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Carpal Bone Fractures

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Carpal bone fractures are probably more common than reported. The eight carpal bones vary significantly in shape and size and how they articulate with the other bones of the wrist. These complex articulations make plain radiologic interpretation of the wrist confusing to many physicians, and therefore missed injuries are probably more common than realized. For example, several case reports have been written on the delayed diagnosis of hamate hook fractures and different radiologic projections that would detect the injury [1–4]. Missed hamate fractures often go undiagnosed for months and can leave patients with wrist dysfunction. The complex three-dimensional relationship of the carpal bones makes plain radiographs difficult to use; therefore CT scanning is probably a more accurate test to understand these fractures fully. Taking CT scans of all wrist injuries is probably not a reasonable solution, however.

Because the incidence of carpal bone fractures is probably underreported, the exact incidence of each injury is difficult to quantify. Scaphoid fractures, which account for about 70% of all carpal bone fractures, are a common source of long-term pain, and often require surgery, are discussed elsewhere in this issue. Thirty percent of carpal bone fractures occur to the other seven bones of the wrist, however, and they can cause significant wrist disability (Fig. 1). Prompt diagnosis and appropriate treatment lead to faster recovery and better long-term outcome in many cases.

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Hamate fractures

Hook fractures

The hook of the hamate protrudes off the hamate into the base of the hypothenar eminence and is palpable 2 cm distal and radial to the pisiform. The relatively thick layer of skin, palmar fibrofatty tissue, and palmaris brevis make palpation more difficult than that of the pisiform. There are multiple attachments to the hook of the hamate including the transverse carpal ligament radially, the pisohamate ligament ulnarly, and the flexor digiti minimi and opponens digiti muscles. The hamate marks the ulnar border of the carpal tunnel and the radial border of Guyon's canal. These attachments may confer some stability to the hook of the hamate, but the intermittent forces also may explain the high rate of nonunion associated with this fracture. The base of the hamate serves as a pulley to the flexor tendons, in particular to the flexor tendons to the fourth and fifth fingers. Demirkan and colleagues [5] showed that with excision of the hook of the hamate, and therefore loss of the hook as a pulley, flexor tendon force decreases significantly, especially with the wrist in extension and ulnar deviation. The deep branch of the ulnar nerve runs just ulnar and in close proximity to the hamate.

Most commonly, fracture of the hook of the hamate occurs in sports involving racquets or clubs. These fractures may occur by direct trauma or indirect mechanisms. During a forceful swing, the base of the club can impinge against the hook of the hamate and cause a fracture (Fig. 2). This fracture would occur most commonly in the left hand of a right-handed golfer at follow-through or when the club head accidentally strikes the

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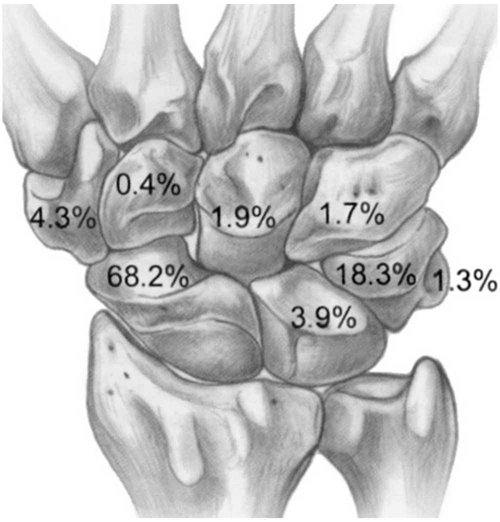

Fig. 1. Relative incidence of carpal bone fractures. (*From* Garcia-Elias M. Carpal bone fractures (excluding scaphoid fractures). In: Watson HK, Weinberg J, editors. The wrist. Philadelphia: Lippincott Williams & Wilkins; 2001. p. 174; with permission.)

ground [6]. It is possible that a strong contraction of the flexor tendons in a wrist position of extension and ulnar deviation or trauma to the pisiform causing tension on the pisohamate ligament could cause an indirect fracture.

Hook of the hamate fractures should be considered in patients presenting with ulnar-sided wrist pain, in particular in patients who play sports that put them at risk. In the acute setting, pain is present with palpation in the hypothenar area. Pain also may be present with resisted flexion of the fourth and fifth finger. These injuries, however, often are missed and are diagnosed as wrist sprains [7]. Therefore, patients may present with more chronic symptoms of pain. Sources of ulnar-sided wrist pain include distal radioulnar joint pathology, triangular fibrocartilaginous complex tears, lunotriquetral (LT) tears, flexor carpi ulnaris tendonitis, pisotriquetral arthritis, and other causes, but hamate fractures should be considered. Pain with resisted small and ring finger flexion, positioning the wrist in ulnar deviation, can suggest hamate nonunion. In fact, hamate nonunion can lead to tendon fraying, and several patients have presented with tendon rupture [8]. Patients who have hook of hamate fracture also may present with symptoms of nerve compression in either the median [9] or ulnar nerve [10].

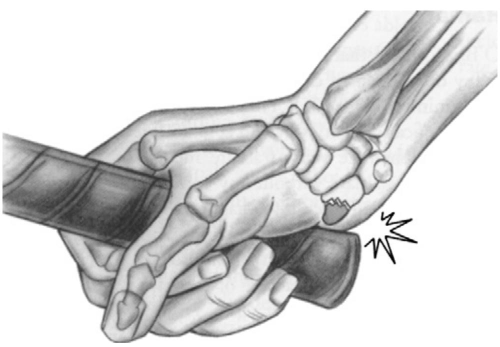

Fig. 2. Mechanism of hook of hamate fracture. (*From* Sennwald GR. Carpal bone fractures other than the scaphoid. In: Berger RA, Weiss AP, editors. Hand surgery. Philadelphia: Lippincott Williams & Wilkins; 2004. p. 418; with permission.)

If a hook of hamate fracture is considered in the differential diagnosis of an acute or chronic wrist problem, appropriate imaging should be ordered. Standard radiographs including posteroanterior, lateral, and pronated oblique views of the wrist may be done. Norman and colleagues [11] proposed three radiologic findings—absence of the hook, sclerosis of the hook, and lack of a cortical density—as signs of hook fractures. Standard views often can be inconclusive, however, and therefore several special views have been proposed. Papilion et al. [12] suggested a lateral radiograph with the thumb maximally opposed (to move it out of the way) and the wrist in ulnar deviation. Having the hand slightly supinated, to bring the hook into greatest profile, can help [2]. A carpal tunnel view is useful also [13]. Any radiograph can miss a hook of hamate fracture if it is not done exactly correctly, especially if the fracture is right at the base. Therefore CT scanning with the hands in a "praying position" remains the criterion for diagnosing this fracture [14].

If the diagnosis of an acute hamate hook fracture is made, and displacement is minimal, cast immobilization can provide consistent healing if treatment is started within 7 days of the fracture [15]. Significantly displaced fractures or fractures that are chronic in nature may not do as well with nonoperative treatment. Boulas et al. [16,17] reported a 14% incidence of flexor tendon rupture in patients who had untreated hook fractures and a low incidence of healing these fractures without treatment. The treatment for these fractures includes fixation with or without bone grafting or hook excision. Success has been reported with bone grafting and fixation. The advantage of this procedure includes good symptom relief and the preservation of the hook as a pulley [18]. Hook excision, however, is the most common procedure and is the one for which there is the greatest experience [10]. Excision involves a carpal tunnel approach, careful dissection of the hook, excision at the base, and soft tissue coverage of the raw bone surface to avoid tendon irritation. Careful dissection is essential to avoid complication such as an injury to the deep motor branch of the ulnar nerve [19].

Body fractures

Hamate body fractures usually occur in association with other injuries, most commonly fracture dislocations of the fourth and fifth carpometacarpal (CMC) joints and fractures to the fourth and fifth metacarpal bases. This injury usually occurs with an axial load injury to a clenched fist. CMC joint anatomy has been studied, and the articular anatomy and ligamentous attachments have been documented in detail [20,21]. The fifth CMC joint, with approximately 30° of motion, is the most mobile; mobility decreases moving radially to the second CMC joint, which has limited motion. The more mobile fourth and fifth CMC joints are more susceptible to injury. Garcia-Elias et al. [22] reported three types of axial dislocations: axial-radial, axial-ulnar, and axial-radial-ulnar. The most common injury is axial-ulnar. Patients present with pain and deformity following an axial load. The injury usually can be identified on plain radiographs. CT scanning can be helpful in preoperative planning.

Hirano and Inou [23] recently classified hamate fractures as type 1 (hook fractures), type 2A (coronal split), and type 2B (transverse split). Coronal split fractures were the most common hamate body fractures in this study. All 2A fractures were associated with CMC dislocations. Because of the motion that occurs at the fourth and fifth CMC joints and the instability associated with fractures in this area, operative treatment is recommended if displacement or subluxation of the joint is evident. In one review in which both the fourth and fifth CMC joints were dislocated, reduction and fixation of the fourth CMC joint always led to spontaneous and stable reduction of the fifth CMC joint because of the ligamentous attachments. Surgery in this series included fixation of the coronal hamate fracture with screw fixation; in addition temporary bridge plate fixation of the fourth CMC joint was done when there was CMC instability despite hamate fixation. Nine of 11 patients in this study had full recovery [24]. A dorsal approach to the CMC joint is used. Treatment involves open reduction and fixation of the hamate body fracture. If the CMC joint remains unstable, temporary bridge plating or Kirschner wire (K-wire) stabilization of the joint should be used (Fig. 3) [25].

Triquetral fractures

The triquetrum is pyramid shaped. It articulates with the hamate distally, the triangular fibrocartilaginous complex proximally, and the lunate medially. Its palmar surface has an almost completely circular cartilaginous articulation with the pisiform. The triquetrum is well protected by ligamentous attachments on both the dorsal and volar side of the wrist. Triquetral fractures, however, make up the most common carpal bone fracture next to scaphoid fractures [26]. Triquetral fractures can involve either the dorsal ridge—the "chip" fracture—or the entire body. Chip fractures are much more common (Fig. 4).

It initially was thought that the chip fracture is an avulsion fracture at the attachment of the strong dorsal ligaments, the radiotriquetral and triquetro-scaphoid ligaments. This fracture would have to occur with the wrist being forced into extreme flexion. Although this may be case in some injuries, it is much more common for chip fractures to occur with the wrist in a position of dorsiflexion and ulnar deviation. The fracture is caused by a shear mechanism with impingement with the proximal hamate, distal ulna, or both. In fact, it has been shown that patients who have dorsal triquetral fractures have a significantly larger ulnar styloid than seen in a control group, suggesting that these patients are at a greater risk of injury from a "chisel" effect from the ulnar styloid [27]. In patients who have wrist injuries and ulnar-sided pain, dorsal ridge triquetral fractures are relatively common and should be considered in the differential diagnosis. Standard anteroposterior, lateral, and oblique radiographs should be obtained. If suspicion remains high, and nothing can be seen on these radiographs, a careful inspection of the oblique radiograph, a repeat radiograph with the hand in slight pronation (bringing the dorsal triquetrum into profile), or even a CT scan should be considered to confirm the diagnosis. With the diagnosis confirmed, rigid immobilization in a cast for a period of 4 to 6 weeks followed by a graded therapy program usually leads to good long-term functional outcomes for isolated injuries of the wrist [26].

Fig. 3. (*A*) Preoperative radiograph and (*B*) CT scan of a 20-year-old male with an axial load injury and displaced hamate body fracture and associated CMC dislocation. (*E–G*) Postoperative radiograph and CT scan showing reduction of hamate and CMC joints.

Fig. 4. Lateral radiograph of a patient who had ulnar-sided wrist pain and a diagnosis of a dorsal triquetral fracture.

Triquetral body fractures are not as common. Usually these injuries occur in conjunction with a fracture-dislocation to the wrist such as a perilunate dislocation and therefore are treated as part of a ‘‘greater arc’’ injury [28]. Isolated injuries to the triquetral body can occur, however, and their displacement probably is underappreciated. Porter and Seehra [29] reported a case of triquetral fracture dislocation treated by open reduction and internal fixation. Skelly and colleagues [30] reported a case of a triquetral body fracture in association with a perilunate dislocation. The initial reduction looked acceptable, but at time of surgery the triquetral body fracture was rotated 180°. Aiki and colleagues [31] recently reported a case of persistent ulnar-sided wrist pain that was caused by pisotriquetral arthrosis secondary to a triquetral malunion. This case was treated successfully by pisiform excision. There is not enough evidence to offer good treatment guidelines regarding triquetral body fractures, but fractures in association with perilunate dislocation or those with more than 1 mm of displacement probably should be considered for surgical treatment to maximize long-term wrist function.

Pisiform fractures

The pisiform, like the patella, is a sesamoid bone enclosed in the sheath of the flexor carpi ulnaris tendon. It lies on the volar surface and articulates with the triquetrum. The pisiform is the last bone to ossify between ages 8 and 12 years. There may be multiple centers of ossification, giving it a fragmented appearance. This normal appearance must be distinguished from a fracture [32]. Acute pisiform fractures are reported as a source of ulnar-sided wrist pain [7]. If a fracture is suspected, the pisiform should be imaged appropriately using standard wrist radiographs. Normal radiographs may miss this diagnosis. As with a hamate fracture, a lateral radiograph with the wrist in slight supination will profile the pisiform. Ultimately, CT scanning may be helpful. If the diagnosis is made, initial treatment should include 4 to 6 weeks' immobilization in a cast followed by a graded therapy program. For patients who have persistent problems, pisiform excision offers reliable pain relief [33,34]. Because of the close proximity of the ulnar nerve to the pisiform, ulnar nerve dysfunction can occur in conjunction with a pisiform fracture. This dysfunction is most likely to be caused by a direct blow injury to the nerve itself, but a compressive neuropathy secondary to a displaced pisiform fracture probably should be explored, and the pisiform bone should be excised on a more acute basis [35].

Capitate fractures

The capitate is the largest of the carpal bones and is well protected in the middle column of the wrist where it is surrounded by the other carpal bones and strong wrist ligaments. Fractures of the capitate are relatively rare. In one review, Rand and colleagues [36] found 11 capitate fractures in 978 carpal bone injuries for an incidence of 1.3%. The mechanism of injury of this fracture is debatable. It may involve a direct blow to the wrist, a fall with the wrist in dorsiflexion and ulnar deviation (with the dorsal radius impacting on the waist of the capitate (Fig. 5), or as a part of a greater arc injury in association with a perilunate dislocation. Patients typically present with wrist pain after an acute injury, and a careful examination can pinpoint the area to the capitate. Radiographs can reveal the fracture, and displacement of as much as 180° of the proximal fragment has been reported even with isolated capitate fractures (Fig. 6) [37]. If patients present with pain, and no fracture is seen on initial radiographs, immobilization and close follow-up is warranted. When there is persistent pain in the area of the capitate, MRI should be considered. The relationship of the carpal bones is complex, and radiographs may miss undisplaced fractures [38].

Treatment recommendations for capitate fractures are based on limited experience because of the rarity of the injury. For undisplaced fractures, cast immobilization is sufficient. With displaced fractures, open reduction and internal fixation through a dorsal approach, most commonly with a variable- pitch headless screw or K-wires, is probably best [39]. For unrecognized, untreated fractures that develop nonunion, treatment depends on the chronicity of the problem and the presence or absence of wrist arthritis. Attempting to restore capitate length and normal carpal kinematics by bone grafting and fixation is recommended. As in the scaphoid, the blood supply to the

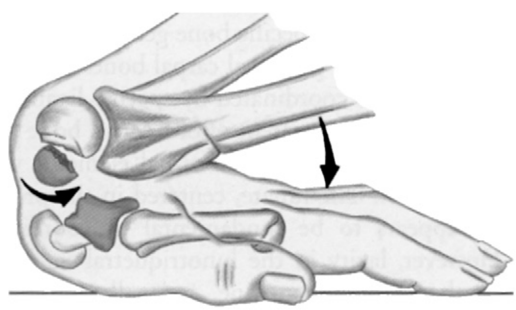

Fig. 5. Potential mechanism of a capitate fracture. (*From* Sennwald GR. Carpal bone fractures other than the scaphoid. In: Berger RA, Weiss AP, editors. Hand surgery. Philadelphia: Lippincott Williams & Wilkins; 2004. p. 410; with permission.)

Fig. 6. Capitate body fracture with 180° of displacement of proximal fragment. (*From* Volk AG, Schnall SB, Merkle P, et al. Unusual capitate fracture: a case report. J Hand Surg 1995;20A:581; with permission from The American Society for Surgery of the Hand.)

capitate is retrograde, usually from the volar side, and therefore has been described avascular necrosis in conjunction with a nonunion. This problem may be avoided by prompt diagnosis and treatment of this injury. In one small series reporting five cases of avascular necrosis, four cases were caused by trauma with a nonunion present. Three cases were treated by bone grafting, and two cases were treated by intercarpal fusion [40].

Capitate fractures occur more commonly in association with other injuries. In the study by Rand and colleagues [36], 13 capitate fractures were identified, but only 3 were isolated injuries. The most common associated pattern was transscaphoid transcapitate perilunate dislocation. Other variants, such as transscaphoid, transcapitate, transhamate fractures, have been reported [41]. Each case should be assessed individually to identify the injured bones and ligaments of the wrist and to formulate a treatment plan. Typically, a transscaphoid transcapitate dislocation would be treated by open reduction and internal fixation of both the scaphoid and capitate, and repair of the lunotriquetral ligament should be considered. Results for these complex injuries are more modest, with some loss of motion being the rule and long-term development of arthritis being common.

Lunate fractures

The lunate is shaped like a crescent. Its distal aspect is concave and articulates with the capitate; proximally it articulates with the lunate facet of the distal radius. In a normal situation, the lateral radiographic view shows the capitate, lunate, and distal radius collinear with the wrist in a neutral position. The lunate is integral in the flexion/extension arc and the radial/ulnar deviation arc at both the radiocarpal and midcarpal joints.

Fractures to the lunate are rare. Teisen and Hjarbaek [42] reported on 17 fractures that occurred in more than 3000 carpal bone fractures over a 31-year period. Of these 17 patients, 8 had other fractures to the carpal bones or wrist. Patterns of fracture in this study included fractures of the volar or dorsal pole, osteochondral fractures, and body fractures in both the sagittal and transverse plane. Of all the carpal bones, the lunate bone has proportionally the largest cartilage-covered area. In particular, the proximal portion of the lunate is made up of articular cartilage with no soft tissue attachment and a poor blood supply [43]. Despite this lack of blood supply, the small case series on lunate fractures have reported few cases of avascular necrosis following fracture. The lunate palmar pole fracture may be the most likely to lead to avascular necrosis of the lunate [44].

Treatment recommendations are based on small case series [45]. For minimally displaced fractures, a period of 4 to 6 weeks of immobilization is appropriate. For displaced fractures of the lunate body, open reduction and internal fixation probably is justified [46]. If small avulsion fractures of the dorsal or volar lip are present, and there is carpal subluxation, care must be taken to reduce the fragments accurately to restore carpal congruity (Fig. 7) [47]. Long-term outcomes in these small series are reasonably good, but outcome would be affected by many factors including patient age, related injuries, amount of articular damage, development of avascular necrosis, and other factors.

Trapezium fractures

The trapezium forms a double-saddle articulation with the base of the thumb metacarpal allowing motion in two planes—both flexion/extension and abduction/adduction. The volar "beak" ligament from the metacarpal to the trapezium is a key structure in maintaining joint stability and resisting dorsal radial subluxation during key pinch. The trapezium body articulates

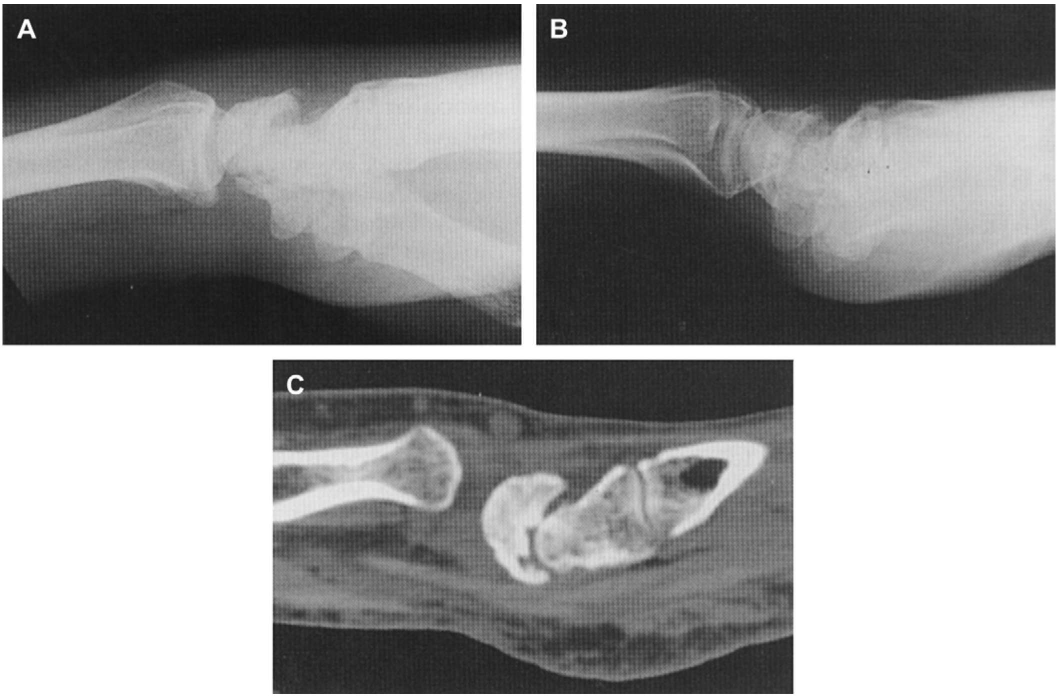

Fig. 7. (*A*) Lateral radiograph of acute volar lip fracture of lunate with associated subluxation. (*B*) Follow-up lateral radiograph with malunion of fracture and subsequent arthrosis. (*C*) CT scan depicting the lunate volar lip malunion with articular incongruity and anthrosis. (*From* Cohen MS. Fractures of the carpal bones. Hand Clinics 1997;13:588; with permission.)

with the carpal bones. The trapezial ridge is a volar structure that serves as a radial attachment for the transverse carpal ligament.

Trapezium fractures include body and ridge fractures. Fractures of the trapezial ridge can result from a direct blow or from an avulsion injury. Pain in the thenar area following a wrist injury should alert surgeons to the possibility of a scaphoid fracture, but trapezial fractures can occur, albeit more rarely. Botte and colleagues [48] reported on an unrecognized trapezial ridge fracture that was a source of longstanding pain for the patient. The fracture was not recognized initially, and a nonunion developed. The patient was offered surgery but refused. She remained unhappy, and litigation was considered because of the delay in diagnosis. Combination injuries including trapezial ridge fractures and hook of hamate fractures secondary to avulsion from the transverse carpal ligament have been reported also [49]. These injuries may be missed on normal radiologic review. Carpal tunnel radiographs should highlight the trapezial ridge. When there is uncertainty, CT scanning can be diagnostic. Initially, immobilization should be attempted. For ongoing symptoms of trapezial ridge fractures, excision can be considered.

Trapezial body fractures are relatively uncommon but can occur with axially loading or shearing mechanisms across the first CMC joint. Therefore associated fractures of either the base of the first metacarpal [50] or the scaphoid [51] are reported. Walker and colleagues [52] have classified body fractures into five types (Fig. 8). The most common fracture (type IV) involves a sagittal split with a radial and ulnar piece. The fracture line involves both the CMC joint and scaphotrapezial joint. The principles of treatment would be similar to the approach to Bennett's fractures. Because this joint is under great stress during pinching, an anatomic reduction of the joint surface is best. McGuigan and Culp [53] reported on 11 patients who had intra-articular fractures of the trapezium and recommend surgery for patients who have 2 mm of displacement or any subluxation of the first CMC joint. If surgical fixation is chosen, a careful approach is mandatory because of the intimate relationship of the nerves,

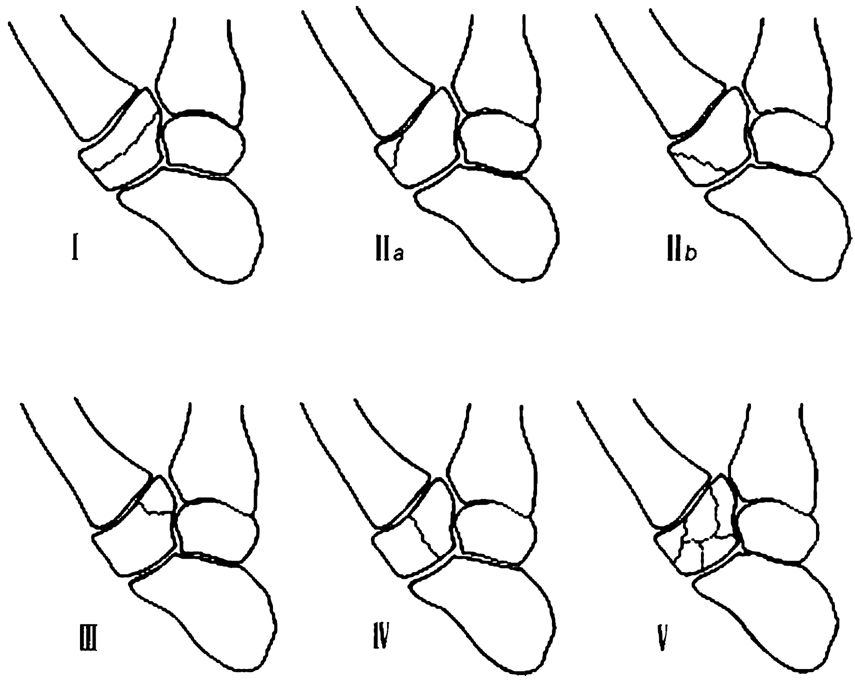

Fig. 8. Classification of trapezial body fractures. (*From* Walker JL, Greene TL, Lunseth PA. Fractures of the body of the trapezium. J Orthop Trauma 1988;2:23; with permission.)

arteries, and tendons in this area. In particular, the radial artery runs between the dorsal radial and dorsal ulnar ridges of the trapezium, and three cases of arterial injury associated with these fractures have been reported [54]. Fixation with K-wires or mini-fragmentary screws usually is sufficient. Unloading of the joint with a mini-external fixator may be necessary for comminuted fractures.

Trapezoid fractures

The trapezoid is tightly positioned between the base of the second metacarpal, capitate, scaphoid, and trapezium with strong intercarpal ligaments. It is wedge shaped, twice as wide dorsally as palmarly, and thereby forms the keystone of the carpal arch. It is the least commonly fractured carpal bone. Because of this position, the more commonly reported injuries include a dorsal dislocation [55]. Axially loading injuries leading to trapezoid fractures can occur [56]. Dislocations can be treated by closed reduction. If closed reduction fails or fracture fragments remain displaced, open reduction is warranted to restore the carpal arch of the hand.

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