Management of Carpal Instability in Athletes

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Hand and wrist injuries are common in most athletic events and sports. The estimated incidence of hand and wrist injuries in athletics constitutes 3% to 9% of all athletic injuries. In particular, wrist injuries in athletes can lead to loss of playing time, inability to perform at preinjury levels, and possible termination of a prospective career. Collision sports such as football have up to 15% of injuries involving the wrist (Fig. 1). However, noncontact sports, such as gymnastics, can also have a high incidence of wrist injuries, ranging from 46% to 87% of participants. A recent review of 870 prospective professional football offensive linemen evaluated at the National Football League combine found 18 players had a history of carpal fractures with a range of severity and treatment modalities. Carpal fractures, ligament injury, and resulting carpal instability represent a spectrum of injuries to the wrist in the athletic patient, both in the acute traumatic setting and in the more chronic overuse syndromes.

ANATOMY

The carpus is a complex set of eight bones and connecting ligaments that link the forearm to the hand. The distal row consists of the trapezium, trapezoid, capitate and hamate from radial to ulnar. The proximal row consists of the scaphoid, lunate and triquetrum. The pisiform is a sesamoid bone within the flexor carpi ulnaris tendon at the level of the triquetrum. The pisiform is a sesamoid bone within the flexor carpi ulnaris tendon at the level of the triquetrum. The scaphoid represents the link between the proximal and distal rows. Extrinsic ligaments are extracapsular and link the distal metacarpals and proximal forearm bones to the carpus. The intrinsic ligaments are intracapsular and link adjacent carpal bones. The lunate is connected to the triquetrum and scaphoid by strong interosseous ligaments. Disruption of these ligaments can lead to dissociative carpal instability. Non-dissociative carpal instability refers to disruption of the extrinsic ligaments and results in instability between the carpal rows or between the radiocarpal joint.

With the scaphoid being a key link between the proximal and distal rows, it is important to consider its specific anatomy. Approximately 80% of the scaphoid is covered by cartilage which limits ligament fixation and vascular channels. Injection studies have confirmed the limited blood supply of the scaphoid with retrograde supply from the radial artery branches through the distal pole. The dorsal radial artery branch enters the scaphoid through the dorsal ridge and provides 70% to 80% of the intraosseous blood supply with the volar branch supply limited to the distal scaphoid tuberosity. Ninety-three percent of dorsal radial artery branches perforate distal to the waist of the scaphoid. Hence, fractures proximal to the waist of the scaphoid can disrupt endosteal blood supply to the proximal pole.

BIOMECHANICS

The biomechanics of the carpus is complex because of the multitude of bones linked to provide a wide range of motion for positioning of the hand while providing a stable connection between forearm and hand for weight bearing.
This is particularly important in the athlete whose events will put additional stress and strain across the wrist and will often require the upper extremity to become a weight-bearing limb as in gymnastics. The distal row of the carpus has minimal interosseous motion and works as a unit with the second and third metacarpal bones. The proximal row has no direct tendon attachments and has more significant interosseous motion. The scaphoid tends to flex especially with radial deviation to accommodate the trapezium and capitate of the distal row. In contrast, the triquetrum tends to extend because of its helicoid articulation with the hamate. The lunate is balanced in between these two carpal bones by the scapholunate interosseous ligament (SLIL) and lunotriquetral interosseous ligament (LTIL). Disruption of the SLIL will allow the lunate to extend through the pull of triquetrum and the LTIL with the resulting dorsal intercalated segment instability (DISI) pattern. Fracture of the scaphoid can also disrupt this linkage and allow for the extension of the lunate and resultant DISI deformity. Likewise, disruption of the LTIL will allow the lunate to flex with the scaphoid with the resulting volar intercalated segment instability pattern.

In one theory of carpal biomechanics, the scaphoid is believed to be the cross-link or tie-rod linking the proximal and distal rows. In general, approximately 80% of axial joint compressive force is transmitted across radioscapoid and radiolunate articulations whereas 20% is transmitted by the ulnocarpal joint. Across the radiocarpal joint, 60% of the axial force is believed to be transmitted through the scaphoid fossa and 40% through the lunate fossa. The mechanisms of injury to the scaphoid and the carpus in general have been studied in detail in several cadaveric studies. The primary requirement appears to be a hyperextension injury past 95°. A fracture of the scaphoid usually begins at the volar waist with a tensile failure then forces propagate to the dorsal surface with compression loading until failure. In another cadaveric study in which the wrists were loaded in extension, ulnar deviation and carpal supination, the scaphoid fractured through the waist as it impinged on the dorsal rim of the radius. Mayfield and colleagues also found that this same mechanism of extension, ulnar deviation and carpal supination produced a progressive perilunar instability pattern. Stage I is characterized by scapholunate diastasis or scaphoid fracture. Increased loading produces stage II with dorsal dislocation of the capitate. Stage III is characterized by lunotriquetral diastasis. Finally, stage IV has complete dislocation of the lunate. Although these studies confirm the usual patterns of injury to the scaphoid and carpal ligaments, flexion injuries to the wrist can also produce scaphoid fractures and should be considered when evaluating the injured athlete’s wrist.

The high rate of nonunion that is seen with displaced scaphoid fractures relates to its poor blood supply and the forces acting on the fracture fragments. In addition to the flexion deformity, the distal pole of the scaphoid is subject to a pronation moment resulting in a three-dimensional deformity. Scaphoid fractures heal by primary bone healing or intramembranous ossification without the benefit of fracture callous to provide initial stability. Stability of the fracture fragments

Fig. 1. Collision sports such as football have a significant number of injuries involving the wrist. Injuries can occur from a fall on an outstretched wrist or from direct collision. Carpal fractures or ligament injuries are common in youth because the radius has a high density and resists fractures. (Courtesy of Steven Conn, BA and Sam Rubin, BA, New Haven, CT; with permission from Yale Athletics.)
determines the amount of strain at the fracture site. The amount of strain determines the type of healing. Strain less than 2% results in primary bone healing. Strain between 2% and 10% results in secondary bone healing. Finally, with strain more than 10% bone cannot heal and fibrous or granulation tissue is formed. The additional demands put on the athlete's wrist can result in a wide range of traumatic lesions in the carpus.

**DIAGNOSIS AND WORKUP**

**History**

The athlete with an injured wrist should have a thorough history and physical examination. In particular, suspicion of a carpal injury should accompany a mechanism consistent with a fall with forced hyperextension or palmar-flexion, such as a collision or a direct blow to the wrist from a ball, a stick, or another player (Fig. 2). Rettig has previously stated that any athlete with radial wrist pain should carry the diagnosis of scaphoid fracture until proven otherwise. Although injuries are more common during competition, many injuries often occur during practice or unsupervised settings and may go unnoticed. Some patients will present with a less acute history of trauma with chronic wrist discomfort, lack of range of motion, inability to perform push-ups, or difficulty with gripping a club or racket.

**Physical Examination**

A thorough physical examination of the wrist should always be done in the workup of wrist pain and injury in the athlete. The degree and location of swelling and passive and active range of motion should be noted. Tenderness with palpation in the anatomic snuffbox or pain with axial loading applied by the thumb is often found with scaphoid fractures. There are also specific examination tests for carpal instability. Watson's test for scapholunate instability involves the examiner placing volar pressure over the athlete's scaphoid tubercle as the wrist is brought from ulnar to radial deviation. Partial tears will illicit pain over the scapholunate articulation whereas complete tears will produce an audible clunk as the scaphoid is dorsally subluxed and then reduced into the radial fossa as the volar pressure is released. In the evaluation for lunotriquetral instability, Kleinman has described the "shear" test in which the examiner stabilizes the radiolunate articulation with the forearm in neutral rotation and with the contralateral hand loads the triquetrum in the anteroposterior plane, creating shear across the lunotriquetral joint that can produce a spectrum of symptoms from pain to an audible clunk. A full neurovascular examination is also important because the more severe forms of carpal instability and perilunate dislocations can be associated with acute median neuropathy.

Fig. 2. Hockey, a stick sport, also involves high-energy collisions. Hand and wrist injuries can result from a direct blow from a stick, a collision with another player, or a fall on the ice. Although hyperextension injuries are more prone to produce carpal fractures or ligament injuries, stick sports such as baseball or golf or tennis can result in hook of the hamate fracture. (Courtesy of Steven Conn, BA and Sam Rubin, BA, New Haven, CT; with permission from Yale Athletics.)
Diagnostic Imaging

At the authors’ institution, plain radiographs of the athlete’s wrist include posteroanterior (PA), lateral, oblique, clenched fist, and PA with ulnar deviation views along with contralateral films to detect subtle fractures or widening indicative of ligamentous injury. MRI is more sensitive for the evaluation of both ligamentous injury and occult scaphoid fractures as compared to plain radiographs and bone scintigraphy.\(^{24,25}\) CT scan may be useful in evaluating carpal fractures particularly with sagittal images parallel to the long axis of the scaphoid to help define collapse or “humpback” deformity.\(^{26}\)

FRACTURES OF THE CARPUS

Scaphoid

The scaphoid is the most common carpal bone to sustain a fracture and represents 60% to 70% of all carpal fractures.\(^{27}\) In athletes, scaphoid fractures have been most commonly associated with contact sports such as football, and in sports with potentially high-impact falls such as basketball, in-line skating, snowboarding, and rodeo-riding. A 1-year survey of hand injuries at the Methodist Sports Medicine Center in Indianapolis found that scaphoid fractures accounted for 19% of all fractures with the highest occurrences in basketball and football players.\(^{28}\) Reister estimated the incidence of scaphoid fractures in college level American football at 1% of players per year.\(^{29}\) Others have found relatively high rates of scaphoid fracture in snowboarders, in-line skating, and rodeo-riders.\(^{30-32}\)

The management of acute scaphoid fractures in athletes remains a challenge. Traditional treatment of the acute scaphoid fracture involves 8 to 12 weeks or more of immobilization in long- and short-arm thumb spica casts.\(^{33}\) However, even with extended periods of immobilization, the incidence of nonunion in nondisplaced scaphoid fractures has been reported to be as high as 15%, and with any fracture displacement can increase the incidence of nonunion to 50%.\(^{34-36}\) Prolonged immobilization in the athletic population can result in stiffness and muscle atrophy that can lengthen the period of therapy in order to return to play. For the athlete, decreasing the risk for developing a nonunion, decreasing the time to union, and decreasing the length of immobilization can all be important issues to consider in terms of decreasing the time to return to play. In-season injury versus off-season injury can also affect the athlete’s decision-making in terms of operative versus nonoperative treatment and also timing of the surgery. Therefore, options for treatment can include nonoperative treatment as definitive management, nonoperative treatment until surgery in the off-season, acute operative treatment. Nonoperative treatment with immobilization until later surgery has several factors to consider in terms of return to sport. First, immobilization of nondisplaced or minimally displaced fractures carries the risk for further displacement and possible carpal instability. Also, return to play with immobilization is sport-specific. The National Football League, the National Collegiate Athletic Association, and the National Federation of State High School Associations allow football players to compete while wearing splints made of rigid materials if the splint is covered by a half inch of cell foam.\(^{37}\) Other sports have state-specific rules, and local authorities should be contacted for further details before making recommendations to patients and their families. Return-to-play guidelines are summarized in Table 1.

Operative treatment of acute scaphoid fractures has also evolved. Rettig and Kollias\(^{38}\) showed that open reduction and internal fixation through a volar Russe approach with the Herbert technique of acute scaphoid fractures in athletes allowed them to return to sport at an average of 5.8 weeks.\(^{33,35}\) Early range of motion can help to decrease adhesions and reduce stiffness. Open volar approaches are associated with disruption of the extrinsic palmar ligaments and instability has been reported after open repair.\(^{39}\) One of the authors (JFS) has shown excellent rates of union with an arthroscopic reduction and percutaneous dorsal fixation.\(^{40}\) This technique is described later in the article and potentially allows for less soft tissue dissection and early return to sport for athletes.

Triquetrum

The triquetrum is the second most common carpal bone to be fractured. Two main fracture patterns are dorsal rim chip fractures and body fractures. The dorsal rim chip fractures can be a result of an avulsion of the dorsal radiotriquetral ligament, compression against the ulnar styloid, or the dorsal proximal edge of the hamate striking the triquetrum in ulnar-deviation.\(^{41}\) Body fractures have been divided into six different patterns.\(^{42}\) Medial tuberosity fractures are associated with direct blows to the ulnar border of the wrist. Sagittal fractures are associated with axial dislocation. Proximal pole fractures can be associated with greater arc and perilunate injuries. Transverse body fractures are associated with scaphoid fractures. The athlete with a triquetral fracture may
show tenderness to palpation just distal to the ulnar styloid with the hand in radial deviation. Treatment generally consists of cast immobilization for 4 to 6 weeks. Body fractures with associated carpal instability or other carpal fractures may be treated with open reduction and internal fixation. Painful nonunion fragments can be excised if necessary.

**Hamate**

Hamate fractures are divided into two patterns: hook of the hamate and body fractures. Hook of the hamate fractures are more common in athletes. They are classically described as resulting from direct impact from a golf club handle, hockey stick, or repetitive trauma from a tennis racquet or shearing applied by the ring and small finger flexor tendons. Ulnar nerve symptoms may occur with these injuries and should heighten suspicion of these often missed injuries. Athletes with these injuries may have weakened grasp and hypothenar pain. Resisted little finger flexion and axial loading of the fourth or fifth metacarpal should be tested. These fractures are often missed on conventional radiographic views. A carpal tunnel or supinated oblique view should be done with CT scan providing the most definitive radiographic evidence. Athletes with hook of the hamate fractures can be treated with cast immobilization, closed reduction and pinning, open reduction and internal fixation (ORIF), and late excision of symptomatic nonunions. Hirano and Inoue found in their series that associated neurovascular and musculotendinous injuries were most predictive of less favorable functional results. Many authors recommend excision with return to sport in 7 to 10 weeks. Excision or ORIF may be complicated by decreased grip strength secondary to the removal of the attachment for

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### Table 1

**Guidelines for return to play after treatment of scaphoid waist fractures with a headless compression screw**

<table>
<thead>
<tr>
<th>Sport and Position</th>
<th>Timing of Return to Play After Treatment with a Headless Compression Screw for Scaphoid Waist Fractures</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>2 weeks</td>
<td>Playing cast</td>
</tr>
<tr>
<td>Line</td>
<td>2–4 weeks&lt;sup&gt;a&lt;/sup&gt;</td>
<td>No cast (brace—2 weeks)</td>
</tr>
<tr>
<td>Skilled basketball</td>
<td>2 weeks</td>
<td>No cast</td>
</tr>
<tr>
<td>Basketball</td>
<td>2–4 weeks</td>
<td>No cast</td>
</tr>
<tr>
<td>Baseball</td>
<td>2–4 weeks</td>
<td>No cast</td>
</tr>
<tr>
<td>Soccer</td>
<td>2 weeks</td>
<td>Playing cast</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>2–4 weeks</td>
<td>Possible playing cast</td>
</tr>
<tr>
<td>Hockey</td>
<td>2–4 weeks</td>
<td>Possible playing cast</td>
</tr>
<tr>
<td>Snowboarding</td>
<td>4 weeks</td>
<td>Playing cast, Wrist guard</td>
</tr>
<tr>
<td>Skiing</td>
<td>2–4 weeks</td>
<td>Playing cast</td>
</tr>
<tr>
<td>In-line skating</td>
<td>2–4 weeks</td>
<td>Playing cast, Wrist guard</td>
</tr>
<tr>
<td>Weight lifting</td>
<td>8–12 weeks; CT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>No cast</td>
</tr>
<tr>
<td>Wrestling</td>
<td>8–12 weeks; CT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>No cast</td>
</tr>
<tr>
<td>Field hockey</td>
<td>2–4 weeks</td>
<td>Possible cast, Wrist guard</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>8–12 weeks; CT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>No cast</td>
</tr>
<tr>
<td>Rodeo</td>
<td>4–8 weeks; CT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Playing cast, Wrist guard</td>
</tr>
<tr>
<td>Boxing</td>
<td>6–12 weeks; CT&lt;sup&gt;a&lt;/sup&gt;</td>
<td>No cast</td>
</tr>
</tbody>
</table>

<sup>a</sup> CT scan—identify 50% bridging bone.

<sup>b</sup> For scaphoid proximal pole fractures, add 4 weeks to timing of return to play. CT scans must be done to confirm healing prior to return to play.

the transverse carpal ligament, pisohamate ligament, and flexor and opponens digit minimi muscles.

**Lunate**

Isolated fracture of the lunate in athletes is rare. Repetitive or previous trauma may put athletes at risk for avascular necrosis of the lunate or Kienböck disease. Some authors feel that athletes requiring extreme weight bearing with the wrist in extension, as with gymnastics and weight lifting, are at increased risk for this disease. Athletes with tenderness at their lunate should be fully evaluated for possible carpal instability or perilunate dislocation. Radiographs may be negative in patients with early Kienböck disease. MRI is needed for definitive diagnosis. The treatment of avascular necrosis of the lunate depends on the stage and varies from carpal or radial shortening procedures in early stages without significant degenerative changes to salvage procedures for pain control without significant promise of return to previous level of range of motion, strength, or return to sporting level.1,47

**Capitate**

Capitate fractures in isolation are also rare and usually occur in association with perilunate dislocations and carpal instability. One unique pattern is the scaphocapitate syndrome which involves a trans-capitate, trans-capitate, perilunate fracture dislocation pattern often with the proximal fragment of the transverse capitate fracture rotated 180 degrees.48 These result from a fall on an extended and radially deviated wrist. The capitate fracture may need open reduction and internal fixation or percutaneous fixation in association with surgical treatment of the associated perilunate dislocation and scaphoid fracture.

**Pisiform**

The pisiform is a sesamoid in the flexor carpi ulnaris tendon that when fractured can disrupt this tendon. Transverse fractures can result from direct trauma or by extreme flexor carpi ulnaris contraction. These injuries are associated with racquet sport athletes.49 Athletes may have ulnar-sided wrist pain, weak grip strength, or decreased range of motion. These fractures may be missed on conventional radiographs, so CT scan or MRI may be needed for diagnosis. Pisotriquetral chondromalacia, tendon subluxation, or osteoarthritis may develop if a malunion or nonunion develops. Acute injuries may be treated with immobilization for 4 to 6 weeks. Chronic symptomatic injuries can be treated with pisiform excision.50

**CARPAL LIGAMENT INJURY AND INSTABILITY**

**Scapholunate Ligament**

Scapholunate dissociation is the most common form of carpal instability in athletes and usually results from excessive wrist extension with the wrist in ulnar deviation.8,18,51 A spectrum of injury exists from sprain to partial tear to complete tear with or without other associated carpal ligament and instability patterns. Chronic and complete injuries will result in progressive flexion of the scaphoid, extension of the lunotriquetral complex, and dorsal intercalated segment instability.8 Athletes with these injuries may give a history with the fall mechanism as previously mentioned in the acute setting or past history. Physical examination findings may include pain dorsally over the scapholunate interval, decreased grip strength, or decreased range of motion. These injuries may be misdiagnosed as subacute wrist sprains by coaches, trainers, and physicians alike. The Watson shift test described previously may be positive for pain or audible clunk. Standard radiographs should be done in addition to a PA view with clenched fist to assess for static and dynamic scapholunate diastasis and should be compared to the contralateral side. MRI is more sensitive and specific to accurately distinguish these injuries from other carpal ligament and tendon injuries.

Arthroscopy is considered the gold standard to assess for dynamic instability (Fig. 3). Geissler and colleagues have defined an arthroscopic instability classification.52 Grade I is defined as attenuation or hemorrhage of the ligament visualized from the radiocarpal side. Grade II adds incongruency with a gap less than the width of a probe between the carpal bones. Grade III has incongruency seen from both the midcarpal and radiocarpal sides, and a probe can be passed through the intercarpal space (Fig. 4). Grade IV has gross instability with manipulation, and the arthroscope can be passed through the intercarpal space. Operative treatments can vary from dorsal capsulodesis, such as the Blatt or Mayo procedures, to tenodesis, such as the Brunelli procedure, where a strip of the flexor carpi radialis is brought volarly through a tunnel in the scaphoid and then dorsally to attach to the distal radius or the lunate to limit scaphoid flexion.53–55 Newer techniques involve reconstruction of the ligament with bone-retinaculum-bone autografts.56,57 Chronic scapholunate instability and resulting DISI deformity can lead to arthritic changes in which salvage procedures such as partial wrist arthrodesis or proximal row carpectomy may become the only option for pain control. The key
to treating the athlete with this injury is early diagnosis and treatment.

**Lunotriquetral Ligament**

Lunotriquetral instability is the second most common form of carpal instability but is approximately six times less common than scapholunate instability. The mechanism of injury is similar, with the athlete usually suffering a fall with wrist extension and radial deviation with intercarpal pronation instead of supination. Athletes will describe ulnar-sided wrist pain, grip weakness, and possible clicking. The Watson shift test and Kleinman shear test may help distinguish scapholunate from lunotriquetral injury. Radiographic examinations are notoriously unreliable to detect these injuries accurately, and even MRI may be unreliable. Luckily, lunotriquetral injuries are less likely to develop degenerative changes and immobilization can lead to acceptable outcomes in 80% of patients. Arthroscopic evaluation is an excellent modality for diagnosis, and debridement of partial tears has shown good results. Athletes can usually expect to return to sport approximately 6 to 8 weeks after arthroscopic debridement. Those who fail initial management with arthroscopic treatment may benefit from ulnar shortening osteotomy which reduces forces on the ulnar side of the carpus and increases stability by tensioning the ulnar sided ligaments. However, an athlete can expect a longer recovery time of 3 to 6 months for this treatment modality before returning to sport.

### Perilunate Dislocations

Perilunate dislocations represent the most severe of carpal ligament injuries (Fig. 5). Mayfield had originally described a reproducible pattern of injuries starting with scapholunate diastasis or scaphoid fracture, proceeding to capitale fracture or ligament injury, then lunotriquetral ligament failure or triquetrum fracture, and finally in the most severe injuries complete dislocation of the lunate into the carpal tunnel. Once again, the mechanism of injury is extreme wrist extension.

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Fig. 3. Arthroscopy is the gold standard to assess for carpal ligament injuries. Geissler and colleagues have defined an arthroscopic instability classification. *(From Geissler WB, Freeland AE, Savoie FH, et al. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am 1996;78:357–65.)*

Fig. 4. Arthroscopic examination from the radial midcarpal joint diagnosis, a grade III tear of the SLIO ligament.
in ulnar deviation with carpal supination. Athletes with these injuries usually describe a high force axial loading moment on their extended wrist. They will have significant swelling and discomfort and they must be evaluated for median and ulnar neuropathy, which may necessitate emergent decompression. All perilunate dislocations require immediate closed reduction as soon as possible with emergent open reduction for those whose closed reduction attempts are unsuccessful.

A 5-year retrospective review of National Football League team physicians found 10 of these injuries from 1986 to 1990. These were treated with a variety of closed and open operative reductions with K-wire pinning for fixation. Return to practice varied from 1.5 weeks to the next season for 4 patients, with one player retiring. Return to game play varied from 2 weeks to next season in two patients, again with one player retiring. Two patients had pin site problems, one had a superficial radial nerve neurapraxia, and one patient went on to median nerve sympathetic dystrophy.

Traditional treatment of these injuries has included closed reduction with percutaneous pinning to open reduction and internal fixation through a combination of dorsal and volar approaches with reconstruction or repair of ligamentous injuries. Arthroscopically aided closed reduction and percutaneous pinning or screw fixation with limited exposures for ligament repair have been described and offer the athlete newer treatment options that may aid in minimizing soft tissue dissection and adhesions and could offer a quicker return to sport (Fig. 6). Further studies will need to evaluate the long-term results of these treatment modalities before specific recommendations can be made for athletes in terms of return to play.

WRIST INJURY PREVENTION

With so much attention focused on diagnosis and treatment of wrist injuries, one must also examine potential preventive measures. There is controversy in the literature as to whether bracing or wrist guards are effective in preventing wrist injuries. One cadaveric model showed decreased carpal fractures, ligament injuries, and capsular tears with wrist bracing. However, others have not shown significant differences in preventing wrist fractures with in-line skating type wrist guards. Prospective and retrospective studies in European snowboarders have show that wrist guards significantly decrease the incidence of wrist fractures and injuries. There is some concern that wrist guards may just change the area of force transmission from a fall. They may produce a stress riser at their proximal edge, and one study reported open forearm fractures as a result of in-line skaters’ using wrist guards. New wrist guards may be tailored for an athlete’s specific demands and potential for injury in the hope that they can decrease carpal injuries but not diminish an athlete’s mobility and ability to perform.

DIAGNOSTIC WRIST ARTHROSCOPY AND PERCUTANEOUS REDUCTION AND FIXATION TECHNIQUES

Diagnostic wrist arthroscopy has become an important part of the surgical evaluation of carpal...
injuries and an adjuvant for the confirmation of fracture and ligamentous reductions (Fig. 7). Although open techniques have the advantage of direct visualization and the ability to address several related carpal injuries through one exposure, arthroscopically assisted percutaneous and minimally invasive techniques have the potential advantage of less soft-tissue dissection, which could lead to decreased postoperative immobilization and less resultant stiffness and atrophy. These potential advantages are intriguing for all patients but especially for the athlete. Prolonged immobilization, larger casts that interfere with return to sport, and lengthy rehabilitation protocols can all delay a return to preinjury performance. The authors present a set of techniques for

Fig. 6. Dorsal trans-scaphoid perilunate dislocation treated with arthroscopically aided closed reduction and percutaneous screw fixation with limited exposures for the LTIO ligament repair using Mitek anchors. The LTIO ligament repair is protected for 6 months with a headless screw, which will be removed later. This offers the athlete newer treatment options that may aid in minimizing soft tissue dissection and adhesions and could offer a quicker return to sport. (Left panel from Weil WM, Slade JF, Trumble TE. Open and arthroscopic treatment of perilunate injuries. Clin Orthop Relat Res 2006;445:120–32; right panel from Park MJ, Ahn JH. Arthroscopically assisted reduction and percutaneous fixation of dorsal perilunate dislocations and fracture-dislocations. Arthroscopy 2005;21(9):1153.)

Fig. 7. Small joint arthroscopy is used in conjunction with mini-fluoroscopy to surgically evaluate the wrist for carpal injuries. The positioning of the imaging unit perpendicular to the carpus provides for accurate evaluation of injuries and confirmation of reduction and implant placement.
arthroscopic evaluation of carpal injuries along with percutaneous reduction and fixation techniques for scaphoid fractures and associated carpal fractures and ligament tears.2

**Imaging**

Once the patient has been placed on the standard operative table, with a hand table extension on the operative side and with a tourniquet placed on the upper arm prior to prepping, then an examination under anesthesia is done to check for possible ligamentous instability as compared to the presumed normal contralateral wrist. The hand is then placed in the wrist traction tower if diagnostic arthroscopy is to be done first. A mini-fluoroscopy receiver is brought in a sterile cover and placed horizontally or parallel with the floor. A fluoroscopic survey of the carpus is then performed and correlated with findings from preoperative examinations, imaging, and examination under anesthesia.

Special attention is paid to fracture location and displacement especially with dynamic stress. Dynamic instability patterns can also be evaluated and defined at this time. If a scaphoid fracture is present, then the central axis of the scaphoid must be found as the next step. The wrist should be pronated and flexed until the reduced scaphoid appears as a “ring,” with the direction of fluoroscopy now representing both the central axis of the scaphoid and the proper direction for screw placement.

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**Dorsal Guidewire Placement for Scaphoid Fixation**

With the central axis now defined by the fluoroscopy, a 0.045” K-wire is placed from a dorsal position volarly and radially along the long axis of the scaphoid (Fig. 8). The wrist must be adequately held in a flexed position to avoid bending or breaking the guidewire. The guidewire is then advanced through the trapezium and the skin at the radial aspect near the carpometacarpal joint. The wire is advanced in the volar direction until the trailing end of the wire clears the radiocarpal joint and the wrist is permitted to return to full extension. Central alignment of the guide pin can now be confirmed in multiple fluoroscopic planes.

**Percutaneous Carpal Fracture Reduction**

If a displaced scaphoid is present, then the next necessary step should be a closed reduction using a percutaneous technique. The guidewire should be advanced volarly and radially into the distal segment of scaphoid fracture. Under fluoroscopic guidance, percutaneous dorsal 0.062” K-wires are placed in the scaphoid fragments as “joysticks” to allow for closed reduction. Often the distal segment needs to be extended and the proximal fragment flexed. The previously placed central guidewire is then advanced in the reverse direction dorsally to cross the now reduced scaphoid fracture. A second parallel guidewire is often needed to hold these unstable displaced fractures.

This technique can be repeated if other displaced fractures in the carpus are noted. Smaller

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Fig. 8. Guidewire placement for scaphoid fixation: The central axis is defined by fluoroscopy, a 0.045” K-wire is placed from a dorsal position volarly and radially along the long axis of the scaphoid. The wrist must be flexed to avoid bending or breaking the guidewire.
K-wires may be more appropriate for the lunate reduction maneuvers. The lead author (JFS) often uses small cannulated compression screws to hold the reduction of other carpal fractures and also for the reduction of ligament injuries such as lunotriquetral instability. Many other authors advocate the use of percutaneous K-wire fixation. In either technique, K-wires are placed initially with the screw fixation technique utilizing arthroscopically aided confirmation of reduction before final screw placement.

A limited dorsal incision can be made dorsally directly over the torn or unstable ligament after preliminary fixation to allow for direct repair with suture anchor fixation or augmentation with autograft or allograft.

**Arthroscopic Evaluation**

Arthroscopic evaluation can be done either initially, before any fracture reduction or fixation is attempted, or after provisional fixation of the scaphoid fracture. The midcarpal and radiocarpal portals are located under fluoroscopic guidance with 19-gauge needles. The small joint arthroscope is placed in the mid-carpal and radiocarpal portals to confirm fracture reduction. The integrity of the scapholunate and lunotriquetral interossei ligaments, along with the triangular fibrocartilage complex, and cartilaginous surfaces of intra-articular carpal bones, can be evaluated. A small snap forceps can be inserted through these portals to dynamically assess the integrity of the ligament complexes which can be confirmed fluoroscopically. The 3, 4 and 4, 5 and the 6R portals are also utilized to assess the radiocarpal joint. Once final reduction positions have been confirmed and all intra-articular pathology that can be addressed through the arthroscope has been achieved, attention is turned to final screw fixation.

**Screw Fixation**

Scaphoid or other carpal screw length can be measured by first ensuring that the guidewire is placed adjacent to the distal cortex. A second wire is placed parallel and up to the proximal pole of the scaphoid and the difference is measured. A screw should be selected that allows 2 mm of clearance both proximally and distally. Implantation of a screw that is too long is the most common complication of percutaneous screw fixation. A cannulated drill is then advanced by hand and is confirmed by fluoroscopic imaging (Fig. 9). The screw is then inserted either dorsally or volarly. Dorsal implantation is favored for proximal pole fractures and volar implantation for distal pole scaphoid fractures. Other carpal bone screw implantation will depend on carpal bone and

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**Fig. 9.** After placement of a central axis guidewire. Two wires, of equal length, are placed. The first leading edge stops at the distal scaphoid; the second leading edge is placed at the proximal pole. The difference between the two wires is the scaphoid length. A headless cannulated compression screw, 4 mm shorter, is selected for implantation. A small incision is made at the base of the central axis guidewire. Blunt dissection is made to the wrist capsule, ensuring no tendons have been impaled. If a tendon has been skewed, the wire is withdrawn and the tendon retracted. A reamer is used to breach the proximal pole, and a headless cannulated screw is implanted. One caveat to be considered when repairing the young is that young bone has higher density, which may result in “push-off” when implanting a screw. To prevent fracture separation, a 0.062” K-wire joystick is inserted into the distal fracture fragment to apply a counter-force as the screw is inserted. A standard size headless compression screw is used because it is stronger than a mini-screw and better resists micro-motion at the fracture site. The screw is implanted using imaging to ensure that the screw is not overdriven into the scaphotrapezial joint. Once the screw is implanted, its position is checked using imaging, with the guidewire advanced volarly so the wrist can be extended.
fracture configuration. Once all fractures have been addressed with screw fixation and reduction and hardware placement is satisfactorily assessed arthroscopically, the guidewires are removed.

POSTOPERATIVE CARE AND RETURN TO PLAY

The postoperative treatment after a carpal fracture, fractures, or ligament injury treated by arthroscopically assisted percutaneous reduction is dictated by the soft-tissue injury that is present. An isolated scaphoid waist fracture without ligament injury can be started on an immediate range of motion protocol with proximal pole fractures immobilized for 1 month postoperatively.² If there has been significant ligament injury, especially injury necessitating surgical reduction and fixation, the athlete needs to be immobilized for 6 weeks postoperatively followed by a protected motion program. A strengthening program is begun for scaphoid fracture to assist with axial loading to stimulate healing. However, contact sports and heavy lifting should be restricted until CT scans confirm healing by bridging callous. The lead author (JFS) has previously developed algorithms for return to sport for specific sports along with their specific restrictions on types of immobilization.² These are summarized in Table 1.

SUMMARY

Carpal fractures and ligamentous injuries are common in athletes and require physicians, trainers, and therapists who treat and diagnosis these injuries to have an understanding of the carpal bone anatomy and vascularity along with the potential for progression to instability. Scaphoid fractures are certainly the most common carpal bone to be fractured in athletes and may be the most challenging to treat in terms of potential for malunion, nonunion, and progression to arthritic collapse. However, attention must be paid to other potential carpal fractures and ligaments in the injured athlete’s wrist. An athlete’s immediate health and safety along with seasonal and career goals must be considered by the treating physician and surgeon in deciding on treatment options that can range from nonoperative immobilization with casting and bracing to operative treatment with classic open exposures and newer arthroscopically assisted techniques, which were described in detail. Research is still needed to further investigate the optimal treatments of all carpal injuries in athletes along with designing new means to prevent these injuries.

REFERENCES