Carpal Fractures in Athletes Excluding the Scaphoid

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KEYWORDS

• Triquetrum • Trapezoid • Trapezium
• Lunate • Capitate • Pisiform • Hamate

A wide range of hand and wrist injuries occur in today's recreational and elite athletes and account for 3% to 9% of all sports injuries.[1–4] The onus is on the physician to discriminate between injuries that can be managed with an early return to sport and those injuries that place the athlete at risk of further injury if not managed aggressively from the outset. The physician and the athlete must understand the balance between safe, early return to sport, and prompt surgical treatment that prevents late disability.

TRIQUETRAL FRACTURES

Incidence

Triquetral fractures are second only to scaphoid fractures as the most common carpal fractures, comprising 3% to 5% of all carpal fractures.[5–8] Two primary fracture patterns are observed; a dorsal chip or cortical fracture and triquetral body fractures. The dorsal chip fracture is much more common, reported to be as high as 93% of all triquetral fractures.[7] Triquetral body fractures more commonly infer a high amount of energy to the wrist, and are observed with perilunate fracture dislocations in 12% to 25% of triquetrum injuries.[6,9–11]

Mechanism of Injury

Different mechanisms have been proposed for dorsal triquetrum fractures. Extreme palmar flexion with radial deviation is believed to cause the dorsal avulsion fracture at the attachment of the strong radiotriquetral and triquetroscaphoid ligaments.[8,12] The more common clinical presentation is a fall onto an ulnarly deviated wrist in dorsiflexion. Wrist dorsiflexion and ulnar deviation has been shown to drive the ulnar styloid as a chisel into the dorsal cortex of the triquetrum.[13–15] Large styloid size has been proposed as a predisposition to this fracture pattern.[15] The chisel action of the proximal edge of the hamate against the distal triquetrum during wrist extension has also been proposed to explain these dorsal triquetrum chip fractures.[7]

Triquetrum body fractures often involve high-energy injuries to the hand and are associated with greater arc perilunate fracture dislocations.[16] Triquetrum fractures alone, with a history of violent collision, should alert the physician to seek out potential ligament injuries around the carpus as 12% to 25% of triquetrum fractures are associated with perilunate fracture dislocations.[17] The more obvious scaphoid fracture seen in the transscaphoid perilunate fracture dislocation, the most common greater arc pattern, can draw attention away from a concomitant triquetrum fracture (**Fig. 1**).[18] Triquetral fractures can also be seen concurrently with fractures of the hamate, distal ulna, or distal radius.[5,7]

Examination

Point tenderness solely over the triquetrum is difficult to elicit in the acute setting given the proximity of the triangular fibrocartilage complex (TFCC) and other ulnar wrist structures. Pain with wrist flexion

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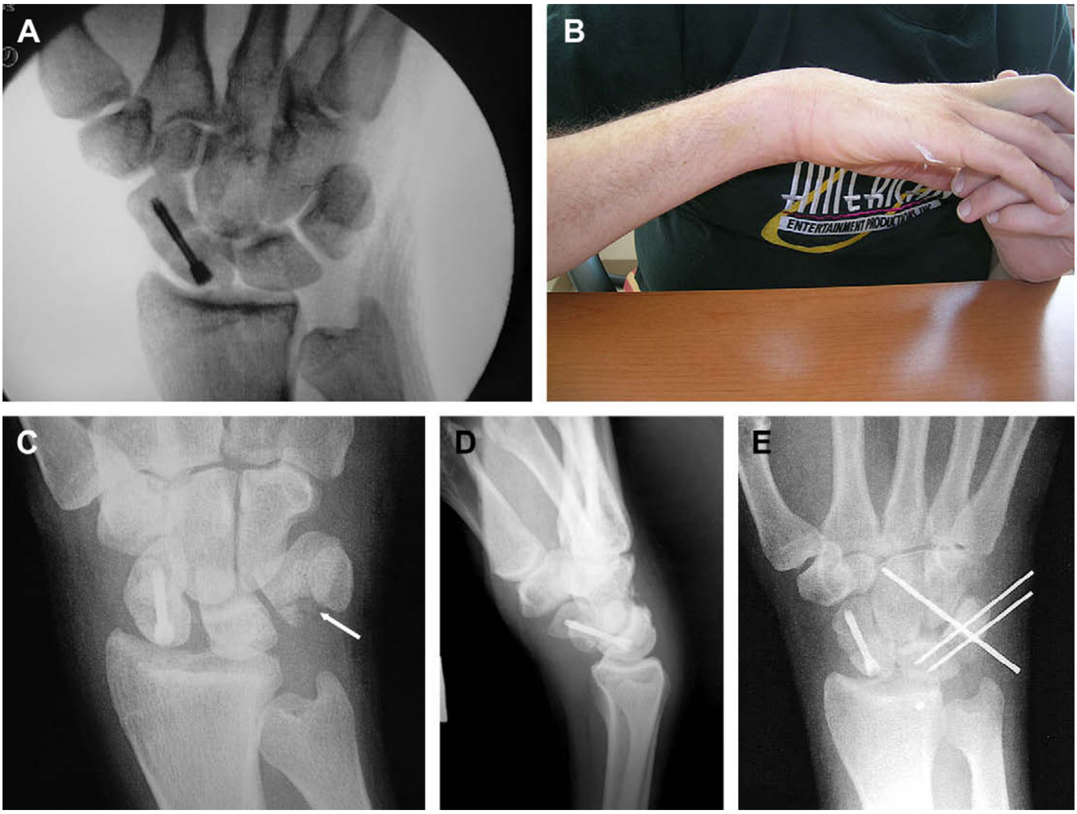

Fig. 1. (*A–E*) A 22-year-old man suffered transscaphoid perilunate fracture dislocation of the wrist. The wrist was reduced in the emergency department and was well aligned with the exception of the scaphoid. The scaphoid was fixed and again the carpus was well aligned on the PA view (*A*) and lateral view. No further treatment was given. At the first postoperative visit he complained of wrist pain and deformity. The wrist was held in a position of flexion (*B*). The PA radiograph shows a triangular appearing lunate and displaced fracture of the triquetrum (*arrow*) (*C*). The lateral radiograph shows a marked VISI deformity resulting from the untreated triquetral fracture with associated lunotriquetral instability (*D*). The PA radiographs after open reduction and pinning of the lunotriquetral ligament and midcarpal joint along with indirect reduction of the triquetral fracture on the radial palmer aspect of the triquetrum (*E*).

and extension is present with dorsal avulsion injuries.

Radiographic Evaluation

Many triquetral fractures can be identified with anteroposterior, lateral and 45-degree pronated oblique radiographs of the wrist.[11,13] The lateral and oblique views often reveal the dorsal cortical fractures. CT scans are helpful in identifying occult triquetral fractures.

Treatment

A dorsal chip fracture is a common incidental finding on the lateral radiograph of an injured athlete. It is useful to determine if the fracture is acute or chronic, and if the recent injury has a mechanism consistent with a triquetral fracture. If all evidence points to an acute injury, the athlete needs to understand that the fracture itself has little consequence. It is the underlying soft-tissue injury that must be treated because the fracture will, most likely, go on to an asymptomatic, fibrous union. Various investigators have recommended immobilization, usually with a short arm cast, for 3 to 6 weeks.[5,7,19,20] The authors try to tailor the treatment to the athlete and the injury. If the wrist is markedly swollen, there is a significant soft-tissue injury that will preclude a rapid return to sports. The wrist is placed in a splint and an MR is obtained to identify extrinsic or intercarpal ligament injuries or occult fractures. In the absence of an obvious operable lesion, the wrist is reexamined in 1 week and usually protected with a cast. If there is negligible swelling and minimal tenderness at the first examination, athletes who do not require wrist motion for their sport are permitted to try to play with a wrist support. This approach must include frequent re-examination to ensure that play is not exacerbating the underlying injury. For injuries in between, short periods of immobilization (1–2 weeks) are preferred with re-examination to facilitate a safe early return to sport. When pain and stiffness persist beyond 8 weeks, MR arthrography is recommended to investigate the possibility of a concurrent intercarpal ligament injury or tear of the TFCC. Dorsal fractures that remain symptomatic can be treated by excision of the ununited fragment.[20] Symptoms emanating from the fragment alone are unusual.

Guidelines for treatment of triquetrum body fractures are less clear. In the setting of a concomitant wrist fracture dislocation, it is common to treat the lunotriquetral ligament injury by pinning the joint and ignoring the fracture to the triquetrum. In the rare instance of a displaced triquetral body fracture, open reduction and internal fixation has been described.[18,21] Pisiform excision has provided pain relief in patients presenting remote from their injury with a malunion, nonunion or post-traumatic pisotriquetral arthritis following a triquetrum body fracture.[22,23]

Complications

The most common complication of a triquetrum fracture is a misdiagnosis or delay in diagnosis. This complication can be avoided with a serial clinical and radiographic examination for athletes presenting with prolonged ulnar-sided wrist pain or tenderness over the triquetrum.

HAMATE FRACTURES

Incidence

Hamate fractures constitute approximately 2% of all carpal fractures.[24] The unique anatomy of the hamate hook places the bone at risk from compressive forces when the palm is struck and shear forces from the adjacent flexor tendons arise during forceful torque of the wrist.[25] The hamate forms the radial border of Guyon's canal and the ulnar border of the carpal tunnel (**Fig. 2**). Injury to the hamate can result in median and ulnar nerve dysfunction, although symptoms of median nerve dysfunction are rare. The diagnosis of hamate fractures can be clinically challenging with many fractures diagnosed long after injury.[26,27]

Mechanism of Injury

Hamate hook fractures occur from direct compressive forces, shear forces, or a combination of both. Both of these forces arise in tennis, in the baseball player when batting and in the golfer during a shot that is hit "fat." The nondominant hand is usually at risk in the batter or golfer. Dominant hands are involved in tennis and other racquet sports when only one hand receives the force of impact. The taut flexor tendons at the base of the hamate exert shear forces during power grip in an ulnarly deviated wrist, as is seen in racquet sports.[24]

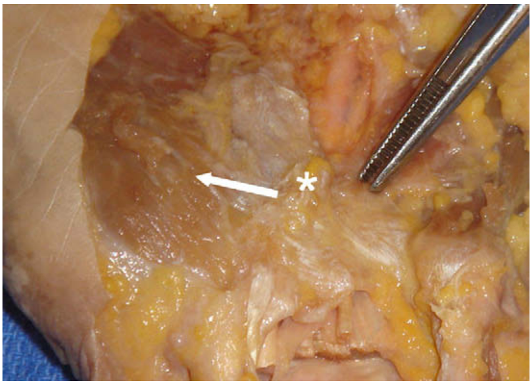

Fig. 2. The TCL forms the roof of the carpal canal (*forceps*) and the floor of Guyon's canal. Pull from the thenar muscles (*arrow*) through the TCL can displace a fractured hamate (*asterix*).

Hamate body fractures generally occur with a high-energy axial load to the fourth and fifth metacarpals resulting in a carpometacarpal (CMC) fracture dislocation.[19,28] Hamate body fractures have been classified as coronal or transverse.[29] Coronal plane fractures result from axial loads applied as described earlier.[30]

Examination

Pain in the ulnar palm aggravated by active grasp is the most common sign of a hamate hook fracture.[31] Tenderness to palpation is elicited directly over the hamate hook, 2 cm distal to the pisiform in line between the second metacarpal head and pisiform.[32] Occasionally, ulnar nerve paresthesias will be acutely present.[31] In delayed presentation, patients present with vague ulnar-sided wrist and hand pain,[31] median[33] or ulnar nerve[34] symptoms, and weakness of grip from affected ulnar-sided flexor tendons.[35] Pain with resisted ring and small finger flexion worsened with wrist ulnar deviation and lessened by radial deviation can uncover the occult hamate hook injury irritating the flexor tendons to the ring and small fingers (**Fig. 3**).[25] Flexor tendonitis of the ring or small fingers is uncommon in athletes. The possibility of a hamate hook fracture should be considered even in the absence of tenderness over the hook or in the face of normal wrist imaging. An unrecognized and untreated hamate hook fracture may lead to a partial or complete rupture of the IVth or Vth deep or superficial flexors (**Fig. 4**).

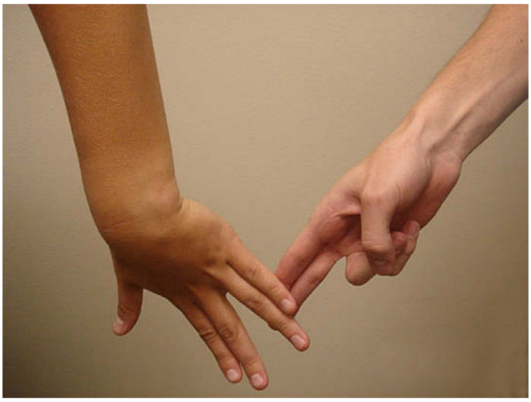

Fig. 3. The combination of wrist ulnar deviation and resisted wrist flexion can elicit pain from tendonitis emanating from a hook of the hamate fracture.

Imaging

Radiographic findings of hamate fractures on standard views of the hand are subtle. The PA radiograph of an uninjured wrist has an oblique articular space separating the distal margin of the hamate from the base of the IVth and Vth metacarpals (**Fig. 5**). This space is lost following a IVth or Vth CMC dislocation with a shear fracture of the anterior aspect of the hamate (**Fig. 6**).

The normal PA radiograph of the wrist also has a circular density at the distal margin of the hamate (**Fig. 7**). **Fig. 7** shows an end-on view of the hamate hook. Loss of this circle occurs with a displaced hamate hook fracture. Increased sclerosis about the circle can occur with a nondisplaced nonunion of the hamate hook.[36] Three specialized views; carpal tunnel view,[37] a supinated oblique view with the wrist dorsiflexed,[38,39] and a lateral view projected through the first web space with the

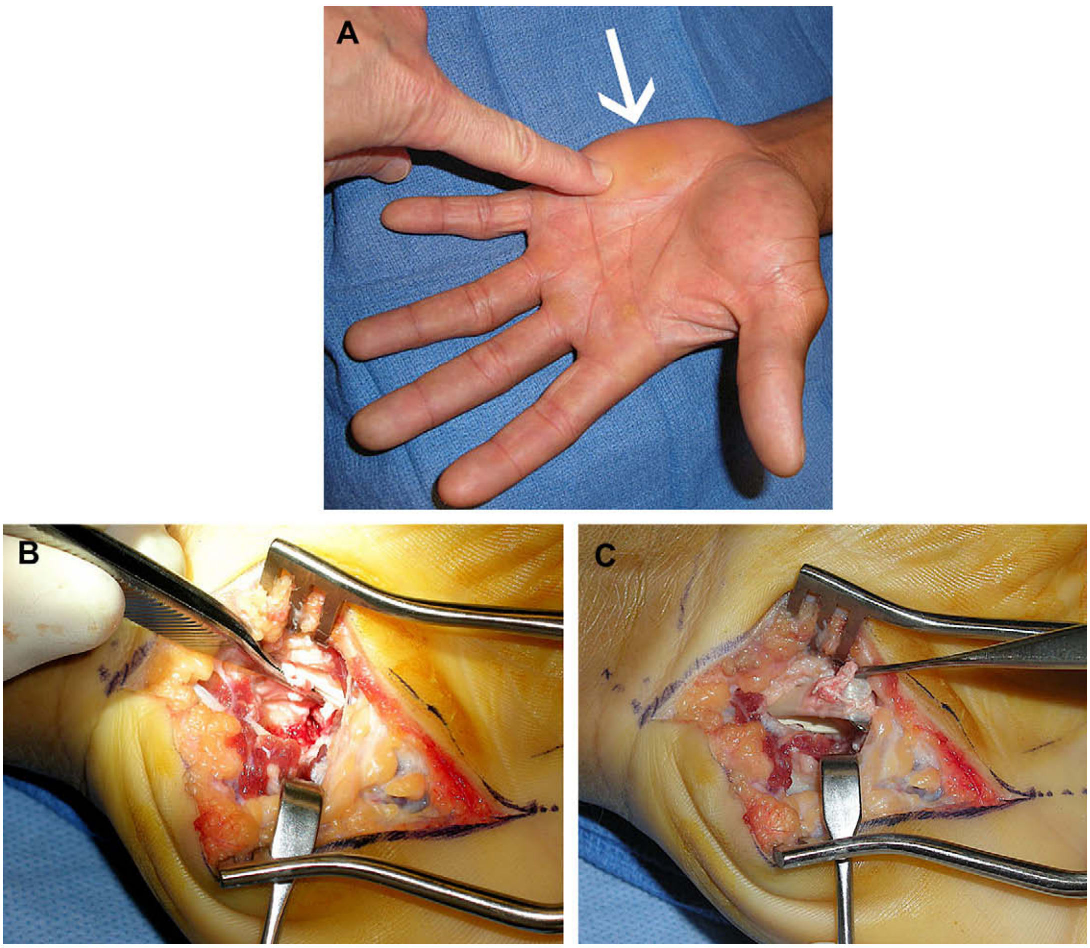

Fig. 4. Callous over the hypothenar eminence in a baseball player with flexor tendonitis and ulnar-sided palm pain (*A*). Fracture distal margin of the hamate at the CMC joint. The hamate hook was not fractured (*B*). Partial flexion tendon laceration from abrasion against the fractured hamate (*C*).

Fig. 5. Posteroanterior view of the wrist with a joint space clearly visible between the base of the fifth metacarpal and the hamate (*arrow*) and all of the other CMC joints.

Fig. 7. Sclerotic circle on the PA view of the wrist results from an end-on view of the normal hamate hook (*arrow*).

thumb abducted,[40] have been described to bring the hamate hook into better view. The carpal tunnel view is commonly used for its reproducible profile of the hook (**Fig. 8**), but can be difficult to obtain if fracture pain precludes sufficient wrist extension.

Fig. 6. Obliteration of CMC joint space in a patient with a III to V CMC fracture dislocation.

Studies have shown the superiority of CT imaging with the hands in the praying position for detecting occult hamate fractures.[41,42] The additional bone detail from a CT scan can also exclude congenital variations such as os hamuli proprium (**Fig. 9**).[18]

Treatment

Displaced fractures of the hamate body are best treated with operative reduction and internal fixation, particularly in the setting of a shear fracture occurring with a IVth or Vth CMC dislocation. The fracture is easily exposed between the IVth and Vth extensor digitorum communis tendons. Fixation of the fracture is best achieved with mini fragment screws. Care must be taken when drilling dorsal to the palmar through the hamate because the motor branch of the ulnar nerve hugs the ulnar and distal margins of the hamate hook (**Fig. 10**).[43]

Treatment options for acute hamate hook fractures include immobilization, open reduction, and internal fixation and excision. Although there is support in the literature for each option, in practice most fractures are treated with excision.

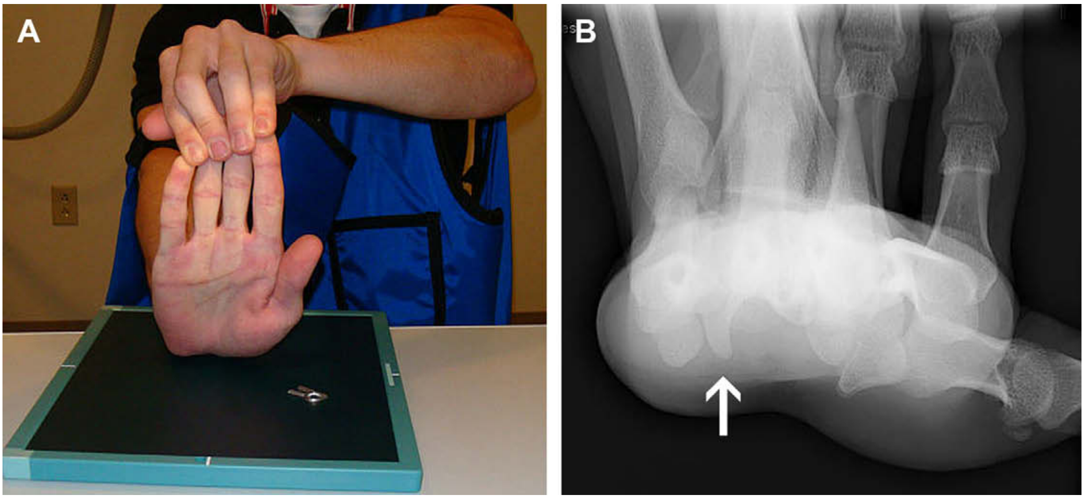

Fig. 8. Hand held in maximum extension to facilitate the carpal tunnel view (*A*). Carpal tunnel view with *arrow* showing the hamate hook (*B*).

Nonoperative management has been successful for nondisplaced hook fractures when diagnosed within the first week of injury.[44] Results are less favorable if hamate hook fractures are treated beyond the first week.[45] It has been suggested that slight wrist flexion with the IVth and Vth metacarpophalangeal joints in maximum flexion lessens the shear forces on the hook from the ulnar flexor tendons. Immobilizing the thumb is believed to minimize the pull of thenar muscles on the hook by the transverse carpal ligament (TCL) (**Fig. 2**).[46]

Proponents of open fixation of hamate hook fractures cite a cadaver study demonstrating loss of strength with removal of the hamate.[47] Although patients should be counseled on this possibility, weakness has not been a significant deficit in clinical studies.[48] Published literature on the results of open reduction and internal fixation (ORIF) is scant. One review reported nonunion or questionable union in 4 out of 9 patients.[26]

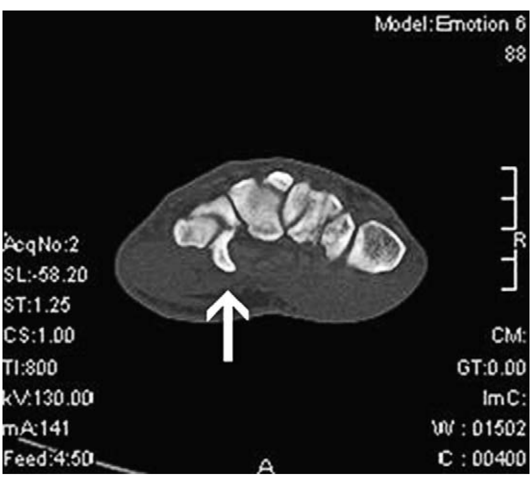

Fig. 9. CT view of the carpal canal illustrating a hamate hook fracture (*arrow*).

Excision of acute hamate hook fractures is considered the optimal treatment of athletes attempting the earliest return to sport (**Fig. 11**A).[39] Exposure is accomplished through a curvilinear incision center over the hamate hook. Crossing the wrist crease should be avoided if possible. Anecdotal experience has suggested that scars in the wrist crease seem to remain sensitive longer than those in the palm. The ulnar nerve and artery are identified radial to the pisiform at the entrance to Guyon's canal. The nerve and artery are traced to the ulnar border of the hamate hook. The motor branch exits the ulnar nerve proper on the dorsal-ulnar aspect of the nerve and then passes dorsal to the ulnar nerve beneath the flexor digiti minimi[49] and around the distal ulnar border of the hamate hook. The motor branch must be mobilized and retracted before exposure of the hamate hook (see **Fig. 10**). The tip of the hook is palpated and is then exposed by elevating the periosteum. The hook is surprisingly long (**Fig. 11**B). Patience is required to safely expose the hook down to its base. Most fractures pass through the base of the hook. In all cases, even those with a fracture that is more anterior through the hook, removal of all of the hook is preferred. This procedure should prevent the remaining bone from irritating the flexor tendons.

A lateral approach has also been described for hamate hook excision. The incision is placed adjacent to the fifth metacarpal. The abductor and opponens digiti minimi are elevated to expose the base of the hamate hook.[50]

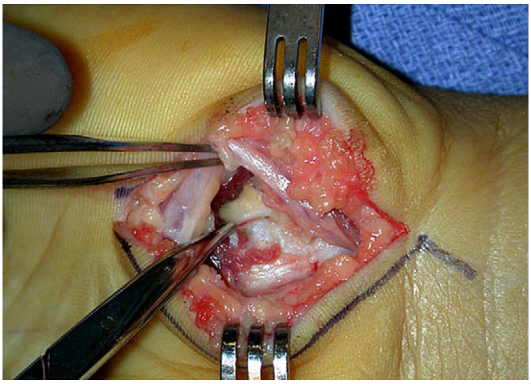

Fig. 10. Deep motor branch of the ulnar nerve (*tip of scissors*) as it passes around the base of the hook of the hamate.

Hamate hook excision is also the recommended treatment of symptomatic nonunions. Case series have demonstrated a predictable return to high levels of sports following excision of the hamate hook.[39,51]

Return to sports following hamate hook excision is generally quick, with scar sensitivity being the limiting factor. Gentle use of the hand is started immediately focusing on the finger range of motion. Sutures are removed at 10 to 14 days as the wound is managed with scar massage and a silicone patch. Light workouts including grip strengthening are permitted with a padded glove, such as a biking glove. Baseball players begin dry swings (no contact) with a bat. Golfers and racquet players can similarly practice swings without contact. Golfers can practice putting and chipping off a mat. At week three, baseball players begin hitting off a tee and progress to hitting pitches, as tolerated. Racquet players start light volleying and progress to ground strokes, as tolerated. Golfers progress from quarter to full swings hitting balls off a mat during week three. In week four they progress from quarter to full swings hitting balls off the grass. Most athletes can return to their sport in 4 to 6 weeks. The scar sensitivity decreases over time, but does not go away for 4 to 6 months.

Complications

Rupture or fraying of the flexor digitorum profundus and superficialis tendons to the ring and small fingers at the irregular surface of the hamate fracture has been reported in a literature review of approximately 14% of cases.[26] Ruptured flexor tendons are repaired with palmaris tendon bridge grafts or end-to-side repairs.[26]

A water shed area of vascularization has been proposed to put the hamate hook fractures at risk for nonunion[52,53] as osteonecrosis of a hamate body[54] and hook[55] after fracture has been reported.

A 3% complication rate has been reported in association with excision of the hamate hook fractures[56] with nerve injury being the most common untoward event.

TRAPEZIUM FRACTURES

Incidence

Trapezium fractures comprise 4% to 5% of carpal fractures.[57–59] Fractures of the trapezium body are most common and described as horizontal and sagittal split, transarticular, dorsoradial tuberosity, and comminuted.[60] Sagittal split fractures are the most common. Volar trapezial ridge fractures, attachment site for the TCL, are less common. Ridge fractures have been classified as type I base fractures and type II avulsion tip fractures.[59] The association of trapezium fractures and first metacarpal fractures is well documented.[58,61,62] Other concomitant injuries include fractures of the scaphoid, distal radius, and hamate.[58,61,62]

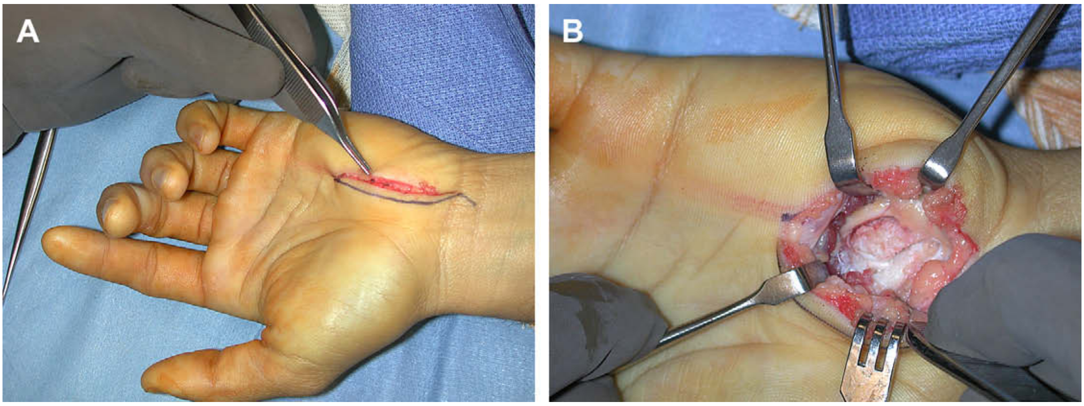

Fig. 11. Exposure of the hamate hook with a curvilinear incision in the palm centered over the hook of the hamate (*A*). Exposed hook of hamate (*B*).

Mechanism of Injury

The protected position of the trapezium below the first metacarpal often prevents direct blows from causing fractures. Many trapezium fractures are the result of high-energy injuries, particularly motor vehicle accidents.[61] These fractures also occur from a fall onto an outstretched hand whereby an axial load on the dorsiflexed wrist drives the metacarpal into the trapezium.[20] The radial styloid can also be driven into the trapezium if the wrist is radially deviated and the thumb is abducted and hyperextended. Lateral body fragments commonly remain attached to the first metacarpal by connecting ligaments, and displace radially and proximally from the pull of the abductor pollicis longus.[17]

Examination

Point tenderness at the volar base of the thumb, just distal to the volar tubercle of the scaphoid is a reliable finding in the acute setting. Painful and weakened pinch is also a telling sign. Pain is often exacerbated with wrist flexion due to the close proximity of the flexor carpi radialis (FCR) to the longitudinal groove adjacent to the volar ridge (**Fig. 12**).

Radiographic Evaluation

Standard views of the hand frequently reveal trapezium body fractures (**Fig. 13**). Bett's view, a pronated anterior-posterior view has been described to better visualize the trapeziometacarpal articulation.[17] The carpal canal view best demonstrates trapezial ridge fractures (**Fig. 14**).[63] CT is useful in chronic cases involving trauma to the wrist and for identifying occult ridge fractures or the rare coronal fracture (**Fig. 15**).[64]

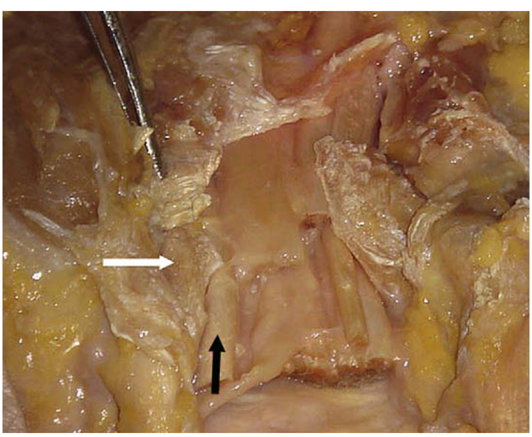

Fig. 12. Anatomic dissection showing proximity of the trapezial ridge (*white arrow*) to the FCR tendon (*black arrow*).

Fig. 13. Oblique view (pronated) view of the wrist reveals a longitudinal fracture of the body of the trapezium. (*Courtesy of* Michael Hayton, MD, Manchester, UK.)

Treatment

Nondisplaced trapezial body fractures can be treated with thumb spica immobilization for 4 to 6 weeks. Intraarticular fractures displaced 2 mm or more, are best exposed through a Wagner approach. An incision is made along the radial and proximal margins of the thenar musculature at the junction of the glaborous skin of the palm and the dorsal skin of the wrist (**Fig. 16**). The thenar muscles are elevated exposing the trapezium and thumb CMC joint. Care should be taken to protect the superficial radial nerve and radial artery.[65] Fixation is achieved with pin or mini fragment screws.[61] The goal of fixation is to minimize the risk of deformity and posttraumatic arthritis. A dynamic traction splint using oblique traction with a percutaneous wire through the first metacarpal attached to an outrigger has been devised in an attempt to permit early motion.[66]

Type I ridge fractures at the base can be treated nonoperatively with cast immobilization for 6 weeks. However, the pull of the TCL and the adjacent FCR may induce fracture motion that prevents healing.[67] Fracture excision has been recommended for type II ridge fractures given the high rate of nonunion (see **Fig. 14**).[59]

Complications

Patients with a missed trapezial fracture may develop irritation of the median nerve[67] or FCR tendon. Posttraumatic arthritis is a common radiographic finding after trapezial body fractures, but is frequently asymptomatic.[61]

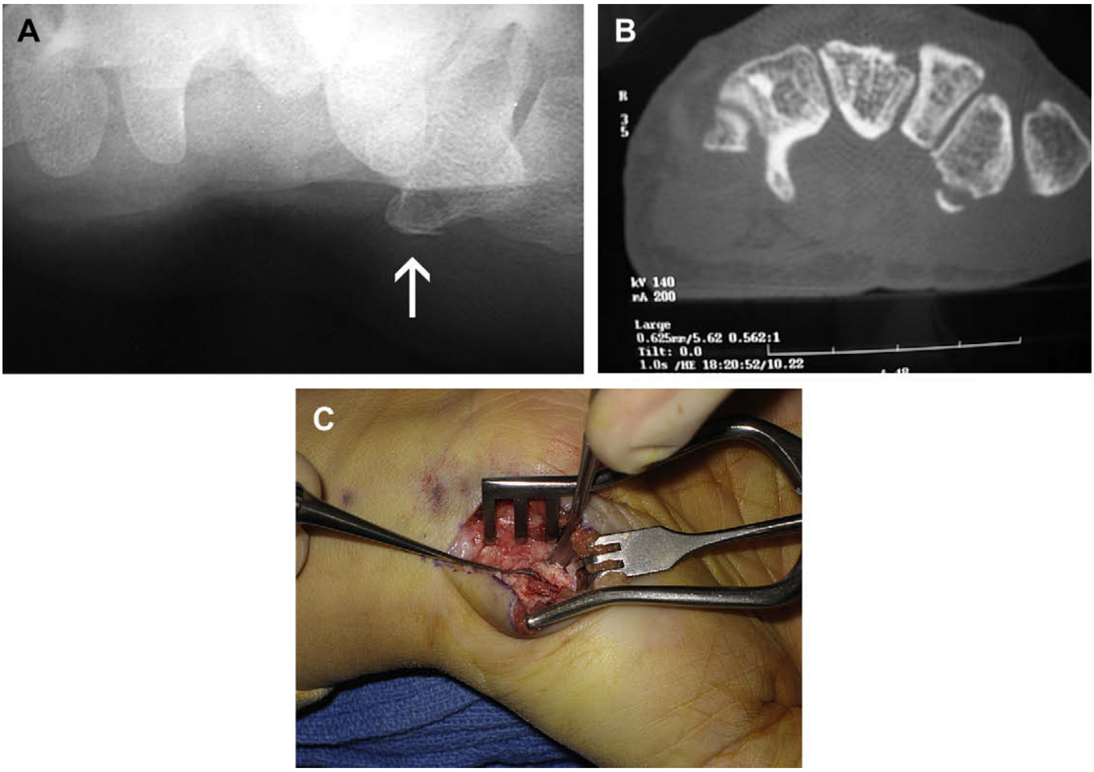

Fig. 14. (*A*) Carpal tunnel view demonstrating a fracture of the trapezial ridge (*arrow*). (*B*) CT scan demonstrating fracture of the trapezial ridge. (*C*) Incision near the base of the thenar eminence with resection of the fractured trapezial ridge.

CAPITATE FRACTURES

Incidence

Capitate fractures comprise 1% to 2% of all carpal fractures.[24] The capitate is protected in the center of the hand by the surrounding carpus bones and metacarpals. A high-energy injury is typically necessary to create a fracture. In one study, capitate fractures occurred four times more commonly as part of a perilunate fracture dislocation than in isolation.[68] The combination of scaphoid waist fracture and capitate fracture with malrotation of the proximal fragment has been called the naviculo-capitate or scaphocapitate, fracture syndrome.[69] The most common fracture pattern is the transscaphoid, transcapitate perilunate fracture dislocation.[68]

Mechanism of Injury

Isolated capitate fractures are believed to result from a direct blow or by an indirect axial load through the third metacarpal with the wrist flexed.[70] The latter mechanism results in a fracture at the neck of the capitate and base of the third metacarpal.[70]

A transscaphoid, transcapitate perilunate fracture dislocation is believed to occur with wrist hyperextension and radial deviation with the radial styloid striking the scaphoid.[69] Another proposed mechanism suggests that the dorsal lip of the distal radius strikes the dorsal surface of the capitate, flipping the unattached proximal pole fragment 180 degrees.[71,72]

Examination

Early diagnosis is aided with a high index of suspicion and careful palpation to localize tenderness dorsal to the fractured capitate.

Radiographic Evaluation

Standard anteroposterior, lateral, and oblique views of the hand often elucidate capitate fractures. Fractures in the coronal plane are better visualized by CT scan[73] or MRI.[74] Imaging with MRI may help assess surrounding ligaments. In practice, MRI is infrequently used in this setting because most of these injuries require surgical treatment by a dorsal approach allowing the surgeon to inspect the intercarpal and extrinsic ligaments, as well as the TFCC.

Fig. 15. CT revealing a coronal fracture through the body of the trapezium on sagittal (*A*) and axial (*B*) views.

Fig. 16. Skin incision for the Wagner approach to trapezium body fractures is along the glaborous skin of the palm and the dorsal skin of the wrist. This approach places the branches of the radial artery and nerve at risk.

Treatment

Nonoperative treatment should only be pursued in nondisplaced neck fractures.

Discontinuation of the cast or splint is advised only after radiographic and clinical signs of healing are present. In those instances whereby plain radiographs provide equivocal evidence of healing, CT images in the coronal plain can be relied on to identify crossing trabecula.

ORIF with pins or compression screws is performed through a dorsal incision between the third and fourth extensor compartments in line with the radial border of the long finger.[20] Palmar flexion of the wrist improves access to the proximal fragment. Concomitant scaphoid fractures and scapholunate ligament repairs can be addressed through the same dorsal approach. Cannulated headless screws from proximal to distal in the capitate provide adequate stability to allow a range of motion in 2 weeks (**Fig. 17**).[20,75]

This injury has a varied prognosis that depends on the extent of injury to the soft tissues and to the articular surface, whether or not the head fragment heals or develops avascular necrosis (AVN). Midcarpal arthritis is a common consequence. Depending on the athlete's sport and response to treatment, this is typically a season-ending, if not a career-ending injury.

Complications

Early diagnosis is the key to success in properly treating capitate fractures. The retrograde

Fig. 17. A 17-year-old man presented 7 weeks after punching a tree, sustaining an isolated right capitate fracture seen on the plain radiographs (*A*), coronal and sagittal CT images (*B, C*). Postoperative radiograph of open reduction internal fixation with a headless compression screw (*D*). (*Courtesy of* Andrew W. Cross, MD, Cincinnati, OH.)

interosseous blood flow of the capitate is much like the scaphoid and places the proximal pole prone to AVN with fractures at mid-level.[76,77] Despite this tenuous blood supply, AVN of the proximal fragment has been reported infrequently in isolated capitate fractures if not associated with high-energy fracture dislocations.[77–80] Higher energy fracture dislocations place the proximal capitate at risk, especially when malrotated.[68,81] Nonunion of isolated capitate fractures occurs in more than 50% of cases.[17] AVN and painful nonunions can be addressed by corticocanellous bone grafts to restore carpal height and promote healing.[82]

As mentioned earlier, stiffness and midcarpal arthritis are common with intraarticular fractures of the wrist, particularly if the fracture occurs with a carpal dislocation.

TRAPEZOID FRACTURES

Incidence

Trapezoid fractures constitute less than 1% of carpal fractures.[26] Like the capitate, the trapezoid is protected by the surrounding metacarpal and carpal bones. Fractures of the trapezoid typically result from high-energy injuries to the hand. There are no series to guide treatment.

Mechanism of Injury

The trapezoid is keystone-shaped and the dorsal surface is twice that of the volar side. This shape, coupled with stronger volar than dorsal ligaments, predisposes the trapezoid to dorsal dislocation.[83] An axial force through the flexed second metacarpal exerts a palmarly directed force on the trapezoid, displacing it dorsally.[84] However, volar dislocation of the trapezoid has been described as a result of a high-energy injury to the hand.[85]

Examination

Point tenderness at the base of the index metacarpal, pain with motion and deformity can lead to the diagnosis. Pain can be elicited with gentle motion of the second metacarpal.

Radiographic Evaluation

Standard anteroposterior, lateral, and oblique radiographs often permit detection of isolated trapezoid dislocations. Fracture dislocations of the trapeziometacarpal joint are best visualized on the anteroposterior view rather than the lateral view. The dislocated trapezoid allows proximal migration of the second metacarpal. The proximal edge of the metacarpal will obscure the normal joint space between the distal scaphoid and the trapezium and trapezoid.[83] Imaging with CT helps to identify occult fractures in patients with chronic pain and localized tenderness after trauma to the hand.[86]

Treatment

Closed reduction of trapeziometacarpal dorsal dislocation is performed with longitudinal traction followed by palmar flexion of the wrist, particularly on the second metacarpal, and dorsal pressure on the trapezoid.[83,87] If the reduction is unstable, percutaneous pin fixation is usually sufficient. Fractures involving joint incongruity or irreducible dislocations are best treated with open reduction and pin or screw fixation.[88] Trapezoid excision in fracture dislocation is contraindicated due to the proximal migration of the index metacarpal.[83,85] Hardware is left in place for 6 to 8 weeks. Unrestricted use is permitted by 12 weeks.

Complications

The trapezoid receives 70% of its interosseous supply through dorsal branches.[52,76] Dorsal dislocations disrupting the dorsal blood supply place the trapezoid at risk for AVN.[89] Symptomatic malunions and nonunions can be treated by arthrodesis of the CMC joint.[17]

PISIFORM FRACTURES

Incidence

Despite its prominence at the base of the hypothenar eminence, the pisiform is fractured much less commonly than the hook of hamate, constituting about 1% of carpal fractures.[26] Approximately half of pisiform fractures are associated with other carpal injuries.[17] In isolation, pisiform fractures can be sagittal avulsion fractures, transverse avulsion fractures, or comminuted fractures.[90]

Mechanism of Injury

The anatomy and multiple structures attached to the pisiform play a role in fracture pattern and management. The pisiform articulates with the triquetrum dorsally, is the origin of the abductor digiti minimi, and serves as the attachment for the flexor carpi ulnaris (FCU) that continues distally as the pisohamate and pisometacarpal ligaments. The TCL also attaches to the pisiform. The pisiform forms the radial wall to Guyon's canal, placing the ulnar nerve and artery at risk when fractured.

Pisiform fractures most commonly occur as a result of a direct blow, such as striking the palm during a fall, during a motor vehicle collision, the brunt of a handgun while firing weapons,[20] or racquet sports.[91] Avulsion of the FCU during resisted hyperextension of the wrist can create a transverse fracture pattern.[90] An analogy has been drawn to the patella, whereby direct blows onto the knee often result in comminuted fractures, whereas an avulsion fracture from the patellar tendon results in a transverse fracture pattern.

Pisiform dislocations have been described as a result of blunt trauma and falls on an outstretched wrist.[92–94]

Examination

Point tenderness over the pisiform or during a shuck maneuver of the pisiform should raise suspicion for fracture. Ulnar-sided wrist pain can be replicated with resisted wrist flexion. Ulnar nerve function should be documented.

Radiographic Examination

Standard radiographs can miss all but the large pisiform fractures due to overlying bone. The carpal tunnel view can more easily demonstrate a pisiform fracture. A reverse oblique view with the wrist in 30 degrees of supination places the pisiform on profile (**Fig. 18**). Studies have shown a consistent parallel relation between the pisiform and triquetrum. Pisotriquetral joint injury should be considered if joint separation is greater than 3 mm or bone surfaces are more than 20 degrees from parallel.[95] Imaging with CT is warranted when the results of plain radiography produces an equivocal result.

Treatment

Successful results have been reported when pisiformectomy is properly performed for pisotriquetral arthritis.[96] Hence, when treating athletes with pisiform fractures, the athlete's goal of quick, safe return to sport can be accomplished with early pisiform excision. Cast immobilization for 4 to 6 weeks can be attempted for acute nondisplaced or small avulsion type fractures when time lost from training or participation is not crucial. Widely displaced fractures with decreased FCU function or symptomatic nonunions are best treated with pisiformectomy.[9,17,20,32,46]

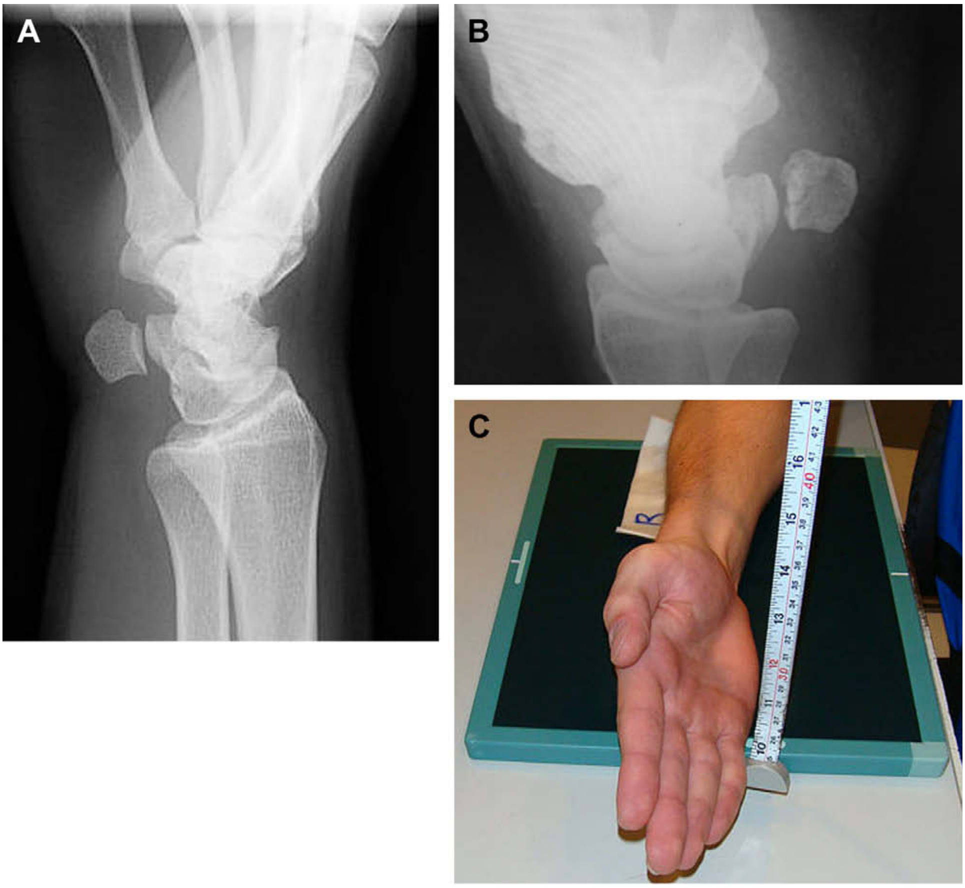

Fig. 18. Semi-supinated carpal radiograph of a normal pisotriquetral joint (*A*) and pisiform fracture (*B*). Proper positioning for the reverse oblique carpal view places the hand in 30-degree supination on the cassette (*C*).

Pisiform excision can be performed through an anterior or lateral approach. The anterior approach is the preferred approach whereby the ulnar nerve is mobilized and gently retracted toward the radial side of the palm. A penetrating towel clip facilitates removal. The pisiform is shaped like a top hat. Care should be taken as the dissection proceeds over the brim of the hat on its radial border. This procedure places the blade close to the ulnar nerve. It is for this reason that the anterior approach is preferred; the lateral approach necessitates a blind release of the bone's radial attachments. Pisiform excision has been performed arthroscopically, but the authors have no personal experience with that technique.

Rehabilitation after pisiform excision is identical to that following excision of a hamate hook, as described earlier. Return to sport is primarily limited by scar sensitivity.

Complications

Ulnar nerve injuries at the time of injury are often neuropraxias[97,98] that resolve with observation. Cautious monitoring of ulnar nerve deficits is reasonable for 8 to 12 weeks after acute pisiform fracture. Nerve exploration with pisiformectomy is recommended if nerve deficits persist after 12 weeks or worsen at any time during treatment.[17]

Ulnar nerve dysfunction after pisiform excision is common. If the nerve was visualized and protected throughout the procedure, observation is reasonable for 8 to 12 weeks. If the nerve was not visualized, immediate exploration is recommended if the 2-point discrimination is greater than 15 mm or if the patient has developed marked intrinsic weakness.

LUNATE FRACTURES

Incidence

Acute fractures to the lunate are rare, constituting 1% of all carpal fractures.[99] Lunate fractures are classified into 5 subtypes based on the vascularity of the bone and location: volar pole, dorsal pole, transverse body, sagittal body, and osteochondral or chip fractures. The most common subtype is the volar pole fracture.[99]

Mechanism of Injury

The lunate is compressed between the distal radius and capitate with extreme wrist hyperextension and ulnar deviation such as during a fall on an outstretched hand. In sports, lunate fractures have been described following a blow to the hand by a ball in line with the forearm.[100]

Examination

Tenderness over the dorsal aspect of the lunate should raise suspicion of a lunate fracture or scapholunate ligament injury. The pain can be accentuated by wrist motion.

Radiographic Examination

Standard radiographic views can miss a small fracture due to overlying bones. Imaging with CT scan or MRI is indicated if clinical examination suggests an occult fracture or ligament injury (**Fig. 19**).

Treatment

Treatment of athletes with lunate fractures is identical to that of triquetral fractures, as described earlier. Marginal chip fractures are often old injuries discovered as incidental findings in a person with a simple wrist sprain. Treatment is tailored according to pain, swelling, and radiographic findings. Small mariginal chip fractures are treated with short courses of immobilization followed by re-examination and re-imaging. Malalignment of the capitate over the lunate or a scapholunate diastasis is consistent with carpal instability. A volar intercalated segment instability (VISI) deformity with a palmar chip fracture or dorsal intercalated segment instability (DISI) deformity with a dorsal chip necessitates operative fixation. It is worthwhile obtaining contralateral views

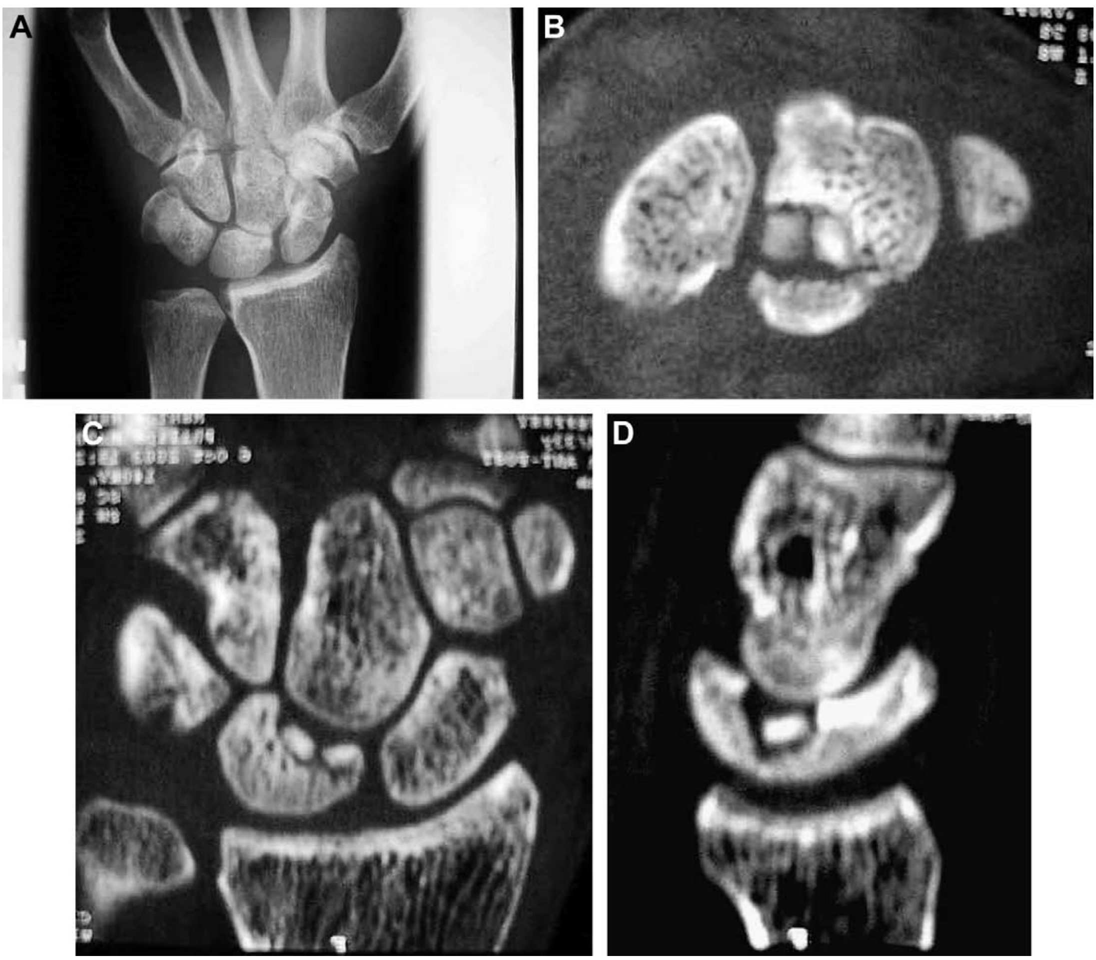

Fig. 19. The curvature of the lunate surfaces and position of the bone in the proximal row can obscure lunate body fractures on standard radiographs (*A*). CT clearly illustrates a lunate body fracture on axial, coronal, and sagittal views (*B–D*).

of the wrist, particularly in a woman with a VISI pattern, as this can be a normal variant.

An extended carpal tunnel approach exposes the volar lunate. Volar pole fractures are often small and may not tolerate headless screw fixation. In those cases the fragment can be secured with a buried pin and a wire suture looped around the volar fibers of the scapholunate ligament.

Fractures that extend into the body of the lunate and into the articular surface are best characterized with CT imaging. The joint surfaces are best seen and reduced through a dorsal approach to the wrist. Comminuted fractures can be managed with cancellous grafting. The construct can be protected with a spanning external fixator.

Complications

Twenty percent of lunates have only a palmar nutrient artery supplying the bone.[52] Displaced volar fragment fractures left untreated place such lunates at risk of AVN and should be anatomically reduced and fixed into place.[101]

There is no consensus on the causal relationship between acute lunate fractures and AVN, or Keinbock disease.[100–102] Long-term follow-up of lunate fractures have failed to show AVN despite half of those patients having ulnar minus variant wrists.[100] There is still reason to be concerned for disruption of the interosseous blood supply with the infrequent horizontal fractures.[102,103] Persistent wrist pain in an athlete following lunate fracture can be evaluated with MR for evidence of AVN. Analyzing the MR for AVN can be difficult. There will be extensive signal change along the lines of fracture. AVN should be diagnosed when there is a homogeneous loss of signal in the entire lunate.

Lunate fractures with intraarticular extension are at risk of midcarpal arthritis.

SUMMARY

Fractures of the carpal bones in athletes are often sport-specific injuries, which can be diagnosed with a complete clinical and radiographic examination of the patient's hand. Special radiographic views can help with the initial assessment; CT and MRI are useful for difficult diagnoses. However, the threshold for obtaining an MRI in an athlete with what seems to be a significant injury is low. The energy imparted on the hand not only creates fractures, but can injure crucial ligaments. Most nondisplaced fractures of the hand can be treated nonoperatively. Early surgical intervention is warranted for displaced intraarticular fractures or carpal malalignment. Excision of the hamate hook and trapezial ridge fractures facilitate an early return to sports.

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