The Mechanism of Ulnar-sided Perilunate Instability of the Wrist: A Cadaveric Study and 6 Clinical Cases

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Purpose To define the mechanism of ulnar-sided perilunate instability using a cadaveric model and correlate these biomechanical findings with 6 clinical cases.

Methods We mounted 16 fresh-frozen human cadaver arms and loaded them to failure in extension and radial deviation, recreating our understanding of the injury mechanism leading to ulnar-sided perilunate instability of the wrist. After testing, we examined the wrists clinically and radiographically. We identified, examined, and treated 6 patients with ulnar-sided perilunate instability over a period of 5 years. Based on these data, we propose a 3-stage mechanism for ulnar-sided perilunate instability of the wrist.

Results In 13 of 16 specimens, we observed failure of ulnotriquetral, ulnolunate, and ulnocapitate ligaments as well as the dorsal scaphotriquetral and dorsal radiotriquetral ligaments. In 11 of these 13, the lunotriquetral interosseous ligament was disrupted, and in 2 of the 11, a dorsal perilunate dislocation occurred. After comparing these laboratory findings with clinical findings in 6 patients with ulnar-sided perilunate instability, we propose the following 3-stage mechanism for ulnar-sided perilunate instability: stage 1, disruption of the lunotriquetral interosseous ligament; stage 2, stage 1 plus disruption of the ulnolunate, ulnotriquetral, and ulnocapitate ligaments as well as the dorsal scaphotriquetral and radiotriquetral ligaments; and stage 3, stage 2 with progression of the injury through the midcarpal joint plus disruption of the scapholunate and radioscapholunate ligaments, potentially resulting in a dorsal perilunate dislocation.

Conclusions We describe a 3-stage mechanism of ulnar-sided perilunate ligamentous wrist injury that can lead to dorsal perilunate dislocation. We recommend considering ulnar-sided perilunate instability of the wrist in patients with ulnar wrist pain after a fall on the outstretched wrist.

Clinical relevance Ulnar-sided wrist injury can lead to subtle forms of perilunate instability. *(J Hand Surg 2012;37A:721–728. Copyright © 2012 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Ulnar, perilunar, cadaver, wrist, radiograph, instability.

PERILUNATE DISLOCATIONS, FRACTURE dislocations, and lunate dislocations represent a small number of all wrist injuries.[1–4] In 1918, Destot[5] published "Injuries of the wrist: a radiographic study," which made substantial contributions to the general understanding of wrist instability. Campbell et al[1] and then Fisk[6] later rekindled interest in the study of carpal instability mechanism. Linscheid et al[7] later applied the concept of the proximal carpal row as an intercalated segment to carpal injuries. In 1980, Mayfield et al[8]

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described the mechanism of perilunate and lunate dislocations of the wrist as a 4-stage progressive injury from radial to ulnar, a concept still accepted by most. Using a cadaver model, they were able to recreate perilunate and lunate dislocations by applying a radial-to-ulnar directed force with wrist extension and intracarpal supination. The 4-stage sequence consisted of the scapholunate interosseous and radioscaphocapitate ligament ruptures (stage 1); progression of the injury through the space of Poirer (stage 2); rupture of the lunotriquetral interosseous ligament (LTIL), permitting perilunate dislocations (stage 3); and then rupture of the short and long radiolunate ligaments, permitting dislocation of the lunate (stage 4).

In 1996, Smith and Murray[9] published a series of 5 cases of volar avulsion fractures of the triquetrum, distinguishing this injury from the more commonly appreciated dorsal triquetral avulsion fracture. The volar triquetral avulsion fracture was shown to be a subtle marker of a major wrist ligamentous injury involving the ulnotriquetral and the ulnolunate ligaments in patients with perilunate injuries of the wrist, which inspired us to investigate the mechanism of this wrist injury. Previously, Viegas et al[10] had characterized their observations of ulnar-sided perilunar instability of the wrist as a 3-stage mechanism based on a cadaver loading model, but no clinical series was provided. In 2001, Shin et al[11] evaluated the treatment of 57 isolated lunotriquetral ligament injuries and noted the mechanism of injury in patients to be a fall, a twisting injury, or sports-related injury to the ulnar aspect of the wrist. This suggested an ulnar-sided wrist injury, prompting further investigation to define the injury in terms of a progressive perilunate mechanism, similar to that seen on the radial side of the wrist. The purposes of this study were to propose a mechanism for ulnar-sided, perilunate instability using a cadaveric model and to correlate these biomechanical findings with a clinical case series.

MATERIALS AND METHODS

After we obtained institutional review board approval, we amputated 8 fresh-frozen, paired, adult upper extremities (16 limbs) just distal to the elbow with all soft tissues remaining. We reasoned that the retention of the skin and soft tissues would better simulate the in vivo situation. The average age of the specimens was 64 years (range, 39–75 y). We reviewed the causes of death for each specimen and did not believe them to have any influence on subsequent mechanical testing of the limb. Before testing, each specimen was thawed to room temperature for 18 hours. We thoroughly examined each specimen for evidence of wrist instability by checking flexion, extension, and radial and ulnar deviation. We also performed a scaphoid shift test as described by Watson et al.[12] Each specimen was imaged using posteroanterior and lateral wrist radiographs in addition to T1- and T2-weighted magnetic resonance imaging. None of the specimens had evidence of previous carpal fracture or ligamentous injury.

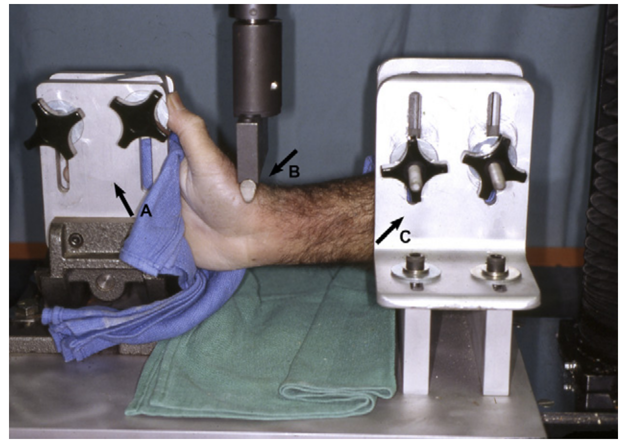

FIGURE 1: Mechanical testing showing the specially designed metal holder for (*A*) positioning of the hand and (*C*) stabilization of the forearm. Each specimen underwent 3-point failure testing (*B*) by gradually increasing the application of load through the actuator bar.

We attempted several trials using various axial loading patterns and models. Based on unsuccessful attempts, we created a testing model with specially designed metal clamps. The specimens were manipulated into pronation and then clamped in place, mounting the specimens in 10° of wrist extension, as estimated by a goniometer placed on the dorsum of the wrist, as well as maximum intercarpal pronation between the fixed forearm and the fixed palm, which we called wrist pronation. The maximum wrist pronation varied from specimen to specimen and was not specifically quantified. We sustained this positioning of each specimen in extension with wrist pronation by placing the actuator bar of the mechanical testing device directly on the radial styloid. Retention of the soft tissues provided minimal interference with contact between the actuator bar and the radial styloid. We applied a gradually increasing force under displacement control at a rate of 10 mm/min from a mechanical testing device (model 1125; Instron Corporation, Canton, MA). Three-point load to failure testing facilitated progressive wrist radial deviation and extension as a counterforce occurring at the interface of the distal ulnar palm and the hand clamp securing the specimen (Fig. 1). Before formal testing,