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CARPAL FRACTURES IN ATHLETES

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Wrist injuries are becoming more prevalent during athletic competition because of increased participation. In the past, injuries that involved the lower extremities were emphasized because lower extremity injuries affected the athlete's ability to jump, run, cut, or push-off. Wrist fractures were thought to be trivial incidents with minimal morbidity.[20] Injuries of the wrist, however, severely affect the ability to throw, catch, shoot, and strike during competition. The tendency to minimize or delay treatment could result in long-term sequelae and adversely affect performance.

The incidence of hand and wrist injuries in sports constitutes 3% to 9% of all sports injuries.[47] The mention of certain sports activities should arouse the suspicion of specific fracture patterns. In general, compressive injuries such as in boxing occur from a fall on an outstretched hand, or a direct blow from a baseball can result in fracture, whereas twisting injuries as in gymnastics can result in ligamentous injuries. Football is notorious for the occurrence of fractures of the scaphoid. Riester estimated the incidence of scaphoid fractures in college football players as 1 in 100.[47] Stick handling sports such as golf, tennis, and baseball are associated with fractures of the hook of the hamate secondary to repetitive stress impaction on the hypothenar eminence. Stark described hook of the hamate fractures in 20 athletes involving tennis, golf, and baseball.[54] Less frequently, a fracture of the trapezial ridge can occur from the same mechanism and can be missed easily, as it may not be apparent

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on routine radiographs. Triquetral fractures are the second most common carpal bone fracture and are thought to occur from a fall on the outstretched hand with the wrist in ulnar deviation, as commonly occurs in skating.[13] Pisiform fractures occur from a direct blow, such as secondary to being struck by a pitched baseball. Lunate and capitate fractures are relatively rare, but Kienbock's disease is thought to be due to repetitive stress, which is common in the athlete.

SCAPHOID FRACTURES

The scaphoid is the most commonly fractured bone of the carpus.[21] Fractures of the scaphoid constitute 60% to 70% of all osseous injuries to the carpals.[12] The injury results from a fall on the hand with the wrist dorsiflexed greater than 90° and can be seen in many sports-related activities.

The scaphoid is suspended the wrist and almost completely covered with articular cartilage. Scaphoid fractures unite by primary bone healing without external callus. Scaphoid fractures have limited surface area for contact, a meager vascular supply, and the potential for synovial fluid to pass between the fracture fragment, which can make healing difficult, if not prolonged. The potential for healing further diminishes if there is a delay in diagnosis and immobilization. Uncomplicated healing can be achieved, however, in most cases of nondisplaced fractures of the scaphoid that are stable and in which casting was initiated within 3 to 4 weeks of injury. The slightest displacement (1 mm) or angulation precludes uncomplicated healing and the physician must analyze the radiographs carefully before concluding that the fracture is suitable for casting.

The scaphoid receives its major blood supply from the radial artery and branches of the anterior interosseous artery. The most important vascular leash enters along the dorsal ridge of the scaphoid. These vessels are responsible for most of the perfusion of the proximal two thirds of the scaphoid.[28] Because most scaphoid fractures (80%) occur at the midportion or waist area, this tenuous blood supply can be interrupted. This affects fracture healing, particularly fractures of the proximal pole, and can cause avascular necrosis. Approximately one third of middle-third scaphoid fractures and virtually all proximal-fifth fractures develop osteonecrosis. Because of the retrograde circulation, a more proximal fracture results in greater time till fracture union. Optimally managed fractures of the waist of the scaphoid average 3 months, whereas fractures of the proximal one third or one fourth rarely unite in less than 4 months. The distal scaphoid has an independent circulation, and fractures of the scaphoid tubercle generally unite within 6 weeks and those of the distal third within 2 months. Thus, the athlete needs to be advised of the relative length of inactivity, particularly in fractures that involve the proximal portion of the scaphoid, if cast immobilization is chosen.

Anteroposterior (AP) and lateral radiographs are mandatory to assess alignment, displacement, and angulation of a scaphoid fracture. In addition, semisupinated and semipronated radiographs demonstrate the distal pole. A scaphoid view with the wrist in ulnar deviation extends the scaphoid for detection of displacement. It is well known that a nondisplaced scaphoid fracture may not be apparent on the initial radiographs (Fig. 1*A*).[36] Because of this, it is important to continue to immobilize the athlete with snuffbox tenderness until the pain resolves or the diagnosis is made radiographically (Fig. 1*B*). The problem is that many athletes simply choose to ignore the discomfort and appear after the season with a defined nonunion (Fig. 1*C–D*). If the athlete demands immediate identification of the pathology before return to competition, then a bone scan can be performed 3 days after injury.[31] A negative scan rules out a fracture.[43] Computed tomography (CT) parallel to the longitudinal axis of the scaphoid is obtained occasionally to evaluate displacement, angulation, and healing when further information is required to manage the fracture.[9] The patient is placed prone with the arms extended overhead, and with the wrist radially deviated to obtain the longitudinal axis of the scaphoid.[52] Coronal slices are performed by supination of the forearm to neutral. Magnetic resonance imaging occasionally is used to assess the vascularity of the proximal pole in equivocal cases of avascular necrosis.[45] This information is helpful for evaluating the prognosis of the injury and preoperative planning, such as use of a vascularized bone graft.

Absolute nondisplaced fractures of the scaphoid can managed by cast immobilization. Union rates up to 90% to 95% have been reported with casting of nondisplaced scaphoid fractures and are the gold standard.[30, 56] Excessive thumb motion, wrist hyperextension, and ulnar deviation predispose to fracture displacement. A thumb spica cast in slight radial deviation and flexion impacts the fracture and reduces stress on the fracture reducing chance of displacement. Fractures at or proximal to the waist of the scaphoid are susceptible to shearing forces created by forearm rotation transmitted by the obliquely oriented radiocarpal ligaments. Nondisplaced fractures of the proximal two thirds of the scaphoid are managed with an above-elbow cast to limit forearm rotation. Fractures of the distal third of the scaphoid and fractures of the tubercle have a more adequate vascular supply and are managed in a below-elbow thumb spica. Surgical stabilization can considered if no signs of healing are evident by 6 to 8 weeks to avoid complications from prolonged immobilization and delayed return to competition. A protective playing splint is recommended for contact athletes for 6 months to decrease risk of reinjury.

Absolute indications for internal fixation of scaphoid fractures include displacement, nonunion, or fracture associated with carpal instability.[18] A scaphoid is considered displaced if there is 1 mm of displacement or 15° of angulation. Even minimal scaphoid angulation is apt to result in malunion and decreased wrist function, which can affect the athlete's performance.[23] Angulation of the scaphoid can be measured by

Figure 1. *A*, Anteroposterior (AP) radiograph in ulnar deviation of a 17-year-old linebacker with hyperextension injury to the wrist and acute snuffbox tenderness. Patient is placed in a thumb-spica playing cast because a fracture of the scaphoid is not apparent on radiographs. *B*, Two-weeks postprocedure with continued snuffbox tenderness. Repeat radiographs do not reveal a fracture. Thumb-spica immobilization continued. *C*, Patient does not return for follow-up despite several attempts. Patient finally returns for follow-up radiographs at 6 weeks, revealing a fracture of the proximal scaphoid.

Illustration continued on opposite page

the intrascaphoid angle or indirectly by the rotation of the lunate. The proximal pole rotates with the lunate into dorsiflexion and the distal pole falls into palmar flexion with a scaphoid waist fracture with no scapholunate interosseous ligament disruption. The radiolunate angle will be greater then 15° and the scapholunate angle will measure greater than 60° in a displaced unstable fracture. A displaced scaphoid fracture indicates an unstable injury prone to nonunion and avascular necrosis with rates as high as 50%.[21, 29, 58]

Relative indications for internal fixation of scaphoid fractures are more controversial.[29, 48] They include delayed presentation, proximal third scaphoid fractures, unstable fracture configuration, and scaphoid malunion. It is well known that the initial radiographs of a nondisplaced

Figure 1 *(Continued). D,* Cannulated compression screw fixation performed through a volar approach and proceeded with uncomplicated healing. *E,* Lateral view of stabilized scaphoid fracture.

scaphoid fracture can be negative and the fracture can proceed undiagnosed. These fractures can present late and lack immobilization necessary for the early stages of healing. A delay in immobilization greater than 4 to 6 weeks increases the incidence of nonunion. An unstable fracture pattern is prone to displacement. A vertical oblique fracture of the scaphoid has an inherent tendency to displace. Early internal fixation prevents displacement and allows good bony apposition. Fractures of the proximal third or fourth of the scaphoid require prolonged immobilization and have an uncertain prognosis. Union can require 4 to 5 months of casting, which creates additional musculoskeletal conditions including muscle atrophy, contracture, and disuse atrophy, which leads to prolonged rehabilitation. Athletes poorly tolerate long immobilization and the lengthy rehabilitation following casting. For these troublesome fractures of the proximal scaphoid, some authors have recommended internal fixation to reduce the known complications of delayed union or nonunion with limited options for salvage. Primary surgery for undisplaced fractures of the scaphoid is a highly controversial topic. Nonetheless, early operative intervention in carefully selected patients can allow the athlete to return to activities with a lower risk of fracture displacement and rehabilitation time.

Fractures of the scaphoid can addressed by way of open or dorsal approaches, percutaneously, or more recently arthroscopically. The choice of surgical approach depends on the scaphoid fracture pattern, associated injuries, and previous surgery.[40] The palmar approach preserves the vital dorsal blood supply and provides easy access to fractures of the middle and distal third of the scaphoid. The palmar approach usually is favored to correct the humpback deformity (if present) in the foreshortened scaphoid. The dorsal approach provides easy access to proximal pole fractures, placement of internal fixation devices, and the potential for vascularized bone grafting.[53, 65]

The palmar approach between the flexor carpi radialis and radial artery provides excellent exposure for reduction and stabilization.[50] The incision starts from the radial border of the flexor carpi radialis and extends over the scaphoid tuberosity. Dissection is continued where the superficial palmar branch of the radial artery is identified and ligated. The volar capsule is opened in line with the incision. It is important to repair the capsule following internal fixation. The scaphotrapezial joint is opened, and the volar tubercle of the trapezium is excised to allow easier access of the compression screw into the scaphoid.[24] A guiding jig can be used, or more recently cannulated screws can be used with or without the jig. Kirschner wire joysticks can used to manipulate the fracture fragments. A provisional Kirschner wire is used for stabilization in addition to the cannulated guide pin because the fragments tends to rotate as the compression screw is inserted.[33] It is important not to make the starting point on the scaphoid to volar and to aim dorsal enough to capture good bone of the proximal pole of the scaphoid.[2] The volar aspect of the distal radius is an excellent source for cancellous bone, and it can be harvested by extending the incision proximally.

The dorsal approach is used primarily for fractures of the proximal pole. It is difficult to gain access to proximal pole fractures through a palmar approach. An incision over the wrist is made in line with the radial border of the long finger. The dorsal sensory branches of the radial nerve are identified and carefully protected. The interval between the third and fourth dorsal compartment is exposed and the dorsal capsule is incised. Care must be taken not to damage the articular cartilage or cut through the dorsal portion of the scapholunate interosseous ligament when the capsule is incised. The wrist is palmarflexed to expose the proximal portion of the scaphoid. Dissection is not continued radially so as not to damage the dorsal vascular supply to the scaphoid. A cannulated screw is inserted adjacent to the scapholunate interosseous ligament and aimed down the center of the scaphoid toward the thumbnail.

Recently, arthroscopically guided percutaneous fixation of acute scaphoid fractures has been introduced. This technique could be a viable option in the athlete with a nondisplaced or minimally displaced fracture of the scaphoid where early return to function is a priority. As discussed previously, however, operative management of nondisplaced scaphoid fractures is controversial and all options should be presented to the patient and family. Arthroscopic reduction of acute scaphoid fractures works best in nondisplaced or minimally displaced fractures. Fractures with severe displacement or comminution are managed best by open reduction.

The distal pole of the scaphoid is identified under fluoroscopy and marked with a needle. Alternatively, a small incision (10 to 15 mm) can be made over the volar tubercle of the trapezium just radial to the flexor carpi radialis. The volar tubercle of the trapezium is excised. The wrist then is suspended by 10 pounds of traction in a traction tower and the wrist is evaluated arthroscopically for any additional pathology. The scaphoid fracture is visualized best with the arthroscope in the radial midcarpal space (Fig. 2*A*). Inflow can be through the arthroscope cannula or preferably through the ulnar midcarpal space. Wrist extension and supination can correct a slight flexion angulation of the fracture if it is present. This should reverse the humpback deformity and close the fracture line. If the fracture line remains open, Kirschner wire joysticks can be percutaneously inserted into the proximal and distal poles of the scaphoid to manipulate the fragments (Fig. 2*A–B*).

The arthroscope then is transferred into the 4-5 working portal. Inflow is placed through the 6-U portal. The blade of the alignment guide is inserted through the 1-2 portal and the hook is swept ulnarly and dorsally to seat into the articular cartilage of the proximal pole of the scaphoid. Ideal placement of the hook is 1 to 2 mm radial to the scapholunate interosseous ligament and just dorsal to the most proximal point of the scaphoid as seen arthroscopically (Fig. 3). Hyperextend the thumb to move the trapezium dorsally so the barrel of the alignment guide sits on the distal pole of the scaphoid. The most dorsal tooth of the guide barrel must engage articular cartilage of the scaphoid, ideally approximately midwidth on the distal pole. Two guide wires are placed through the guide across the fracture site. The position of the wires is evaluated under fluoroscopy and at least 2 mm of bone on both sides of the wire should be seen. The bone then is drilled with the cannulated drill and the screw is placed (Fig. 4). As in open screw placement, the most common errors are the alignment guide is placed either to volar or medial on the distal pole of the scaphoid.

With minimal soft tissue dissection involved in arthroscopically guided fixation of acute scaphoid fractures, athletes can be returned to play as tolerated. A soft thumb spica cast is necessary to protect the wrist in certain sports.

HAMATE HOOK FRACTURES

The hook or the body of the hamate is involved in 2% to 4% of carpal bone fractures.[46] The hook of the hamate protrudes from the base of the hamate into the hypothenar eminence. The hook of the hamate is the site of origin for the flexor digiti minimi, opponens digiti minimi hypothenar muscles, pisohamate ligaments, and the distal attachment of the transverse carpal ligament.

Fractures of the hook of the hamate are rare in the general popula-

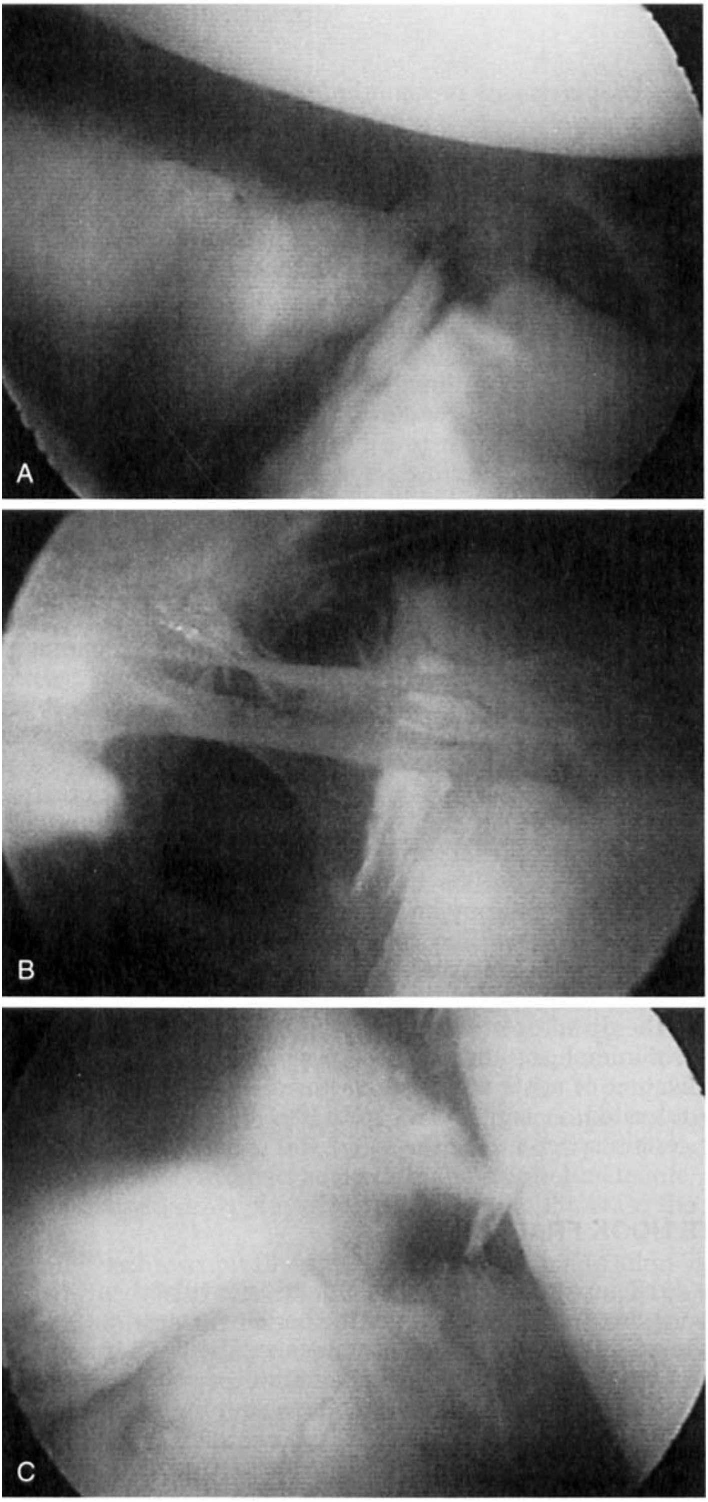

Figure 2. *See legend on opposite page*

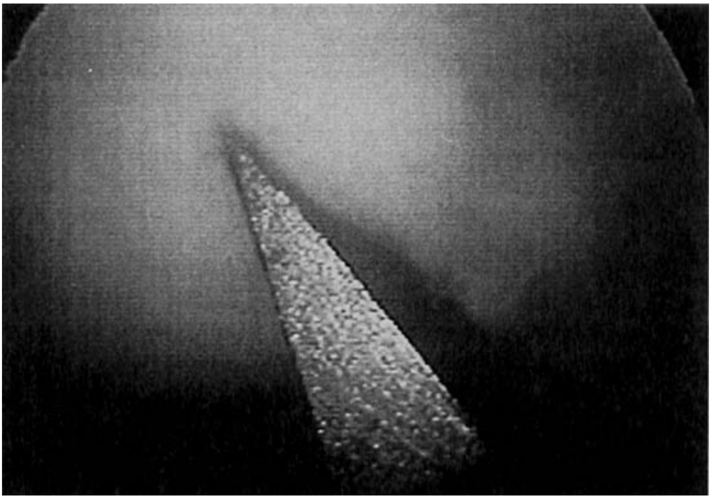

Figure 3. An alignment guide is inserted through the 1–2 portal. The tip of the alignment guide is placed 1 mm to 2 mm radial the scapholunate interosseous ligament and dorsal to the most proximal point of the scaphoid. The arthroscope is in the 4–5 portal.

tion but are more common in athletes who participate in racquet sports. The hook of the hamate is at risk for fracture in any athlete who actively swings a racquet, bat, or club. Direct compression of the handle of the club against the protruding hook is the primary cause of fracture. In addition, contraction of the attached hypothenar musculature and adjacent flexor tendons also can contribute to the fracture. The wrist nearest the handle is at risk for fracture. The nondominant hand usually is affected in baseball players and golfers, whereas the dominant hand is involved in tennis and racquetball players.

Fractures of the hook of the hamate occur frequently, but usually present late as chronic pain at the base of the hypothenar eminence, ulnar nerve paresthesias into the ring and small fingers, and weakness in grip strength.[16] Patients are tender to palpation over the hamate hook, located approximately 2 cm distal and radial to the pisiform. Fractures of the hamate hook are difficult to visualize on standard AP and lateral radiographs, which often delays the diagnosis.[41] Clues to a fracture of a hamate hook on the posteroanterior view include absence of the hook or cortical ring sign, and sclerosis in the region of the hook.[42] The hamate hook can be visualized with a radiograph taken with the wrist in

Figure 2. *A*, Arthroscopic view of a displaced scaphoid fracture as seen from the radial midcarpal space. *B*, Kirschner (K)-wire joysticks were placed to manipulate the fracture fragments. *C*, The fracture was reduced anatomically as seen from the midcarpal space and stabilized provisionally by K wires.

Figure 4. AP view of the reduced and stabilized scaphoid. Patient was in midseason and returned to competition in a thumb-spica playing casts 2 weeks postoperatively.

slight supination and full radial deviation, or by carpal tunnel views.[1] Alternatively, CT scans can be used to evaluate the hamate hook.

Management of hamate hook fractures is similar to management of fractures of the scaphoid. Healing of acute nondisplaced fractures of the hamate with immobilization is a viable treatment option.[63] The fracture must be nondisplaced, diagnosed early (usually within a week), and immobilized until union has been achieved, however. The healing process usually is prolonged and averages 8 to 12 weeks owing to the limited vascular supply. The wrist is casted in slight flexion and the metacarpophalangeal joints of the ring and small fingers are flexed to 90°. Because the hook of the hamate serves as the attachment for the pisohamate ligament and hypothenar musculature, displacement of the fracture is common and close radiographic follow-up is necessary.

Early surgical intervention is recommended if the fracture is displaced or the diagnosis is delayed to minimize morbidity and to facilitate early return to sporting activities.[26] While some authors have recommended open reduction and internal fixation, the prognosis is guarded owing to the small size of the fragments and limited blood supply.[22, 60] Most studies have shown no functional loss following excision, which allows earlier return to activities.[11, 26] Excision of the hamate hook is performed through a volar approach releasing Guyon's canal. Careful dissection and retraction of the ulnar nerve, particularly the motor branch, is necessary because it usually is in direct contact with the base of the hamate and can be injured easily. The base of the hamate is quite deep through a volar approach, and the dissection is tedious. The bone edges are smoothed off and the periosteum closed to prevent irritation to the ulnar nerve. Postoperatively, the patient is returned to sport as tolerated. Patients usually have symptoms of tenderness along the hypothenar eminence for several months and the use of well-padded gloves facilitates an earlier return to competition.

Fractures of the body of the hamate usually result from an axially directed force through the small metacarpal. Occasionally, hamate body fractures occur in association with "greater arc" perilunar fracture dislocations. The force travels through the scaphoid and capitate and into the proximal body of the hamate. The small finger–hamate carpometacarpal joint is important for function of the hand during grip and normally allows approximately 30° of motion. Displaced fractures of the hamate are managed by open reduction and compression screw fixation through a dorsal approach.[25] The stability of the carpometacarpal joint also should be assessed and temporarily stabilized by Kirschner wire fixation if unstable.

TRIQUETRAL FRACTURES

Fractures of the triquetrum are the second most common carpal bone fracture in sports. Triquetral fractures represent 3% to 4% of all carpal bone injuries.[6, 15] The mechanism most commonly resulting in a triquetral fracture is a fall on the wrist in dorsiflexion and ulnar deviation, as occurs in skating.[37] This causes impingement of the hamate or ulnar styloid on the dorsal margin of the triquetrum. Fractures of the triquetrum have been shown to be more common in patients with a long ulnar styloid, which impacts on the triquetrum.[35] The second mechanism of injury is a soft tissue ligamentous avulsion from the dorsal cortex of the triquetrum.[38] The strong dorsal radiotriquetral and scaphotriquetral ligaments insert on the dorsal cortex of the triquetrum. A palmar flexion injury case disrupt and avulse these important ligamentous attachments, resulting in a fracture. The triquetrum is visualized best radiographically with the wrist partially pronated. This projects the triquetrum away from the adjacent carpal bones.

Management of triquetral fractures is usually not complex. The wrist is immobilized for 4 to 6 weeks. A playing splint or cast can be used for contact athletes. The patient should expect to experience a mild discomfort over the dorsum of the wrist for several months. Hocker reviewed his results in these injuries and showed excellent return of motion and function of the wrist. In the rare case of symptomatic nonunion, excision of the painful dorsal fragment is recommended.

Fractures of the body of the triquetrum occur infrequently. These fractures usually are associated with severe trauma causing widespread bony and ligamentous injury to the wrist. The force in a perilunate fracture dislocation travels through the important volar wrist ligaments, resulting in their disruption, and into fracture of the radial aspect of the triquetrum.[34] Occasionally, the initial radiographs demonstrate a fracture of the body of the triquetrum only, and the associated ligamentous disruption is not apparent. A patient with an isolated triquetral body fracture, where the proximal row looks initially intact, should receive close follow-up with serial radiographs looking for instability, particularly of the scapholunate interval. Fractures of the body of the triquetrum associated with scapholunate instability are managed by early primary repair of the ligamentous disruption and fixation of the triquetral fracture with a compression screw.

PISIFORM FRACTURES

The pisiform is a sesamoid bone contained within the tendon of the flexor carpi radialis tendon. It articulates with the concave facet of the triquetrum. This articulation occasionally can be seen with the arthroscope in the 4-5 or 6-R portal and is a normal variant. Because of its superficial location at the base of the hypothenar eminence, the pisiform is vulnerable to fracture from direct trauma.[32] Pisiform fractures can occur in sports secondary to a direct blow, such as being struck by a baseball or a fall on the outstretched hand. Occasionally, pisiform fractures are seen in marksmen from the force transmitted through the brunt of the handgun, similar to fractures of the hook of the hamate seen in racquet sport players.

The pisiform also serves as attachment for the origin of the pisohamate and pisotriquetral ligaments, transverse carpal ligament, and the abductor digiti minimi muscle. Because of these attachments, a fracture of the pisiform also can result from an avulsion mechanism. Fractures of the pisiform frequently are associated with additional carpal or ligamentous injuries. There is a 50% chance of an associated injury to the distal radius or carpus when a fracture of the pisiform is identified.[49] Just as in fractures involving the body of the triquetrum, a high index of suspicion for additional injuries and close follow-up is necessary when pisiform fractures are identified. Fractures of the pisiform account for 1% to 3% of all carpal bone injuries.

The pisiform is difficult to visualize on standard posteroanterior and lateral radiographs. The pisiform is visualized best on an oblique radiograph taken with the wrist supinated 45° form the lateral position and slight extension. Alternatively, the pisiform can be visualized on the clenched fist AP view with the wrist in ulnar deviation.

Acute nondisplaced pisiform fractures are managed by 3 to 6 weeks of immobilization in a short-arm cast or splint. Most heal by bony or fibrous healing. Comminuted fractures are managed optimally by early excision.[17] Incongruity at the pisotriquetral joint can cause persistent pain, particularly with grip and radioulnar motion. Athletes complain of continued pain while swinging a bat or golf club. The pisiform is approached through a volar Z-plasty approach. The transverse limb is centered over the distal palmar crease. The ulnar neurovascular bundle is identified and protected. The pisiform fracture fragments then are shelled out of the flexor carpi ulnaris tendon. The tendon fibers must be left intact to preserve the function of the flexor carpi ulnaris. Arnold noted little or no functional impairment with excision.[5] Athletes can return to early resumption of activities with padded gloves to alleviate residual wound tenderness.

TRAPEZIUM FRACTURES

The trapezium forms a saddle articulation with the base of the thumb metacarpal. Fractures of the trapezium constitute 1% to 5% of all carpal bone fractures. Fractures of the trapezium typically involve the body or the ridge. The longitudinal ridge of the trapezium projects in a palmar direction and serves as attachment for the transverse carpal ligament. The tendon of the flexor carpi radialis passes along a groove formed by the trapezial ridge. Fractures of the trapezial body are more common. These fractures generally occur from a fall on the outstretched thumb, resulting in the base of the thumb metacarpal being driven axially into the trapezium. This results in a vertical shear fracture of the radial aspect of the trapezium body. The body of the trapezium is split and displaced proximally with the attached metacarpal resulting in subluxation or dislocation of the joint. The ridge of the trapezium is superficial and can be palpated just distal to the scaphoid tubercle at the base of the thenar eminence. As the ridge is superficial, fractures of this structure generally are caused by a direct trauma, such as a fall on an outstretched hand or being struck by a pitched ball.

Fractures of the body of the trapezium can be seen on standard posteroanterior and lateral views. A pronated anteroposterior view further defines the articular surface and is helpful in detecting any displacement. Fractures of the trapezial ridge are not seen readily on standard posteroanterior and lateral radiographs. A fracture of the ridge of the trapezium is visualized best on a carpal tunnel view.

Displaced fractures of the body of the trapezium are managed best by open reduction and internal fixation.[19] Nondisplaced fractures are rare and require close follow-up, because these injuries are unstable and prone to displacement. Fractures of the trapezium are addressed through a volar approach. The thenar musculature is reflected, exposing the fracture site. The fracture is stabilized by compression screws, Kirschner wires, or a combination of both. Frequently, because these are compression injuries, bone graft is needed to support the articular surface. Cancellous bone graft can be obtained from the volar aspect of the distal radius or from the tip of the olecranon.

Fractures of the ridge of the trapezium are easily missed. Patients present with pain at the base of the thumb and pain with wrist flexion. Trapezial ridge fractures are divided into two types. Type I trapezial ridge fracture is located at the base fracture, and type II ridge fracture represents an avulsion of the tip.[14] Acute type I ridge nondisplaced fractures can be managed by cast immobilization. Similar to scaphoid fractures, however, minimal displacement precludes fracture healing and operative management is recommended. Cast immobilization of displaced ridge fractures usually leads to painful nonunion, delaying the athlete's rehabilitation and return to activities. Chronic injuries are associated with carpal tunnel syndrome and tendonitis or rupture of the flexor carpi radialis tendon. Immediate excision of the displaced fragment through a volar approach allows for an uncomplicated recovery and an early return to sports participation.[44] The fragment is removed through a volar approach and reflection of the thenar musculature. The flexor carpi radialis tendon must be identified and protected because it is easy to injure during excision of the fragment. Padded gloves are used to minimize impairment from wound tenderness, which can last for several months. Type II ridge fractures usually are treated by a trial of casting with the thumb in abduction. If symptoms persist, the avulsion fragment is excised.

TRAPEZOID FRACTURES

The trapezoid is positioned between the trapezium, scaphoid, capitate, and the index metacarpal. In this well-protected position, the trapezoid is the least commonly fractured carpal bone, involving fewer than 1% of all carpal fractures.[49] When the trapezoid is fractured, the mechanism of injury is usually a high-energy axially directed force driving the index metacarpal proximally.[64] This can result in a shear fracture or dorsal avulsion of the trapezoid and dorsal subluxation of the index metacarpal. Occasionally, the trapezoid is dislocated dorsally and the index metacarpal migrates proximally into the space previously occupied by the trapezoid.[55]

Fracture or fracture–dislocation of the trapezoid is usually evident on standard posteroanterior, lateral, and oblique radiographic views. A lateral view also can reveal a dorsal dislocation of the trapezoid.

Closed reduction and percutaneous pinning or cannulated compression screw fixation of fracture–dislocation of the trapezoid can be attempted. Open reduction and internal fixation is usually necessary, however, and provides optimal reduction of both the fracture and dislocation under direct visualization. The subluxed or dislocated index metacarpal is managed by Kirschner wire fixation for approximately 6 weeks. The pins are pulled in the office and the athlete is returned to activities in a playing splint.

CAPITATE FRACTURES

Similar to the trapezoid, the capitate is centered within the carpus and is well protected from injury. Fractures of the capitate account for 1% to 2% of all carpal fractures. The capitate articulates with the scaphoid and lunate proximally, and is well attached to the long metacarpal distally to form the central column of the hand and wrist. Fractures of the capitate can occur as an isolated injury, or as part of a scaphoid perilunar fracture dislocation.[51, 59] Isolated fractures of the capitate are being diagnosed with increasing frequency, probably caused by heightened awareness of these injuries. Isolated fractures usually occur through the neck or body of the capitate. In the scaphocapitate perilunar fracture dislocation, the mechanism of injury is a high-energy fall with the wrist hyperextended and radially deviated (Fig. 5). The force is transmitted through the scaphoid, which fractures at the waist, and into the capitate resulting in a fracture of the neck.[57] The proximal capitate fragment can continue to rotate up to 180° and assume a position of hyperextension in relation to the hand.[3]

The head of the capitate is covered almost completely with articular cartilage, similar to the proximal pole of the scaphoid. Like proximal pole scaphoid fractures, the head and neck of the capitate are subject to major vascular disruption and prolonged healing. Capitate fractures are associated with poor outcomes, because uncomplicated healing seldom occurs with only cast immobilization. These fractures are inherently unstable and delayed union, nonunion, and avascular necrosis are well known with these injuries.[46] These factors need to be considered if cast immobilization is recommended, because healing can take several months, delaying the athlete's rehabilitation and return to play.

The athlete presents with severe pain over the dorsum of the wrist after an hyperextension twisting injury, usually after a fall. Routine posteroanterior, lateral, and oblique radiographs are sufficient to make the diagnosis. Occasionally, initial radiographs of a nondisplaced capi-

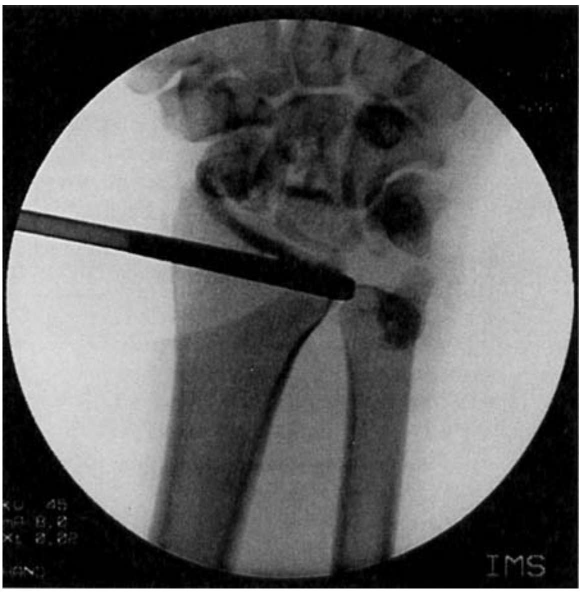

Figure 5. Anteroposterior fluoroscopic view of a scaphocapitate perilunate dislocation in a 17-year-old running back who fell on his outstretched hand.

tate fracture appear normal. Just as in scaphoid fractures, patients with continued wrist pain following trauma require serial radiographs and temporary immobilization until the pain resolves or a diagnosis is made. The fracture subsequently is recognized when resorption at the fracture site allows visualization.

Absolute nondisplaced acute fractures of the capitate can be treated by cast immobilization for 6 to 8 weeks. The athlete is not returned to activities until the fracture has healed, to avoid displacing the fracture during competition. Even 1 mm of displacement is evidence of instability and adversely affects the ability of the fracture to heal itself. This significantly delays the athlete's rehabilitation and return to sports.

Displaced fractures of the capitate, nondisplaced capitate fractures not detected for several weeks, and scaphocapitate perilunar fracture dislocations are best managed by open reduction and internal fixation. The capitate is addressed through a dorsal incision between the third and fourth dorsal compartments. The incision is in line with the radial border of the long finger. Palmar flexion of the wrist provides access to the head of the capitate, which may be rotated 180°. One or two headless cannulated compression screws can be placed from proximal to distal, providing good stability (Fig. 6). The scaphoid can be stabilized from the same dorsal approach or a separate volar approach if it is fractured. Frequently, however, the associated scaphoid fracture is unstable and it is difficult to obtain an anatomic reduction from the dorsum. If the scaphoid cannot be reduced from the dorsum without extensive soft tissue dissection and potential injury to the dorsal blood supply to the scaphoid, then a separate volar approach is made. Provisional Kirschner wire stabilization to hold the scaphoid anatomically reduced is necessary before insertion of a headless compression screw. Associated ligamentous injury of the scapholunate interosseous ligament is repaired dorsally, if present. Range of motion of an isolated displaced capitate fracture that was stabilized can be initiated in a few weeks, and the athlete returned to activities in a protective splint several weeks later. Open reduction of these injuries can decrease significantly the athlete's time to return to competition.

It is important to reestablish carpal height in the management of an established capitate nonunion. Corticocancellous interposition bone grafts are usually necessary to reestablish carpal height and prevent carpal collapse and instability.

LUNATE FRACTURES

The lunate is well enclosed within the large lunate fossa of the distal radius. Because of this, isolated fractures of the lunate body are rare. The distal portion of the lunate forms a concavity to articulate with the head of the capitate. Fractures of the body of the lunate usually occur from direct axial compression as the head of the capitate is driven proximally into the lunate. The dorsal lip of the lunate may be fractured

Figure 6. *A*, Capitate stabilized by 2 compression screws through a dorsal approach. Scaphoid is reduced and stabilized through the same dorsal incision. The patient has a complete disruption of the lunotriquetral interosseous ligament that is repaired primarily with a suture anchor. *B*, Lateral view of reconstruction. *C*, K wires are pulled 8 weeks postoperative. AP view of the healed scaphoid and capitate fractures. *D*, Lateral view. Patient resumed athletic activities 6 months.

as the head of the capitate impacts on it and the dorsal distal edge of the radius in a severe hyperextension injury. If the capitate appears volarly subluxed on a lateral radiograph, a fracture of the volar lip of the lunate is suspected.

Patients present with pain over the dorsum of the wrist and generalized swelling. Fractures of the lunate are difficult to visualize on standard radiographs because of overlapping of the adjacent carpals. CT is extremely helpful to visualize the fracture fragments and particularly to evaluate for any displacement.

Fractures of the lunate must be diagnosed and managed promptly. The concern is the possible association of a lunate fracture that fails to unite and the development of Kienbock's disease. Nondisplaced fractures of the lunate are treated by cast immobilization with close follow-up for any displacement. Incorporation of the flexed metacarpophalangeal joints partially relieves the compressive forces across the lunate and can reduce the risk of fragmentation and collapse.

Displaced fractures of the lunate require open reduction and internal fixation, particularly if the capitate is subluxed in a volar direction. Fixation of volar lip fractures can be difficult, because frequently the fragment is quite small. The fragment can be too small for screw fixation and Kirschner wires then are used to stabilize the fracture. Percutaneous transfixing wires from the scaphoid into the capitate are placed to hold the capitate reduced and to decrease compressive loads across the lunate if the fixation is tenuous.

A vascular necrosis, or Kienbock's disease, occurs primarily in young adults, and occasionally is seen in the athletic population. The exact etiology has yet to be determined. Numerous causes have been proposed, including a single traumatic event or repetitive microtrauma, particularly in susceptible individuals with vascular insufficiency and ulnar minus variance.[4, 8, 27] It is postulated that, in patients with an ulnar minus variant, the shortened ulna leads to increased shear forces across the lunate. Patients who sustain a fracture of the lunate require close observation for the development of signs of avascular necrosis. Protective splinting generally is recommended for athletes who return to competition.

Patients with Kienbock's disease present with dorsal wrist pain and swelling. Most patients have a loss of motion, particularly in extension. The diagnosis is a made by plain radiographs, or MR imaging if plain radiographs are normal and the diagnosis of Kienbock's is suspected.

Kienbock's disease is divided into four stages depending on the radiographic appearance. Stage I is defined as positive wrist pain with normal radiographs. The diagnosis is confirmed by MR imaging or a positive bone scan. Stage II is defined as wrist pain with radiographic evidence of lunate sclerosis and cystic changes. Stage III Kienbock's disease is divided into two types. Type A shows lunate sclerosis with collapse of the lunate without proximal migration of the capitate. Type B reveals collapse of the lunate and proximal migration of the capitate.

Stage IV Kienbock's disease is defined as lunate collapse and secondary arthritis.

Management of Kienbock's disease involves unloading the lunate.[39] Initially, cast immobilization was suggested for stage I disease. Most authors now recommend either ulnar lengthening or radial shortening for patients with ulnar minus variance in stages I, II, and III. Radial shortening is technically easier to perform and avoids the necessity of taking iliac crest bone graft.[62] The shortening osteotomy of the radius is performed through a volar approach. An osteotomy can be performed either at the metaphyseal–diaphyseal junction and a T-plate used to stabilize the bone, or at the level of the diaphysis and a compression plate for bone stabilization. Theoretically, the metaphyseal–diaphyseal junction is more vascular, which decreases the risk of a nonunion. Fixation with a T-plate, however, is not as strong and an osteotomy at the level of the diaphysis and stabilization with a compression plate is preferred. Stage IV Kienbock's disease is treated by either limited or total arthrodesis, depending on the quality of the remaining articular cartilage.[61]

In the athlete, the goal is to maintain as much painless range of motion as possible to limit impairment of function. All treatment options limit wrist range of motion. Some athletes are not able to return to sport if it demands a full range of motion. Wrist-leveling procedures, however, affect range of motion less than do salvage intracarpal fusions. It is important to diagnose Kienbock's disease in its early stages so the patient can be a candidate for a wrist-leveling procedure, which provides the athlete with the best opportunity to return to competition. For this reason, patients who sustained a previous fracture of the lunate require periodic observation for signs of avascular necrosis, so it can be caught in its early stages.

SUMMARY

A review of the literature shows that 3% to 9% of all athletic injuries occur to the hand or wrist. Also, hand and wrist injuries are more common in pubescent and adolescent athletes than adults. Although knee and shoulder injuries are more common athletic injuries, an injury to the hand or wrist significantly can impair the athlete's ability to throw or catch a ball, or swing a bat or racquet. A college football player trains year round for just 11 or 12 hours of playing time. An athletic injury that occurs during the season can have profound consequences for the athlete's career and emotions. When defining a management plan for a particular wrist athletic injury, the time to heal the injury and the time to rehabilitate fully must be considered. The athlete must be informed fully of the length of recovery.

The continued advancement of fixation methods and techniques are diminishing fracture morbidity considerably. Small-cannulated compression screws that provide rigid fixation can be inserted with decreased surgical dissection, thus preserving critical vascular supply and promoting accelerated healing and earlier rehabilitation. The arthroscope as a valuable adjunct in the management of wrist fractures was virtually unheard of years ago, but is now common. The ability to arthroscopically guide a cannulated compression screw to stabilize a scaphoid fracture without a formal open volar approach can reduce surgical morbidity significantly and allow the athlete to return to competition more quickly.

Mechanisms of injury that cause osseous fractures of the wrist are fairly high energy. A high index of suspicion for associated soft tissue injuries should be kept in mind when fractures of the wrist are identified. The wrist is composed of eight carpal bones tightly interwoven with each other by intrinsic and extrinsic wrist ligaments. The management of carpal fractures depends on prompt diagnosis, stable and anatomic alignment of the involved carpal bone, protective immobilization of the injury, and thorough rehabilitation. Displaced fractures of the hook of the hamate, trapezial ridge fractures, and comminuted pisiform fractures are managed best by early excision to promote uncomplicated recovery and early return to sport. For most athletes, return to competition can be expedited safely with the use of padded gloves and custom playing splints or casts.[7, 10] The sports medicine physician always must put the athlete's safety first when deciding the appropriate time for return to competition.

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