobe pioneered the surgical technique of UCL reconstruction when he reported his initial results in a landmark article in 1986.[15] Before the advent of surgical reconstruction, injury to the UCL often ended the patient's participation in overhead sports, especially baseball pitching. The surgical approach of the senior author is a modification of the original technique as described by Jobe et al.[15] The modifications include elevation of the flexor-pronator muscle mass without detachment and subcutaneous rather than submuscular ulnar nerve transposition.[2] We continue to perform subcutaneous ulnar nerve transposition in every case because of the uncommon incidence of serious complications and the possible protective affect of transposition that seems to prevent the occurrence of late ulnar nerve symptoms. Our surgical technique also requires complete surgical exposure and protection of the ulnar nerve for proper tunnel placement. Because of the relatively complete dissection and exposure of the ulnar nerve from the cubital tunnel, this technique leads to ulnar

paresthesias postoperatively in approximately 16% of patients, but the symptoms usually resolve within 2 weeks after surgery. Currently we use a small sleeve of the medial intermuscular septum, rather than flexor muscle fascia, to hold the ulnar nerve anterior to the medial epicondyle. However, we agree with other authors that ulnar nerve transposition is not mandatory.[28,30] Several authors have reported excellent early results with a muscle-splitting reconstruction technique without ulnar nerve transposition.[13,25,28,30] We have no experience with these techniques, although the initial results appear promising. Anecdotally, however, we have been involved in the treatment of several patients with UCL reconstruction without ulnar nerve transposition that later required nerve transposition for continued symptoms of ulnar neuropathy. Clear indications for either ulnar nerve avoidance or transposition are still lacking.

Ulnar collateral ligament reconstruction was effective at all levels of play, including the highest level of professional baseball (major league). A higher percentage return was seen at the major league level (75%) than the minor league level (73%). We believe that this may be attributed to the inherently higher talent level present in these patients, as well as their level of determination to return for a high level of professional income. Several patients progressed to a higher level of play after reconstruction, indicating not only maintenance of prior throwing performance but also possibly an improvement in function. Elevation of performance may be the result of strength gains during rehabilitation, resolution of long-term symptoms that had previously hindered the player's progress, or technical or mechanical improvement during the course of rehabilitation. The durability of repair is not currently known, although we are attempting to determine the long-term results in this patient population.

Medial epicondyle fracture has occurred in 5 patients to date, 4 during the current study period. Each fracture occurred through the most superficial part of the medial epicondyle tunnel, and the graft has remained intact. We attribute this fracture to the pull of the flexor muscle mass on the thin cortical bone in this area. We subsequently modified our tunnel placement on the medial epicondyle to place the tunnels somewhat deeper (lateral) on the epicondyle to allow a wider cortical rim. However the shape of some medial epicondyles require more superficial tunnel placement with a higher risk of fracture. Alternative drilling and fixation techniques may prove less likely to result in medial epicondyle fracture, although no large reports are available at this time to confirm.

The incidence of serious elbow injury in organized baseball at the adult level (college and professional) is not well documented. Many people involved in organized baseball have reported a rise in the incidence of serious arm injuries in recent years, although exact statistical numbers are not available. Anecdotal experience from our clinic certainly attests to a rise in UCL injuries. In 2001, we performed more than twice the number of UCL reconstructions than in 1996 (Figure 4).

The reason for the increase in UCL injury and diagnosis is multifactorial, but most likely is related to a combination of improved diagnostic techniques, heightened awareness,
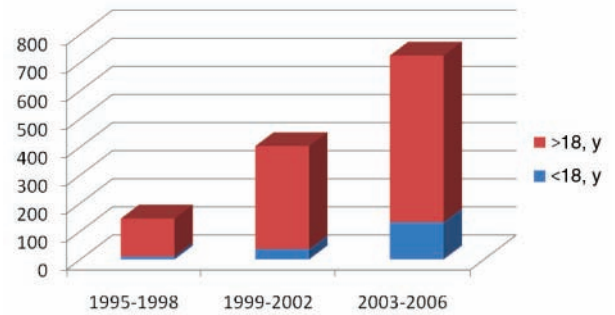

Figure 4. Increased number of total ulnar collateral ligament (UCL) reconstructions performed at our institution during consecutive 4-year periods. Note the relative increase in percentage of UCL reconstructions performed in adolescent patients.

increased chance of positive outcome with current techniques, and potentially most important, overuse of young throwing arms. In the decade of the 1990s in the United States, year-round competitive youth baseball leagues became more prevalent. As a result, the best young pitchers are throwing many more competition pitches each year and learning to throw more difficult pitches (breaking balls) at an earlier age. Lyman and colleagues[17] have reported increased risk of shoulder and elbow pain in youth baseball pitchers 9 to 12 years old who throw more than 600 pitches in a season, or 75 pitches in a game. Further research is needed to determine the relationship between activity level (ie, pitch count) and elbow injury at all levels of organized baseball. Although surgical reconstruction appears to be successful at returning the athlete to prior levels of competition, prevention of injury should be our goal.

A major weakness of this study was the inability to contact 21% of eligible patients. Only 79% of patients eligible at minimum 2-year follow-up were evaluated. This percentage is less than we would ultimately like to report; however, the nature of professional baseball as an occupation of "migrant workers" makes these patients change location frequently, which increases the difficulty of providing adequate long-term follow-up. Athletes that are able to return to baseball may or may not be easier to contact than those athletes that have retired or otherwise not returned to competition. Efforts to locate patients included multiple attempts at contacting the home phone number, parents' phone, athletic trainers, professional teams, collegiate teams, baseball statistical books, and Internet-based personal locator devices. The effort to obtain meaningful, complete data continues.

Other weaknesses include retrospective data collection by phone interview, with possible recollection bias, and inability to obtain physical examination and radiographic follow-up because of the wide geographic area covered by this patient population. Additionally, no specific outcomes score for the throwing elbow was available during data collection; however, recent development of a validated elbow outcomes measure will allow additional information to be gathered concerning subtle functional limitations.

CONCLUSION

Ulnar collateral ligament reconstruction with subcutaneous ulnar nerve transposition was found to be effective in correcting valgus elbow instability in the overhead athlete and allowed most athletes (83%) to return to previous or higher levels of competition in less than 1 year. A complication rate of approximately 20% can be expected, most commonly involving temporary ulnar nerve sensory neurapraxia. Further research is needed to quantify the factors responsible for an apparent increase in incidence of UCL and other serious arm injuries in competitive overhead athletics.

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