Fractures of the Carpal Bones Excluding the Scaphoid

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Carpal fractures excluding the scaphoid can cause morbidity that is disproportionate to their incidence because they are easily overlooked and are often harbingers of a wider wrist injury. Failure to recognize a more global injury pattern can result in undertreatment and permanent wrist dysfunction. Diagnosis requires a high index of suspicion, familiarity with carpal topography to guide the physical examination, and judicious use of specialized radiographic views and ancillary imaging techniques.

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Fracture of the carpal bones, excluding the scaphoid, account for approximately 40% of all carpal fractures.1 Paradigms for evaluation and treatment of the fractured scaphoid are well delineated in the literature. The less common fractures of other carpal bones have received considerably less attention. However, these injuries can produce morbidity that is disproportionate to their incidence for several reasons. First, carpal fractures excluding the scaphoid may have a subtle clinical and radiographic presentation and are easily overlooked. Diagnosis requires familiarity with carpal topography to guide the physical examination and judicious use of specialized radiographic views and ancillary imaging techniques based on clinical suspicion. Second, such fractures are often harbingers of significant ligamentous disruption or associated carpal fractures. Failure to recognize a more global injury pattern can result in undertreatment and permanent wrist dysfunction.

We examine the incidence, mechanisms of injury, associated osseous and ligamentous injuries, physical examination findings, useful radiographic views, and ancillary imaging techniques and management principles of these often overlooked carpal fractures.

Triquetrum

Triquetral fractures are probably the most common carpal fracture excluding the scaphoid. In a population-based study conducted in Bergen, Norway, triquetral fractures comprised 31% of all carpal fractures.1
Triquetral fractures can involve the dorsal rim or body.\textsuperscript{2} Fractures of the dorsal rim can result from avulsion of the dorsal intercarpal, dorsal radiocarpal, or lunotriquetral ligaments during a hyperflexion/radial deviation injury to the wrist. Alternatively, hyperextension/ulnar deviation injuries can produce an impaction fracture when the ulnar styloid or hamate chisel into the dorsal triquetral rim (Fig 1).\textsuperscript{3,4}

Triquetral body fractures most commonly involve the medial tuberosity, typically caused by a direct blow to the ulnar border of the wrist. Other fracture patterns involving the body include comminuted, transverse, or sagittal fractures and are commonly associated with higher energy mechanisms of injury. Triquetral body fractures may be the sole radiographic manifestation of a more global wrist injury including axial disruption of the carpus secondary to severe dorsopalmar crush or a perilunate greater arc injury (Fig 2).\textsuperscript{5,6}

Physical examination reveals dorsoulnar wrist tenderness over the triquetrum. Standard wrist radiographs are typically diagnostic. The oblique view is the most useful for visualizing dorsal rim fractures.\textsuperscript{2} Occasionally, bone scan or computed tomography (CT) may be necessary to corroborate clinical suspicion.

Cast immobilization is sufficient for dorsal avulsion/chisel fractures and nondisplaced fractures of the triquetral body if carpal instability has been excluded. Patients should be counseled that dorsal rim fractures may produce prolonged soreness.\textsuperscript{2} In addition, progression to symptomatic nonunion may occur and can be treated with fragment excision and ligament repair. Isolated, nondisplaced body fractures can be treated with cast immobilization. Triquetral body fractures that are displaced or are part of a broader ligamentous insult require surgical treatment to reduce and stabilize the fracture and, when necessary, address carpal instability.\textsuperscript{6-8}

**Hamate**

Hamate fractures constitute approximately 7\% of carpal fractures and can involve the hamular process (hook) or, more commonly, the body.\textsuperscript{1} Body fractures are typically associated with a broader hand and/or wrist injury, most commonly dorsal fracture dislocation of the 4th and/or 5th carpometacarpal (CMC) joints (Fig 3).\textsuperscript{9} The typical mechanism is axial loading of the flexed CMC joints (eg, striking an unyielding object with a clenched fist), that produces a coronally oriented fracture of the dorsal, distal hamate with variable degrees of comminution.\textsuperscript{10} Body fractures also may be associated with greater arc peri-
lunate injuries or axial carpal dislocations. The latter injury is associated with dorsopalmar crush and flattening of the carpal arch, which produces sagittal-oblique hamate body fracture.

Fractures of the hamular process are typically isolated injuries. The mechanism of injury is classically direct trauma to the patient’s nondominant hand by the base of a golf club, bat, or racquet. Falls on an outstretched hand can also produce hook fractures, either by direct trauma or flattening of the carpal arch with avulsion by the transverse carpal ligament. The hook of the hamate may fracture at the tip, waist, or base.

Physical examination of the typical body fracture (CMC joint fracture dislocation) reveals dorsoulnar wrist swelling. Tenderness is well localized to the CMC joints. Loss of knuckle prominence from abnormal flexion of the metacarpal(s) or abrasions over the metacarpal heads may be present. Poorly localized tenderness should alert suspicion for additional ligamentous disruptions, particularly in patients with a history of high-energy injury (eg, dorsopalmar crush).

In contrast, patients with hook of the hamate fractures may have a subtle initial presentation, and the injury can be easily overlooked. Diagnosis requires a high index of suspicion. Patients may complain of poorly localized palmar wrist pain aggravated by power grip. Examination reveals tenderness over the hamular process (radial and distal to the pisiform) and, often, over the dorsal aspect of the hamate. Pain can be elicited with resisted ring and small finger distal interphalangeal joint flexion when the wrist is in ulnar deviation (Fig 4). Pain is relieved when the test is performed with the wrist in radial deviation.

Patients with delayed presentation may have flexor tendon rupture that should be specifically excluded during the initial examination. Patients with hamular process and hamate body fractures require a thorough evaluation of ulnar nerve function, particularly the deep motor branch, because both injuries can be associated with ulnar neuropathy. Associated carpal tunnel syndrome has also been reported.

Hamate body fractures are usually apparent on standard wrist radiographs, particularly the oblique and lateral views. When associated with a fracture dislocation of the CMC joints, the metacarpals are usually flexed, with their bases residing in an abnormal dorsal position and relative to the intact carpus and adjacent metacarpals. Hamular process fractures are notoriously difficult to visualize with standard radiographs. The carpal tunnel and 30° supinated oblique views are valuable additional radiographic projections that may visualize hook of hamate fractures (Fig 5). Transverse CT images or bone scan should be obtained if the diagnosis remains in question.

Nondisplaced, isolated hamate body fractures may be treated with immobilization. More commonly, these fractures are part of a larger injury, and surgical
treatment is usually required to reduce and stabilize
the hamate fracture and to address carpal or carpo-
metacarpal instability.\textsuperscript{8} Acute, nondisplaced hamular
process fractures may be treated with cast immobi-
lization.\textsuperscript{19} Symptomatic nonunion has been reported,
particularly in fractures adjacent to the hamular pro-
cess base. Excision of the ununited fragment pro-
vides reliable symptomatic and functional improve-
ment.\textsuperscript{15,17} Certain investigators recommend excision
of asymptomatic nonunions to minimize the risk for
flexor tendon rupture.\textsuperscript{11} Others recommend open re-
duction and internal fixation of nonunion based on the
possible functional importance of the hamular process
as a pulley for the digital flexors.\textsuperscript{20}

\textbf{Trapezium}

Trapezial fractures comprise approximately 3\% of
carpal fractures and can involve the body or
ridge.\textsuperscript{1,21} Ridge fractures are typically isolated injuries
caused by direct trauma or avulsion by the transverse carpal ligament during a fall on an outstretched hand.

Palmar classified ridge fractures based on location and propensity for healing. Type I fractures involve the base of the ridge and typically heal with immobilization. Type II fractures involve the tip of the ridge and can progress to symptomatic non-union.

Trapezial body fractures may occur during extreme wrist dorsiflexion and radial deviation, effectively crushing the trapezium between the base of the thumb metacarpal and the radial styloid. Vertical transarticular body fractures may be the most common type. This fracture pattern may be associated with fracture dislocation of the 1st CMC joint and a thumb metacarpal Bennett’s fracture secondary to a direct blow to the adducted and flexed thumb.

Physical examination of patients with trapezial ridge fractures show tenderness localized just distal to the scaphoid tuberosity. Pain can be elicited with resisted wrist flexion by producing apposition of the flexor carpi radialis against the trapezial ridge. Carpal tunnel syndrome is a common comorbid condition and should be excluded specifically. Body fractures may show abnormal dorsoradial prominence of the thumb metacarpal base. Tenderness is localized to the CMC joint and/or the distal aspect of the anatomic snuffbox.

Radiographic evaluation of suspected trapezial ridge fractures should include a carpal tunnel view. Occasionally, CT may be required to delineate an acute or chronic ridge fracture. Body fractures, especially if associated with concomitant thumb CMC joint dislocation, are often distinguishable on standard wrist radiographs, although CT is sometimes required to visualize the fracture. An oblique lateral, with the ulnar aspect of the hand down and the forearm in 20° of pronation, may reveal more subtle body fractures by decreasing the radiographic overlap between the trapezoid and trapezium.

Trapezial ridge fractures can be treated with cast immobilization. Symptomatic nonunions may be treated with fragment excision. Body fractures with intra-articular displacement should be reduced anatomically and rigidly fixed.

Pisiform

Pisiform fractures account for approximately 2% of all carpal fractures. The pisiform is a sesamoid attached to the flexor carpi ulnaris tendon proximally, and to the pisohamate, pisometacarpal, and pisotriquetral ligaments distally. Additional soft-tissue attachments include the abductor digiti minimi and the trans-
verse carpal ligament.30 The ulnar nerve and artery are immediately radial to the pisiform in Guyon’s canal.

The typical history is a fall on an outstretched hand that most often produces a transverse pisiform fracture by a combination of both direct and indirect mechanisms. The pisiform becomes fixed at the pisotriquetral joint when the outstretched hand strikes the ground; forceful contraction of the flexor carpi ulnaris then produces a transversely oriented avulsion fracture. Other injury patterns include comminuted, parasagittal, and osteochondral impaction fractures (Fig 6).5,31

Physical examination reveals tenderness over the pisiform. Examination should exclude other wrist injuries (eg, perilunate dislocation, distal radius or additional carpal fracture) that can occur in up to 50% of pisiform fractures.32 The ulnar nerve requires evaluation, particularly in patients with comminuted fractures that result from a direct blow and those with established posttraumatic pisotriquetral osteoarthriti-s.33,34 Pisiform fractures are poorly visualized on anteroposterior and oblique wrist radiographs but may be visualized on the lateral view. Additional projections that bring the pisiform and pisotriquetral joint into profile are the carpal tunnel view and the 30° supinated lateral radiograph.32,33 Occasionally, CT or bone scan may be required to corroborate clinical suspicion.

Most pisiform fractures can be treated with splint immobilization. Symptomatic posttraumatic osteoarthriti-s or nonunion can be treated with pisiform enucleation and reconstruction of the flexor carpi ulnaris with minimal adverse sequellae.33-35 Fractures that have a transverse, as opposed to longitudinal, orientation functionally disrupt the flexor carpi ulnaris function and have a more guarded prognosis.5

**Lunate**

Lunate fractures comprise approximately 1% of all carpal fractures.1,21 Their incidence may have been previously overestimated because some investigators included fractures that occurred in the setting of Kienbock’s disease, and others have probably ascribed dorsal triquetral fractures to the lunate.5 In 1 series, only 17 cases of lunate fracture were collected over a 31-year period.21

Lunate fractures can involve the dorsal or palmar poles or the lunate body.21 Dorsal pole fractures may result from scapholunate or lunotriquetral interosseous or dorsal radiocarpal ligament avulsion. Alternatively, impingement of the dorsal pole between the radius and capitate during extreme wrist dorsiflexion can produce an impaction fracture. Palmar pole fractures may result from avulsion by the long and short radiolunate ligaments.19 Body fractures occur secondary to axial loading of the lunate between the capitate head and lunate fossa.

Examination reveals painful wrist motion and localized tenderness when the fracture is dorsal. Fractures of the lunate may be the radiographic harbinger of a more global carpal injury (eg, perilunate dislocation) and demand rigorous evaluation of the wrist.

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**FIGURE 6.** (A) Anteroposterior wrist radiograph of a patient with ulnar-sided wrist pain shows a possible fracture of the pisiform. (B) Carpal tunnel view clearly shows a displaced parasagittal pisiform fracture.
Radiographs frequently fail to visualize or underestimate the size or displacement of fracture fragments. Therefore, CT is invaluable to evaluate lunate injuries, particularly body fractures.

Lunate fractures should be approached with caution because even seemingly innocuous, isolated fractures may functionally detach critical wrist ligaments and lead to profound malalignment of the carpus. Alternatively, lunate fractures may be part of a larger ligamentous insult. Patients whose fractures do not appear to warrant surgical intervention require meticulous follow-up care to ensure that wrist malalignment does not develop.

Palmar pole fractures require reduction and fixation because they produce functional loss of the long and short radiolunate ligaments. Untreated, this fracture may produce profound volar flexion and dorsal translation of the lunate. Failure to recognize and treat this injury can produce chronic palmar subluxation of the capitate and midcarpal arthritis (Fig 7). Conversely, large dorsal pole fractures require fixation because they can produce functional loss of the dorsal component of the scapholunate interosseous, the dorsal radiocarpal and lunotriquetral ligaments. Loss of dorsal constraints can lead to dorsiflexion and volar translation of the lunate and secondary arthritis. Occasionally, dorsal lunate avulsion fractures are limited to the attachment of the scapholunate interosseous ligament (Fig 8). This fracture pattern requires reduction and fixation to prevent dorsal intercalated collapse instability of the wrist. Axial compression injuries with displacement and/or articular impaction require reduction and fixation (Fig 9). Neutralization of axial loads with an external fixator may assist in maintaining the reduction. Patients should be counseled that lunate fractures can be complicated by avascular necrosis, nonunion, and carpal malalignment.

**CAPITATE**

The capitate is central and well protected within the carpus and infrequently injured. Capitate fractures comprise approximately 1% of all carpal fractures.

![FIGURE 7. A minimally displaced fracture of the (A) lunate volar pole was treated with cast immobilization. The patient developed significant displacement of the (B) volar lunate fragment (arrow) and midcarpal collapse with severe lunate flexion and palmar subluxation of the capitate. (C, D) Open reduction of the volar pole, with its attached long and short radiolunate ligaments, and the midcarpal joint restored carpal alignment.](image-url)
FIGURE 8. (A) Anteroposterior radiograph of a patient who sustained a fall on an outstretched hand shows a radial styloid (arrow) and 5th metacarpal fracture. A subtle abnormality is evident at the radial aspect of the lunate. Examination revealed tenderness over the scapholunate ligament and a positive Watson’s maneuver during examination under anesthetic. (B) A dorsal wrist approach confirmed lunate avulsion fracture of the scapholunate ligament. (D) The scapholunate joint and lunate avulsion fracture (arrow) were reduced and secured with (C, D) K-wires.
Capitate fractures can involve the body or the distal dorsal articular margin. Body fractures are usually transverse and may result from a direct blow that causes multiple carpal bone fractures or as part of an incomplete or self-reduced perilunate injury. The scaphocapitate syndrome is a manifestation of the perilunate injury pattern. Wrist extension results in scaphoid fracture and, with further extension, the capitate impacts on the dorsal lip of the radius. A transverse fracture of the capitate body occurs, and its proximal fragment can rotate 180° in the sagittal plane as the hand returns to a neutral position. The articular cartilage of the capitate head then faces distally in opposition to the fracture surface of the distal capitate fragment (Fig 10). Transscaphoid, transcapitate, perilunate injuries can also occur without malrotation of the capitate head. Avascular necrosis of the proximal fragment is possible because the head has no soft-tissue attachments.

Dorsal distal articular margin fractures of the capitate occur as part of the 3rd CMC joint fracture dislocation. The mechanism of injury is axial loading combined with a flexion moment applied to the long finger metacarpal. Occasionally, such fractures are produced during fracture dislocations of the 4th CMC joint because the capitate typically has a facet for articulation with and ligamentous attachment to the 4th metacarpal (Fig 2). Fractures of the 3rd metacarpal base should be distinguished from an os styloideum, a common accessory bone that resides within the extensor carpi radialis brevis at the level of the CMC joint. Roughly one half of capitate fractures are associated with additional osseous and/or ligamentous injuries (eg, dorsal fracture dislocation of the CMC joint or transscaphoid perilunate injury), and the other one-half are isolated.

Physical examination may reveal localized tenderness for isolated capitate fractures or more diffuse swelling and tenderness if the fracture is part of a wider wrist injury. Standard wrist radiographs may not reveal isolated body or dorsal articular margin fractures. CT in the coronal plane for transverse fractures and in the parasagittal plane for articular margin fractures can show fractures that do not manifest on plain radiographs. Magnetic resonance imaging is useful to predict healing potential of transverse body fractures by visualizing the vascular status of the capitate head.

Nondisplaced, isolated, capitate fractures can be treated with cast immobilization. Capitate fractures that are part of a larger wrist injury should be fixed along with associated osseous/ligamentous injuries. The seemingly isolated but displaced capitate fracture requires meticulous evaluation because displacement occurs with concomitant osseous or ligamentous injuries (Fig 11). Patients with capitate fractures should be counseled that functional limitation is common secondary to nonunion, avascular necrosis of the proximal pole, capitate collapse, symptomatic midcarpal arthrosis, or associated injuries. Painful midcarpal arthrosis can be treated with midcarpal arthrodesis.

**Trapezoid**

The trapezoid is well protected by the osseous architecture of the 2nd CMC joint. The base of the 2nd metacarpal is fish tailed and interlocks with...
the trapezium, capitate, 3rd metacarpal, and trapezoid. The inherently stable joint geometry is reinforced by strong ligaments and explains why the trapezoid is the least common carpal fracture. Hove reported no cases of trapezoid fracture in an analysis of 183 consecutive carpal fractures collected over a 10-month period. Most reports are limited to individual cases.

Most trapezoid fractures occur during CMC joint dislocation, either isolated or in association with fracture dislocations of multiple CMC joints. The usual mechanism is high-energy axial loading of the index or adjacent metacarpals.

Physical examination reveals tenderness and swelling localized to the involved CMC joints. The 2nd CMC joint is notoriously difficult to visualize on routine radiographs. Mehara and Bhan described a radiographic view that brings the 2nd CMC joint into profile. The thumb is positioned in maximal palmar abduction, and the radial border of the hand and thumb are placed flat against the cassette by hyperpronating the forearm. The radiograph beam is directed 30° off of the vertical line, toward the palm. CT in the parasagittal plane is often necessary to visualize fracture dislocations of the 2nd CMC joint.

Nondisplaced fractures can be treated with cast immobilization. Displaced fractures require reduction and fixation of the trapezoid and metacarpal. Adjacent CMC joint injuries should be addressed at the same setting. Symptomatic chronic injuries can be treated with CMC joint arthrodesis.
SUMMARY

Carpal fractures can cause disproportionate morbidity relative to their incidence. Timely diagnosis and effective treatment of these injuries requires a high index of suspicion, judicious use of specialized radiographic views and ancillary imaging techniques, and an understanding of commonly associated patterns of osseous and ligamentous injury. Patients should be counseled that even with ideal treatment, these fractures can produce significant morbidity that requires additional treatment to improve wrist function.

REFERENCES