SCIENTIFIC ARTICLE

Magnetic Resonance Imaging Findings in Acute Elbow Dislocation: Insight Into Mechanism

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Purpose To identify with magnetic resonance imaging the location and severity of ligamentous injury after acute elbow dislocations. Based on observations that many elbow dislocations arise from an initial acute valgus load, we hypothesized that all patients would have a high-grade medial injury but not all would demonstrate injury of the lateral ligaments.

Methods The medial collateral ligament was subdivided into anterior bands of the anterior bundle of the medial collateral ligament (MCL) and posterior bands of the anterior bundle of the MCL, whereas the lateral collateral ligament was divided into the lateral ulnar collateral ligament and the radial collateral ligament. Distinction on magnetic resonance imaging was made between normal morphology and low-grade partial tear ($< 50\%$ of the ligament fibers), high-grade partial tear ($\geq 50\%$), and full-thickness disruption. The site of disruption was also characterized.

Results Acute magnetic resonance imaging studies for 16 patients were included. No low-grade tears or intact evaluations of either the anterior or posterior bands of the anterior bundle of the MCL were observed; most demonstrated complete tears. The lateral ulnar collateral ligament most frequently showed complete disruption but was occasionally intact. The radial collateral ligament infrequently showed full disruption. Complete tears involving either the anterior or posterior portions of the anterior band of the MCL were significantly more common than complete tears involving the ligaments on the lateral side.

Conclusions After elbow dislocation, complete ligamentous tears were more common on the medial versus the lateral side. Whereas the lateral ligaments were occasionally preserved, this was never observed on the medial side. These data suggest a sequence of failure starting on the medial side with subsequent variable energy dissipation laterally. *(J Hand Surg Am. 2014;39(2):199–205.*

Type of study/level of evidence Diagnostic IV.

Key words Elbow dislocation, magnetic resonance imaging, medial/lateral collateral ligaments.

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THE ELBOW IS THE SECOND MOST commonly dislocated human joint, with a reported annual incidence of 5.2 of 100,000.[1] Elbow dislocations can result in disabling sequelae, including recurrent instability, posttraumatic contractures, and arthritis.[2,3] The deforming forces and mechanism of elbow dislocation are not entirely understood; the relative contribution and sequence of soft tissue disruption are still in question. Whereas some investigators advocated that acute elbow instability

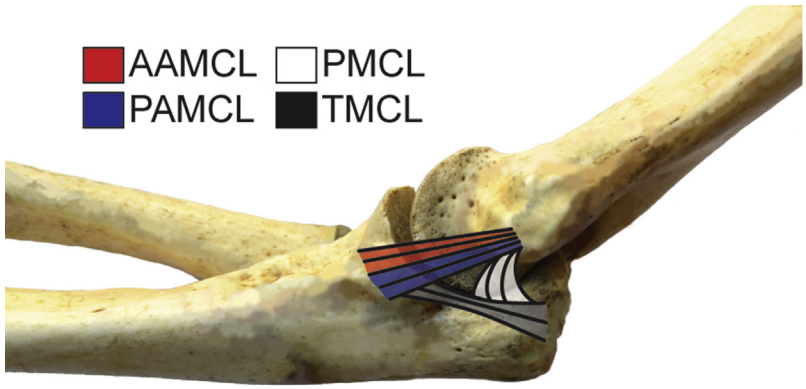

FIGURE 1: Medial collateral ligamentous complex. PMCL, posterior bundle of the medial collateral ligament; TMCL, transverse bundle of the medial collateral ligament.

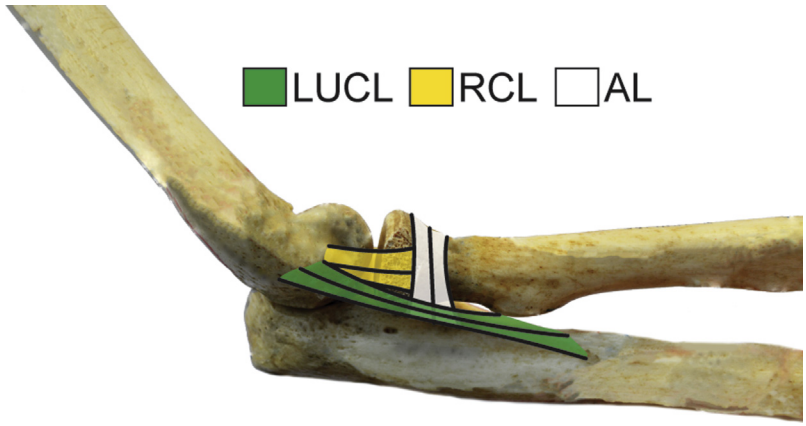

FIGURE 2: Lateral collateral ligamentous complex. AL, annular ligament.

begins with disruption of the lateral ligamentous complex,[4–6] others suggest a medial-sided origin of ligamentous rupture.[7–10]

The anatomy and function of the elbow's collateral ligament complexes have been well described.[11–18] The medial collateral ligament, also referred to as the medial ulnar collateral ligaments, consists of 3 components: the anterior, posterior, and occasionally present transverse bundle (Fig. 1). The anterior bundle is further divided into anterior (AAMCL) and posterior (PAMCL) bands.[17] The AAMCL is the most important valgus stabilizer of the elbow,[11–16] whereas the PAMCL functions as a co-stabilizer to valgus force with increasing contributions as the elbow is progressively flexed.[17] The posterior bundle is a minor secondary constraint,[17] and the transverse bundle does not contribute to joint stability.[18]

The lateral (or radial) collateral ligament complex consists of 4 components: the lateral ulnar collateral ligament (LUCL), radial collateral ligament (RCL), annular ligament, and when present, the accessory lateral collateral ligament (Fig. 2). The LUCL is the most important clinically, because deficiency results in posterolateral rotatory instability.[5,6] The RCL contributes to varus stability[12] and resistance to posterior lateral rotatory instability,[19] whereas the annular ligament primarily stabilizes the proximal radioulnar joint.[18]

The purpose of this observational study was to catalog the incidence of ligamentous disruptions after acute elbow dislocations. Based on prior *in vivo* observations showing that most elbow dislocations result from valgus loading,[10] we hypothesized that there would be a greater proportion of high-grade ligamentous disruptions involving the medial ligaments compared with the lateral ligaments.

MATERIALS AND METHODS

We obtained institutional review board approval and searched the senior surgeons' databases for patients who had received treatment for International Classification of Diseases−9 code 832.00, closed unspecified dislocation of elbow, between 2009 and 2012.

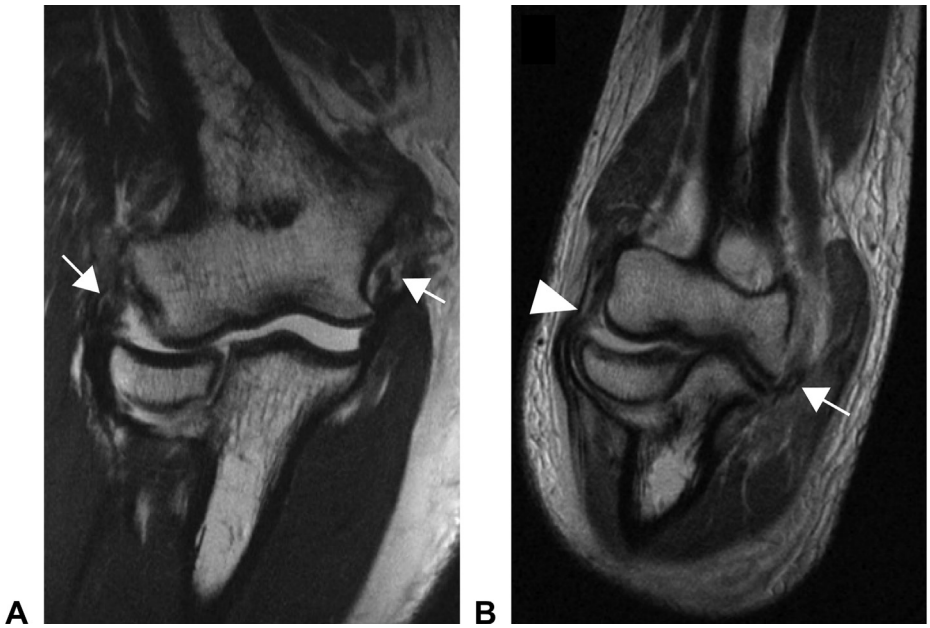

FIGURE 3: Findings on selected postdislocation MRI images. **A** Patient with complete AAMCL and PAMCL avulsions along with LUCL and RCL avulsions from their respective humeral origins (arrows). Image also depicts subluxation of radial head with medial opening of ulnohumeral joint. **B** Patient with complete AAMCL and PAMCL proximal avulsions (arrow) with concomitant proximal partial tears of the LUCL (arrowhead) and RCL.

The resulting medical record numbers were cross-referenced in our institution's Picture Archiving and Communication System for presence of an elbow magnetic resonance imaging (MRI) study.

We performed a retrospective chart review on this cohort of patients to assess clinical documentation of elbow dislocation and the temporal relationship between dislocation and MRI study. All included patients reported a fall onto an outstretched hand. Consistent with previous studies, patients with intra-articular fractures 3 mm or less or osteochondral lesions were included, because these are frequently present after dislocation.[7,20] An acute MRI was arbitrarily defined as having been obtained within 8 weeks of the injury. Exclusion criteria were an interval greater than 8 weeks between dislocation and MRI study, history of previous elbow dislocation, prior surgery involving the affected joint, and associated extra-articular or greater than 3-mm intra-articular fracture. All patients were treated nonsurgically using an overhead motion protocol, with orthosis positioning and rehabilitation exercises tailored specifically to their elbow stability.[21,22]

All MRI studies were performed using coronal fast short tau inversion recovery and gradient recalled acquisition, followed by coronal, sagittal, and axial fast spin echo technique. All examinations were performed at either 1.5 or 3 T (HDx; General Electric Health Care, Waukesha, WI) with either a linear wrap or an 8-channel phased array extremity coil. Maximum through-plane resolution in the coronal plane was 1.5 mm with no interslice gap, and the maximum in plane resolution was 254×406 μ.

A senior musculoskeletal radiologist (H.G.P.) assessed blinded images for signal intensity and morphology of ligamentous complexes (Fig. 3). Because the MRI was performed in full extension, which tensioned the anterior bundle, assessment of the medial ligamentous complex was directed to the AAMCL and PAMCL. Also, the LUCL and the RCL were evaluated, which was facilitated by obtaining the MRI in as much supination as tolerated. Distinction was made between normal morphology and signal, low-grade partial tear ($<$ 50% of the ligament), high-grade partial tear ($\geq$ 50%), and full-thickness disruption. Partial-thickness tears were characterized by abnormal ligamentous morphology and signal intensity on fluid-sensitive sequences, with full-thickness tears demonstrating an area of complete discontinuity along the course. The site of disruption was also characterized as occurring at the humeral or distal attachment, or midsubstance.

We also recorded bone marrow edema patterns, associated intra-articular fractures and chondral and osteochondral defects, along with signal intensity and morphology of the flexor-pronator mass and common extensor origin.

For statistical analyses, chi-square test was used to assess the association between location and severity.

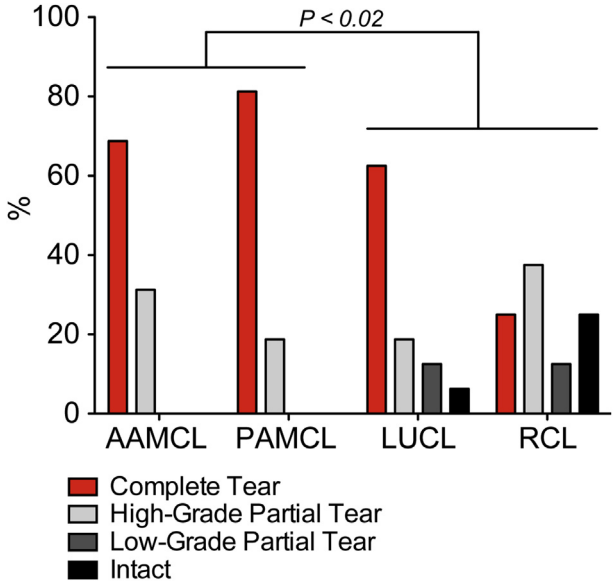

FIGURE 4: MRI findings demonstrating the degree of involvement of medial (AAMCL and PAMCL) and lateral (LUCL and RCL) ligamentous structures. The lateral collateral ligament was occasionally viewed as intact or with a low-grade partial tear. Complete tears involving the medial side (AAMCL/PAMCL) were more common ($P < .020$) than complete tears involving the lateral side (LUCL/RCL).

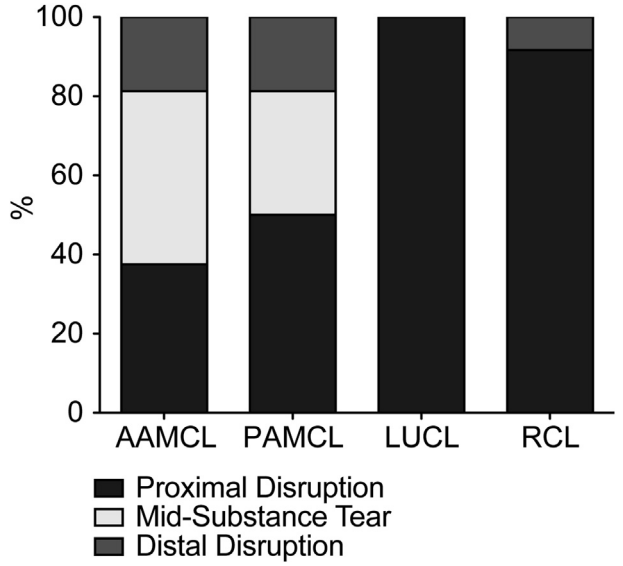

FIGURE 5: Location of ligamentous disruption of studied collateral ligaments.

For comparing injuries across sites, severity variables were dichotomized into either complete tears or incompletely torn/intact ligaments, and 2-tailed Fisher exact test was used to analyze contingency tables. For all tests, $P < .050$ was considered statistically significant.

RESULTS

The initial search query identified 107 patients over the study period. A total of 16 patients with simple dislocations and appropriate MRI evaluations were included. Indications for obtaining an MRI were high-level athletes (n = 6), clinical instability (n = 3), abnormal radiographic finding (n = 2), and ulnar nerve distribution paresthesias (n = 1). Four patients had already obtained MRI evaluations before referral to us. There were 10 men and 6 women, and 11 left elbows and 5 right ones. Mean age was 38 years (range, 17−70 y), and mean elapsed time from dislocation to MRI evaluation was 16 days (range, 1−56 d).

On the medial side, most tears were complete disruptions (69% AAMCL and 81% PAMCL; $P < .001$) compared with partial or intact (Fig. 4). There were no low-grade partial tears or intact AAMCL or PAMCL ligaments. The AAMCL disruptions occurred at the humeral origin in 37%, midsubstance in 44%, and at the ulnar insertion in 19% (Fig. 5). The PAMCL disruptions were humeral (50%), midsubstance tears (31%), or ulnar (19%) avulsions.

Lateral-sided disruption was more variable. Most of the LUCLs were completely disrupted (63%) compared with partial or intact ligaments (37%) ($P < .006$), but several patients had intact or low-grade lesions. All LUCL disruptions were from the humerus. Of all ligaments evaluated, the RCL showed the most heterogeneous involvement, with complete disruption in 25% of studies. The vast majority of RCL injuries were proximal (92%), with 1 injury at the distal attachment.

Complete tears of either the AAMCL ($P < .030$) or PAMCL ($P < .004$) were more frequent than complete tears of the RCL. Complete tears involving the medial side (AAMCL and PAMCL) were more common than complete tears involving the lateral side (LUCL and RCL) ($P < .020$).

All MRI studies showed increased signal in fluid-sensitive sequences in both the common extensor and flexor-pronator origins. Associated osseous findings were coronoid fracture (10), radial head impaction (8), trochlear impaction (5), capitellum edema (4), capitellum osteochondral shear and radial head fracture (3 each), and capitellum fracture (1). We found a high percentage of dislocations to have involvement of the coronoid process (63%). Anterior osseous injury involving the coronoid process was more frequently observed when the LUCL was completely torn, compared with when it was partially or completely intact (90% vs 17%; $P = .003$). Most studies

showed lateral column involvement, with radial head involvement in 68% and capitellum involvement in 50%.

DISCUSSION

The mechanism of acute elbow dislocation has evolved from the traditional teaching of a hyperextension mechanism.[23] Osborne and Cotterill[4] proposed that the "essential lesion" producing elbow instability and dislocation was "failure of the posterolateral ligamentous and capsular structures." In a similar fashion, O'Driscoll et al[5,6] described a spectrum of instability progressing from posterolateral rotatory instability to frank dislocation that involved sequential soft tissue disruption from lateral to medial, termed the "Horii circle."

Whereas some authors have advocated the relative importance of the LUCL, others have suggested that sequential soft tissue disruption begins medially. These include a cadaveric study showing markedly more medial versus lateral ligamentous disruptions in simulated elbow dislocations,[8] a clinical series showing more valgus than varus instability under anesthesia after dislocation,[7] and an epidemiologic study cataloging the preponderance of posterolateral elbow dislocations that suggest a requisite medial disruption.[3]

To support a medial-sided origin of instability, we recently used YouTube to evaluate the arm position, deforming forces, and suspected mechanism in a series of 62 *in vivo* elbow dislocations.[10] Our findings demonstrated that most elbow dislocations are the result of a hyperphysiologic valgus moment occurring to an extended elbow. This would require an initial and requisite AAMCL disruption, which has been shown biomechanically to be the most important soft tissue constraint to valgus instability.[11–16] In this model, the subsequent soft tissue disruption would progress from the medial to the lateral side.

Magnetic resonance imaging to further address the question of soft tissue disruption sequence is a noninvasive diagnostic modality that has been shown to be reliable for evaluating the presence and extent of injuries to both the medial[10,24–28] and lateral collateral ligamentous complexes.[29,30]

Because the medial-sided disruption was present in all injuries, we believe that most dislocations, especially those experienced from a fall on an outstretched hand, experience a valgus torque sufficient to tear the medial ligaments. After failure of the medial ligaments, the lateral ligaments fail depending on the amount of remaining deforming torque and the rate of its application. In agreement with prior studies regarding the direction of displacement, failure of the lateral side results from the posterolateral rollout. However, the variable degree of injury that we observed suggests that the amount of remaining energy is variable and not always sufficient to cause complete disruption of the lateral side.

The concept of rotatory injury progression from medial to lateral is further supported by the finding that anterior osseous involvement of the coronoid process was nearly universal when the LUCL was completely disrupted and was seldom found when the LUCL was partially or completely intact. In addition, the frequent osseous findings involving the lateral column further corroborate this injury model, because the radial head and capitellum articulation is a known secondary valgus constraint.[12,15] These lateral column injuries were most commonly an impaction type, which also suggests a valgus loading mechanism.

Given the sensitivity of MRI for detecting radiographically occult fractures, we did not exclude elbow dislocations with small associated intra-articular fractures, because most studies showed some osseous involvement. The 3-mm cutoff was used in accordance with previous studies, because most simple elbow dislocations show small osteochondral fragments or avulsion fractures intraoperatively that are not seen on conventional radiographs.[7,20]

A recent MRI study by Rhyou et al[9] evaluated ligamentous injury and bony contusion patterns after both simple elbow dislocations and isolated ligamentous injuries. Resulting injuries to the medial and lateral collateral ligaments were broadly classified into distraction or stripping type based on the distance of the collateral ligament end from its respective epicondylar attachment at the time of MRI. The authors suggested a medial-sided origin of instability based on the high proportion of distraction injuries to the medial collateral ligament along with the frequency of a valgus bone contusion affecting the radial head and capitellum. Although these findings are consistent with the current study, the authors did not employ a grading system and did not evaluate the RCL or individual bands of the medial collateral ligament.

Others have reported on ligamentous findings after acute elbow dislocations, but results are limited to case reports[31,32] or broadly classify disruption as involving the medial versus lateral side without any grading system or attention to individual ligaments.[33–35] A common theme in all MRI studies of elbow ligamentous injuries, as we report here, is a preponderance of humeral avulsion injuries of the lateral ligamentous complex,[28,29,33–36] with a more

variable location of medial collateral ligament disruptions that can be midsubstance tears or humeral or ulnar avulsions.[24,25,33,34,37]

This study was limited by its size and retrospective nature. Magnetic resonance imaging evaluations are not routinely performed after simple elbow dislocations. The patients in this cohort had heterogeneous indications for an MRI evaluation, and because they represent a minority of patients treated for this injury, the possibility of a selection bias cannot be eliminated. However, given that all dislocations were first-time acute events, that fracture-dislocations were excluded, and that the history in all patients was a fall onto an outstretched hand, the studied cohort is likely representative of this injury. Performing a prospective MRI study of sequentially presenting patients with simple elbow dislocations would eliminate this bias, but it would require a major and potentially unnecessary additional health care cost.

Our findings show that acute elbow dislocations are traumatic events often resulting in pan-ligamentous disruption. This highlights the possibility of multiple mechanisms of elbow dislocation and suggests that the most common injury pattern may begin with a medial-sided ligamentous disruption. Information on elbow ligamentous injuries is important for directing post-dislocation rehabilitation, because various protocols and positions can selectively protect or stress different ligaments.[21,22] Understanding the anatomic sites of structural failure may also aid in conceptualizing preventative measures and surgical repair techniques.

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