Complex and rare fracture patterns in perilunate dislocations

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Published online: 5 April 2011
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Abstract

Introduction The wrist represents a complex anatomic region in the upper extremity and a highly functional and intricate structural joint. Perilunate injuries have classically been described as involving a greater or lesser arc as described by Mayfield and imply a specific pattern of force transmission. The greater and lesser arc classifications do not include descriptions of when non-scaphoid carpal fractures occur as part of a perilunate injury.

Methods/Results We present three cases of complex and rare perilunate fracture dislocation patterns and discuss the surgical management as a treatment model for these complex wrist injuries: the trans-scaphoid, trans-capitate perilunate dislocation, the trans-scapholunate ligament, trans-capitate dislocation, and the trans-scaphoid, trans-triquetral perilunate dislocation.

Discussion Although there is a low incidence of injury to non-scaphoid carpal bones, it is beneficial to understand the approach to the perilunate reduction and scaphoid fixation through a combined volar and dorsal approach, which will

also allow for the reduction and fixation of more rare and complex carpal fractures.

Keywords Greater arc injury · Fracture dislocation · Trans-scaphoid · Perilunate dislocation · Carpal fracture · Mayfield classification

Introduction

The wrist represents a complex anatomic region in the human extremity and a highly functional and intricate structural joint. The classic mechanism of a fall on an outstretched hand can produce a broad spectrum of injuries from the distal forearm to the tip of the digit, with location and severity of injury dependent on the magnitude and direction of force applied to the hand and wrist [2, 3, 5, 7, 9, 10, 13–16, 18, 19, 22].

The carpus provides significant multi-planar mobility of the wrist in both flexion/extension and radial/ulnar deviation [21]. In addition, the carpus maintains stability during supination and pronation. These composite motions rely on the precise interaction of several rows of individual bones, stabilized by multiple critical ligaments. The more common patterns of perilunate and lunate injuries/dislocations have been well categorized. Mayfield classified the distinct patterns of dislocation and ligamentous injury resulting in progressive perilunar instability [11].

The Mayfield staging of perilunate fracture dislocations are part of a spectrum of wrist trauma and injuries known as “lesser arc” injuries [11]. The dislocation pattern depends on the direction and path of transmitted force through the carpus. In addition, there are fracture dislocation patterns analogous to the Mayfield pattern of injury in which force is transmitted through the scaphoid rather than the

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scapholunate ligament. In Mayfield stage 1 injuries, force travels between the scaphoid and lunate bones. This energy transmission disrupts the scapholunate ligament and then exits along the midcarpal joint. Stage 2 injuries result when transmission of force disrupts capitolunate attachments and lead to dislocation of the capitate from the lunate, with the lunate remaining in the lunate fossa of the radius. The Mayfield stage 3 injury occurs when energy passes between the lunate and triquetrum, disrupting the lunotriquetral ligament. In all of stages 1–3, the lunate maintains its position in the lunate fossa of the radius. In the Mayfield stage 4 injury, a true lunate dislocation occurs as the lunate attachments to the scaphoid, capitate, and triquetrum are disrupted and the lunate is dislocated from the lunate fossa. Commonly associated with high-energy injury, a large percentage of these injuries include direct acute contusion and/or compression of the median nerve in the carpal tunnel [20]. Treatment of median nerve pathology plays a significant role in the choice of treatment of the underlying perilunate injury. Although closed reduction and conservative treatment/splinting has been described as initial management in some of these situations, surgical correction will ultimately be required to adequately treat these injuries [7, 11, 12, 20, 21].

The lesser arc injuries represent a truly ligamentous injury of the carpus. In the greater arc injuries, force transmission passes through bone resulting in combined fracture and dislocation patterns [22]. In the greater arc injury analogous to the Mayfield stage 1 injury, force is transmitted through the scaphoid, producing a fracture. As force passes through the scaphoid, it then may continue through ligamentous structures creating a trans-scaphoid perilunate dislocation (Mayfield stage 2 or 3 equivalent fracture dislocation).

Uncommonly, force may continue along the greater arc and continue to pass through adjacent carpal bones such as capitate and triquetrum rather than intercarpal spaces as seen in the typical greater or lesser arc injuries. These injury patterns also result in carpal instability and median nerve pathology but require management of a bony rather than ligamentous disruption.

Graham described a third transverse wrist injury pattern, which he labeled the “inferior arc” injury [7]. In this schema, radiocarpal dislocation is described in terms of the force transition passing from lateral to medial through the radiocarpal joint. Accordingly, pure ligamentous disruption rarely occurs, and more commonly, there is a fracture of the radial styloid or the juxta-articular margin. The fracture patterns described are of two types: a large fragment type and a small fragment type. Graham also suggests that the presence of ulnar-sided pathology, including ulna styloid fracture and/or triangular fibrocartilage tear, indicates a more severe trauma.

In 2008, Bain and colleagues described the translunate arc injuries, suggestive of a higher velocity wrist injury [1]. Their description encompasses all perilunate injuries with an associated translunate fracture pattern. These high velocity wrist injuries lead to further destabilization of the carpus due to the need to first stabilize the lunate bone to itself and then stabilize the remaining carpal bones to the lunate. The authors also propose a modification of the greater and lesser arc classifications to include the rarer perilunate carpal bone injuries.

Management of common carpal injuries in wrist trauma has been well described [4, 6, 11, 12, 20, 21]. Thorough history and physical examination will clarify mechanism, energy transmission, and velocity of force through the wrist. In addition, physical examination will suggest nerve involvement, wrist stability, and severity of injury. Imaging provides more definitive diagnosis. Initial plain radiographs will indicate common injury patterns, and computed tomography can assist with more detailed evaluation of bony injury. MRI may assist with ligamentous evaluation in patients with little or no bony involvement on CT or plain radiographs and findings suggestive of ligamentous injury and/or instability, but is often unavailable in the emergency department setting.

The trans-scaphoid perilunate dislocation pattern is a well-described variant of the Mayfield perilunate injury. The trans-capitate perilunate dislocation is a much less common variant. Even rarer is the trans-scaphoid, trans-triquetral perilunate dislocation. These fracture dislocation patterns have very few reported cases in the literature and little information as to the diagnosis, management, and surgical approach for treatment. We report three cases of these atypical perilunate injuries and discuss how injury pattern will influence the type of operative management as well as the anticipated ultimate recovery from injury.

Patient Reports

Patient 1

A 24-year-old, right-hand-dominant male was involved in a high-speed motorcycle accident. The patient presented with complaints of left wrist pain and weakness of grip in the left hand. On examination, the patient's left hand and digits were well perfused. The patient denied any paresthesia and had normal and symmetric sensation of the hand and digits. He had a grossly edematous left wrist with decreased flexion and extension in addition to decreased grip strength.

Radiographic evaluation of the left forearm, wrist, and hand showed ulnar styloid and carpal fractures (Fig. 1). There was a mid-waist scaphoid fracture and a proximal pole capitate fracture with 180° rotation of the proximal

Fig. 1 AP X-ray of patient 1, day of injury. The scaphoid fracture and ulna styloid fracture can be clearly seen. The proximal capitate fracture is difficult to visualize

capitate fragment. There was also widening of the scapholunate interval. The full complexity of the injury pattern was better demonstrated on CT scan of the wrist (Fig. 2). Kaulesar Sukul described this fracture dislocation pattern as the “scaphocapitate syndrome” [8].

The patient was taken to surgery for open reduction and internal fixation of multiple carpal fractures. The carpus was approached through a dorsal incision passing through the third extensor compartment. Using Kirschner wires, the capitate was reduced and stabilized. An Accutrak screw (Acumed LLC, Hillsboro, OR, USA) was then placed to internally fixate the capitate bone. A Kirschner wire was used to gain control of the proximal and distal scaphoid segments, and the fragments were reduced. An Accutrak screw was then placed to fixate the bone. The perilunate dislocation was then reduced. At this point, the scapholunate ligament was repaired using 3-0 Ticron suture (Covidien, Mansfield, MA, USA). A Kirschner wire was placed to fixate the scaphoid to the lunate to support the ligamentous repair. The patient was placed in a short arm thumb spica splint.

At 3 months post surgery, the patient showed radiographic evidence of union (Fig. 3). CT scan was obtained to verify union within the capitate due to the possibility of capitate head avascular necrosis following surgical treatment of these injuries. At 7 months after injury, left wrist

range of motion was symmetric to the uninjured right side. Grip strength was 80% of the uninjured side. Median nerve sensation was symmetric to that of the ulnar nerve. The patient returned to all pre-injury activities by 12 months after injury.

Patient 2

A 42-year-old, left-hand-dominant male was involved in a motorcycle crash at 60 miles per hour. He presented with complaints of severe right wrist pain as well as diminished sensation and paresthesias in the thumb, index, and middle fingers. He lost consciousness after the collision and was amnesic to events including the position of his hand on impact.

Plain radiographs of the right wrist revealed severe carpal disruption (Fig. 4). The trauma surgery service ordered a CT scan of the wrist concurrently with consulting the hand surgery team. Due to the patient’s polytrauma, the arm was positioned on the torso for the CT scan. Interpretation of the images was difficult due to this positioning, and the radiologist initially reading the study misidentified the injury as a lunate dislocation only (Fig. 5). Evaluation of the plain radiographs and CT scan by the hand surgery team identified a trans-capitate lunate dislocation (Mayfield 4 analogue). The proximal capitate fragment was rotated 180°.

The patient’s other injuries were deemed sufficiently stable to allow for immediate operative repair. The median nerve was released through and extended open carpal tunnel release incision. Through this incision, a large defect in the volar wrist capsule was identified as was the lunate bone sitting within the carpal tunnel. The proximal pole of the capitate was present at the level of the wrist capsule defect and remained attached to the radioscaphocapitate ligament.

A dorsal wrist incision was then made and the wrist through the floor of the third extensor compartment. The distal pole of the capitate was identified. The capitate fracture was reduced and stabilized with an Accutrak screw (Acumed LLC). With the wrist distracted, the lunate was then reduced onto the radius and the capitate onto the

Fig. 2 **a** Volar projection 3D CT reconstruction demonstrates the dislocation of the remainder of the carpus from the lunate and proximal scaphoid fragment. **b** Dorsal projection 3D CT reconstruction shows the proximal scaphoid fragment inverted and resting on the dorsum of the lunate bone

Fig. 3 AP (a) and lateral (b) views of the wrist 3 months after injury. The fractures have united headless compression screws which remain in the scaphoid and capitate

lunate; 1.6-mm Kirschner wires were then passed percutaneously to stabilize the scaphoid to the lunate and capitate and the triquetrium to the lunate. The patient was placed in a short arm thumb spica splint.

At 8 weeks post surgery, when the patient returned to the clinic for a scheduled visit, he was noted to have a right wrist infection. This did not respond to pin removal and antibiotics. MRI of the wrist 1 week later demonstrated union of the capitate but also a deep space infection. The infection resolved with 6 weeks of antibiotics. At 4 months after injury, range of motion of the right wrist was 30° flexion, 10° extension. Grip strength was 80 lb. Imaging at 5 months after injury demonstrated significant arthrosis of the radiocarpal and midcarpal joints. The patient returned to his pre-injury work as an auto mechanic. He reports ability to perform all activities with his right hand and no significant pain. Median nerve sensation recovered to pre-injury level and was symmetric to that of the uninjured left side.

Patient 3

A 22-year-old, right-hand-dominant male was an unrestrained front seat passenger in a high-speed motor vehicle collision. His chief complaint was left wrist pain. Additionally, the patient reported progressive paresthesia in his left index and middle fingers with subjective weakness in his hand. The patient stated that he attempted to brace his collision with the dashboard of the vehicle by using his left hand. He recalled striking his left hand along its ulnar border while his arm was outstretched. The patient maintained light touch sensation to the thumb, ring, and small fingers, but had loss of light touch sensation over the index and middle digits. Additionally, over the period of time that progressed for completion of his workup, his light touch sensation deficit progressed to include his thumb.

Radiographic evaluation of the patient's left wrist and hand demonstrated a dorsal perilunate dislocation, with an associated displaced trans-scaphoid fracture. Additionally, the triquetrium had a displaced fracture through its midline

Fig. 4 Patient 2. AP (a) and lateral (b) X-rays demonstrate volar dislocation of the lunate bone into the carpal tunnel and fracture of the proximal pole of the capitate

Fig. 5 Due to the patient's polytrauma, CT scan of the wrist was performed with the extremity resting on the torso. Because of this positioning, true axial, coronal, and sagittal views were not created. This led the radiologist initially interpreting the structures volar and volar–distal to the radius to identify them as a fractured and dislocated lunate rather than a dislocated lunate and fractured capitate

(Fig. 6). This combination of injuries was compatible with a Mayfield 3 injury pattern, with force exiting the triquetrium bone rather than the lunotriquetral ligament.

Due to the patient's median nerve deficit, he was taken to surgery emergently. A volar approach was used first for an extended carpal tunnel release. The median nerve was decompressed and showed evidence of contusion and traumatic edema. To address the bony injuries, a separate dorsal approach through the floor of the third compartment was used. The perilunate dislocation was reduced. A Kirschner wire was placed into the lunate bone and a second into the distal pole of the scaphoid to serve as manipulation levers. The scaphoid fracture was manually reduced and an Accutrak screw was used for rigid internal fixation. The triquetrium was then manually reduced and

fixated with a 1.1-mm Kirschner wire (Fig. 7). The patient was placed in a short arm volar thumb spica splint.

The patient ultimately united both of his fractures (Fig. 8). At 3 months after surgery, his left wrist range of motion was 45° flexion, 55° extension, 15° ulnar deviation, 12° radial deviation. Grip strength was 85 lb on the left as compared to 110 lb on the right. At 4 months after surgery, he returned to his pre-injury employment as a warehouse worker including heavy lifting. He reports no pain in his left wrist and no impairment with activities of daily living. Median nerve sensation recovered to pre-injury level and was symmetric to the uninjured right side.

Discussion

The perilunate fracture dislocation represents a group of complex wrist injuries and is associated with high-energy trauma. The resulting fracture patterns present reconstructive challenges to the hand surgeon. Median nerve contusion and acute compression are commonly associated with these injuries.

Plain radiographs are often sufficient to adequately define the injury. Bain and colleagues [1] note that CT scan may be useful to better characterize carpal bone injuries and imply that the lack of a CT scan may have been the reason why a coronal fracture of the lunate was not identified in their third patient. CT scan quality can be affected by the ability to position the patient's arm in the scanner. Due to the other areas of pain and injury in the second patient in the current study, his arm was on his torso during the CT scan, and the injury was initially characterized incorrectly by the radiologist. Increasing the availability of telemedicine services can allow the attending hand surgeon to view the images from

Fig. 6 Patient 3. AP (a) and lateral (b) X-rays demonstrate fracture lines through the scaphoid and triquetrium. Lateral view demonstrates dorsal displacement of the distal triquetrium fragment which remains attached to the hamate

Fig. 7 a, b The fractures and dislocations have been reduced. The scaphoid is fixated with a headless compression screw. The triquetrum is fixated with a Kirschner wire

home, which can aid in the confirmation of diagnosis and initiating appropriate management for these patients.

There is disagreement in the literature regarding whether volar, dorsal, or combined approach represents the best option for the treatment of these injuries [16]. After median nerve decompression through an extended open carpal tunnel release, the volar wrist capsule is easily visualized and can be used for the reduction of the lunate and/or capitate [2, 3, 13, 16]. The authors of the current study have not found this approach, in isolation, to be adequate to address the carpal bone injuries. We prefer a dorsal approach to treat displaced and/or comminuted scaphoid fractures as well as any other bony injury including the capitate and triquetrum injuries found in the patients in this study. In the case of the first patient who did not have median nerve involvement or dislocation of the lunate, a volar wrist incision was not required. A single incision

dorsal approach to the carpus provided sufficient access for fixation of the bony and ligamentous injuries.

The transmission of force through the wrist at the time of the trauma will dictate the path of damage that results in a spectrum of possible injury patterns [2, 3, 5–7, 9, 10, 13–16, 18, 19, 22]. Wrist posture at the time of injury is one of extension, intercarpal supination, and ulnar deviation [12]. The classic Mayfield perilunate dislocation combines transmission of force through carpal ligaments, the lesser arc injury, resulting in ligamentous tear and dislocation [7, 11, 20, 21]. In some cases, force transmission travels through the scaphoid bone, the greater arc injuries, and results in a combined fracture dislocation. The mechanism of injury is typically high-energy impact onto an outstretched hand and results in energy transmission to the wrist. In rare cases mixed, fracture dislocation patterns present [10, 15, 19]. Such injuries do not conform to the

Fig. 8 At 3 1/2 months after surgery, the fractures are united and the carpal arcs remain congruent (a, b)

lesser arc or greater arc force transmission patterns. Bain and colleagues recommend classifying perilunate injury patterns into three groups: greater arc (defined as any trans-osseous component), lesser arc (defined as purely trans-ligamentous), and translunate arc (defined as any bony injury to the lunate) [1].

In the patients presented in this report, the less common fracture patterns through capitate and triquetrium in association with the trans-scaphoid perilunate injury were present. Variation of wrist position, the location of impact, and transmission of force may be a causal factor of these more rare injuries such as the trans-triquetral injury. In patient 1, direct impact and extremely high velocity of injury resulted in a trans-capitate fracture. Patient 2 was amnesic to the events surrounding his motorcycle collision. The authors hypothesize that if radial deviation was present to a greater degree and intercarpal supination was present to a lesser degree, there may have been more tension on the scapholunate ligament and less tension on the radioscapho-capitate ligament, allowing force to transmit through the scapholunate ligament rather than the scaphoid bone. In patient 3, severe ulnar deviation may have placed the lunotriquetral ligament and radial portion of the triquetrium bone over the lunate facet, causing force to transmit through the triquetrium bone rather than the lunotriquetral ligament.

Kaulesar Sukul [8] collected a total of 12 previous reports of scaphocapitate syndrome for his paper. All but one of the papers reviewed in his study had a single patient case report. Final range of motion and grip strength were reported only qualitatively. As such, direct comparison of the patients in this study is difficult. At 1 year out from injury, all patients in this series reported minimal if any pain and had returned to all pre-injury activities including working as an auto mechanic (patient 2) without restrictions or limitations.

No large series data is available for patients with triquetral fractures as part of a perilunate injury. At 1 year out from injury, function of patient 3 in the current study has similar grip strength (85 versus 90 lb) but less range of motion (100° total arc versus 150°) as compared to the case reported by Soejima and colleagues [17].

In our experience, we have observed that complex injuries of the carpal bones with preserved ligamentous structures allow for better recovery than less complex carpal injuries in which more ligamentous injury occurs. For the ligamentous injuries, it is more difficult to achieve stable repair and fixation and maintain flexibility and range of motion. Patient 2 had both a scapholunate and lunotriquetral ligament injury. In addition, his postoperative course was complicated by a severe wrist joint infection requiring formal washout. Not surprisingly, his recovery of motion was poor. However, the same strong motivation to

return to work that may have led to his postoperative infection may also explain his early return to full duty at work (4 months after injury) and subjective report of high satisfaction with his outcome. For the patients with trans-osseous rather than trans-ligamentous injuries such as patients 1 and 3 in this series, the bony damage may lead to a more difficult repair but a better long-term outcome due to maintained stability of the native ligaments.

Conclusion

The trans-scaphoid and trans-scapholunate ligament perilunate dislocations represent the most common perilunate injury patterns [2, 3, 5, 6, 9, 10, 12–16, 18, 19]. For these injuries, a dorsal surgical approach or a combined dorsal and volar approach will provide appropriate exposure and access to reduce and fixate these injuries [13]. In rare instances, variations of force transmission may result in less commonly encountered carpal bone injuries such as the trans-capitate or trans-triquetral injuries seen in our patients. In these cases, carpal realignment and fixation can be achieved via dorsal or combined dorsal and volar surgical approaches. Understanding the force transmission and its effect on carpal bones and ligaments and proper identification of what structures are injured allows the hand surgeon to successfully address the more complex and rare fracture patterns.

Disclosure The authors have no conflicts of interest, commercial associations, or intent of financial gain regarding this research.

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