EMERGENCY MEDICINE PRACTICE

AN EVIDENCE-BASED APPROACH TO EMERGENCY MEDICINE

Wrist Injuries: Emergency Imaging And Management

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March 15, 2000: A 20-year-old woman presents to the ED after falling while she was rollerblading. She has a swollen wrist, but no tenderness in the snuffbox. Her films are normal. She is discharged with instructions to return if she has any problems.

August 12, 2001: You receive an operative report from a local orthopedist. He has copied you on a procedure note regarding a 21-year-old woman with a condition you've never heard of—"Kienbock's disease." You wonder, "What does this have to do with me?"

WHILE wrist injuries are common, they can hardly be described as routine. True, most of us can identify a radius fracture when we see one, and we can usually recognize a carpal fracture. We also know that navicular tenderness suggests an occult fracture, which requires follow-up with an orthopedist.

However, wrist injuries are often quite complex. They comprise a continuum of bony, muscle, and ligamentous damage. Physical exam and radiographic findings are rarely conclusive. Moreover, both recognized and occult injuries can lead to significant long-term sequelae. Because patients rely on their hands for careers and day-to-day activities of all kinds, complete recoveries are usually a must. It is little wonder that wrist injuries (especially missed or delayed diagnoses as well as inadequate treatment) are common causes of malpractice suits against emergency physicians.[1]

The literature on wrist injuries can be confusing. The emergency literature is sparse, while studies in the orthopedic, hand, and radiologic journals focus on retrospective, operative, and often theoretic concerns. Short of splinting everything, the emergency physician is often left without a comprehensive guide for the evaluation and management of wrist injuries. This issue of *Emergency Medicine Practice* aims to fill this void by describing the state of the art ED management of wrist injuries.

State Of The Literature

Much of the management of wrist injuries is based on anecdote, tradition, and

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CME Objectives

Upon completing this article, you should be able to:

1. list both common and rare types of bone, muscle, and ligamentous wrist injuries;
2. explain the indications for radiography and other diagnostic studies in the scenario of wrist injury;
3. describe how mechanism of injury as well as patient age and occupation affect wrist injuries and their management; and
4. discuss appropriate emergency management of wrist injuries, including pain management as well as indications for splinting, referral, and follow-up.

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local practice. There are few prospective, randomized trials to support the different emergency treatment strategies. Moreover, given the nature of wrist injuries, this is unlikely to change. Imagine trying to convince the hospital's institutional review board to randomize ulnar dislocations to either next-day reduction or treatment in the ED. It would be no easier to persuade multiple centers to standardize treatments and enroll patients for once-a-year occurrences like perilunate dislocations. Therefore, we as emergency physicians are largely left with small retrospective series and "common sense." Common sense, however, does not lend itself to the rigorous methodology that is the foundation of evidence-based medicine. As one writer mused, "Common sense is part of the home-made ideology of those who have been deprived of fundamental learning, of those who have been kept ignorant."[2]

Epidemiology

Injuries to the wrist account for about 2.5% of orthopedic injuries seen in the average community ED.[3] In one study, the incidence of wrist injuries that prompted radiography was 26 per 10,000 per year.[4] In more practical terms, the average emergency physician sees wrist injuries at least several times each month, if not every day or week.

Most wrist injuries (90%) are the result of a fall on an outstretched hand. While the characteristics of wrist injuries vary with age, no age group is spared. Children fall at play; the elderly fall in their homes. A recent study also suggests that wrist fractures in the elderly may be strongly associated with falls due to vestibular dysfunction.[5]

While falls are the predominant cause of wrist injuries among patients of all ages, the type and outcomes of the injuries sustained do vary by age. Young children almost never have carpal fractures but may sustain distal radial fractures (especially torus [bulging of the cortex] and greenstick fractures). A fall on an outstretched hand in a toddler or young child may also result in a radial head or supercondylar humerus fracture. Adolescents and young adults are more likely to injure the carpal bones, especially the scaphoid. When they do sustain a distal radius fracture, it is often complex and associated with other injuries. With increasing patient age, scaphoid fractures become less common, while distal radius fractures become more so.

In addition, adults are more involved in the kinds of sports and recreation activities that put them at higher risk for wrist injuries. This accounts for a rise in high-velocity injuries associated with bicycling, skating, and other outdoor sports seen in suburban EDs. Physicians in urban areas may also see crush injuries due to industrial accidents.

Pathophysiology: Anatomy And Biomechanics

The wrist joint allows a range of motion from about 75˚ volar flexion to 70˚ dorsal extension, with about 45˚ of ulnar and radial deviation and 180˚ of rotation. This mobility, in combination with the extrinsic flexors and extensors, permits remarkable dexterity.

The wrist includes all of the bones and articulations from the distal radius and ulna to the carpometacarpal joint. This includes the bases of the five metacarpals, eight carpal bones arranged in two rows, and the distal 4-5 cm of the radius and ulna. As you read this section, palpate your own anatomy and identify the important landmarks.

Bones

The carpals are arranged in two semi-parallel arches. From radius to ulna the proximal arch includes the scaphoid, lunate, triquetrum, and pisiform. The distal row (radius to ulna) includes the trapezium, trapezoid, capitate, and hamate. The trapezium and trapezoid are also known as the greater and lesser multangulars. Because the distal carpals are intimately connected to the metacarpals, they are more stable and less frequently injured.

Articulations

The proximal row of carpals sits in the concavity formed by the triangular fibrocartilaginous complex (TFC) and the radial styloid. The articulation between the two rows of carpals is called the mid-carpal joint, and the scaphoid bridges and stabilizes the two rows.

The radius articulates with the lunate, scaphoid, and the ulna. The ulna has no direct connection with the carpals, but it is joined to the triquetrum by the TFC. Articulation between the radius and ulna is through the TFC and the sigmoid notch on the ulnar surface of the distal radius, which allows rotation of the forearm. Since the TFC forms the ulnar border of the wrist, it is important to the wrist's stability.

Muscles

Most of the muscles that move the wrist attach to the metacarpals, allowing the carpals to move passively. The flexor carpi ulnaris is the only muscle that connects to the carpal bones (the pisiform). About 60% of flexion and radioulnar deviation occurs at the midcarpal joint, 60% of extension occurs at the radiocarpal joint, and rotation occurs mostly at the radioulnar joint.[6]

Ligaments

While the bones are easily discernible on x-ray, it is the ligamentous elements that stabilize the wrist. They dictate much of the injury pattern and account for many missed wrist injuries. The ligamentous support of the wrist consists of the extrinsic ligaments (which bind carpal to forearm) and intrinsic (which bind carpal to carpal). There are many named ligaments making up these groupings, but to the non-operative physician, the overall function is best conceptualized in groups. The individual extrinsic ligaments essentially form a single dorsal and two volar arcades. The volar arcades approximate two "V"-shaped arches, starting at the radial styloid, reaching the carpals distally, and returning toward the ulnar styloid, attaching at the TFC. The proximal ligamentous arch reaches the lunate in the proximal row of carpals; the distal ligamentous arch reaches to the capitate. Between these two arches is an unreinforced area of the joint capsule called the *space of Poirier*, at the approximate level of the luno-capitate junction. With forceful extension, this space can widen and tear; failure of

ligamentous integrity can lead to instability or dislocation between the carpal rows.[7] Because the extrinsic ligaments attach at the styloids, their integrity is crucial to the stability of the wrist.

"Believe those who are seeking the truth. Doubt those who find it."—André Gide

ED Evaluation

Serious or life-threatening injuries take precedence during any patient encounter in the ED. With the exception of an uncontrolled arterial bleed, acute wrist injuries by themselves are never a life threat. However, don't be lulled by a primary complaint of wrist pain before evaluating the patient. That wrist complaint may simply be the most painful of the injuries caused by a high fall; likewise, it could be a marker of cardiac syncope in an elderly patient.

History

Important historical considerations include when and how the injury occurred. Remember that cuts and even superficial abrasions ("hesitation cuts") to the volar wrist may be evidence of a suicide attempt; at least 7% of suicidal adolescents present with wrist lacerations.[8]

Understanding how the various mechanisms influence wrist injury will help direct both the physical examination and evaluation of films. As mentioned, 90% of traumatic wrist injuries result from a fall on the outstretched hand, giving us the onomatopoeic acronym "FOOSH."[9] FOOSH injuries comprise the most frequent and well-recognized trauma to the wrist—fractures of the distal radius and scaphoid. This same mechanism can also break bones located on the palmar surface of the hand by direct impact (i.e., the hamate and pisiform) and can lead to significant ligamentous injuries. A fall on an outstretched hand may cause more proximal injury as well, often to the elbow or even shoulder.

Direct trauma to the wrist usually breaks the more exposed bones, such as the styloids and triquetrum or metacarpals. The carpals, especially the hamate, may be injured if someone wielding a stick (golf club, baseball bat, or nightstick) hits an unyielding object (ground, fastball, or skull). Extension or rotational injuries can lead to dislocations, such as ulnar dislocation. Injuries outside of the FOOSH mechanism typically don't cause scaphoid fracture or Colles'-type radius fractures.

Punctures, foreign bodies, amputations, punch injuries, and crush (roller) injuries probably cause more disabilities than fractures. If the injury is open, determine what contaminants are possible, such as water, soil, or foreign bodies. In such patients, tetanus status is an important concern.

In patients with acute injuries, pain in the wrist is the predominant symptom. When patients present days to weeks after injury, they may have other complaints. Patients with ligamentous injury may note a "clunk" or snapping sensation with movement of the wrist and frequently report loss of hand strength.

Ask about pre-existing medical conditions such as rheumatoid arthritis as well as previous injuries, because these may alter the baseline function and radiographic appearance of the wrist. If emergent surgery is anticipated, determine the time of the patient's last meal. Standard questions regarding allergies and current medications may be helpful if analgesics, antibiotics, or other medications are anticipated.

Physical Examination

Once the ABCs have been addressed, evaluation of any orthopedic injury starts with confirmation of neurovascular integrity. Both the ulna and radial arteries are readily available to exam. In addition to the usual volar location, the radial pulse can often be palpated in the snuffbox as well. In most people, patency of either one of these vessels is sufficient to perfuse the hand. Capillary refill at the fingertips will confirm the distal circulation.

The Allen test may be helpful in cases of suspected arterial injury.[10,11] To perform this test, the patient should be supine with his or her hand in the air. Then have the patient repeatedly pump his or her fist. Instruct the patient to clench his or her fist tightly for several minutes while you apply firm pressure to both the ulnar and radial arteries. Initially release the radial artery and determine how long it takes for the blanched hand to return to its normal color. Repeat this test, this time releasing the ulnar artery while maintaining pressure on the radial artery. Use the opposite hand as a control. A significant delay in refill time requires emergent consultation with a surgical specialist. Remember that victims with arterial injuries will likely have nerve damage as well due to the proximity of these structures.

Neurologic integrity of the hand is best confirmed with two-point discrimination. Most people can detect two points at 0.5 cm apart on the finger pads. Splitting a tongue blade with a twisting motion provides two sharp points that can be placed in the longitudinal axis of the fingertip border (so as not to cross between nerve fields). Motor testing becomes difficult with pain, but gross function should be confirmed. Test all three major nerves. To test ulnar nerve motor function, ask the patient to abduct his or her fingers (spread them apart against resistance). This will challenge the first dorsal interossei, which are supplied by the ulnar nerve. The sensory branch supplies the volar aspects of the fifth finger and the radial and the ulnar half of the fourth finger. To test the median nerve, have the patient lay his or her hand flat with the palm up, and then lift the thumb straight up from the palm. Press against the thumb to determine appropriate resistance (the median nerve innervates the abductor pollicis brevis). The sensory function of the median nerve is best tested at the distal pulp of the index finger. The radial nerve supplies the motor function to wrist and finger extension via the extensor muscles of the forearm but does *not* innervate the intrinsic muscles of the hand; therefore, a motor deficit of the radial nerve is unlikely in an isolated wrist injury. To test the motor branch of the radial nerve, have the patient extend the thumb or wrist against gravity. The sensory innervation of the radial nerve is best examined in the first dorsal web space (between the thumb and index finger).[12]

Suspicion of a particular injury should prompt targeted assessment of the jeopardized nerve. For instance, when a hamate injury is suspected (classic mechanism or tenderness over the base of the hypothenar eminence), closely examine the motor and sensory function of the ulnar nerve. This nerve passes close to the hook of the hamate and can be crushed during trauma to the hamate. When a Colles' fracture is likely, perform a detailed assessment of the median nerve. This nerve may be damaged by either direct injury from a fracture fragment or by stretching.

Look for any break in the skin in association with an orthopedic injury, as this may represent an open fracture. In addition, depending on the mechanism, a search for foreign bodies may be warranted.

In addition to examining for injury to the hand, manipulation of the fingers and metacarpals can provide clues to carpal injury. Look at the stance of the resting hand. Are all of the fingers in a normal cascade (index and thumb the least flexed position, progressing to greater flexion in the third, fourth, and fifth digits)? An extended finger usually signifies a flexor tendon injury, while abnormal flexion identifies an extensor tendon defect. Next, examine the range of motion of each finger and test the tendon strength against resistance. Test the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS) separately. Test the FDP by having the patient flex the distal interphalangeal joint of each finger. To test the FDS of an individual digit, hold all of the other fingers in full extension at the distal joint while asking the patient to flex the proximal interphalangial (PIP) joint of the finger in question. It is important to test *both* the FDP and the FDS, because patients with a complete laceration of the superficial tendon may still be able to flex the finger by using the FDP.[13]

In the patient with blunt wrist trauma, push each finger directly into the hand. By applying axial force on the fingers (and thus the associated metacarpals), the carpal bones are stressed. For example, axial loading of the third digit will elicit pain in capitate or lunate fractures. Pain increased by axial loading of fourth and fifth metacarpals is frequent with hamate injury. Flexion of these fingers will also cause pain in the hypothenar eminence in those with a fracture of the hook of the hamate.

A meticulous wrist exam is, of course, crucial. Occasionally, tenderness and swelling will limit the exam, but time devoted to careful examination is likely to be fruitful. Physical examination is the best guide to which (if any) films are necessary. Order additional films based on your exam to focus on the suspected injury. Snuffbox tenderness mandates different radiographic views than tenderness of the ulnar styloid or the hamate.

The skin and connective tissue around the wrist is generally mobile and devoid of fatty deposit. The bones of the wrist are small but close to the surface. Most of the carpal bones are palpable—try to feel each one to determine the point of maximal tenderness. Remember key aspects of the surface anatomy of the wrist. Important landmarks include the anatomical snuffbox on the radial border of the wrist, the scaphoid tubercle (palpable below the thenar eminence), the pisiform (felt below the ulnar border of the hypothenar eminence), and the radial and ulnar styloids.

The proximal extent of the wrist is marked by the radial and ulnar styloids. The *anatomic snuffbox* is defined proximally by the radial styloid, dorsally by the extensor pollicis longus tendon, and volarly by the extensor pollicis brevis and the abductor pollicis longus tendons (the ideal location for snorting snuff). The scaphoid (navicular in the older literature) is palpated in the floor of the snuffbox. *Lister's tubercle* is the prominence on the dorsal aspect of the distal edge of the radius, just radial to the middle of the wrist. Rolling distally, just over the tubercle, and slightly ulnar, with the wrist in neutral position, there is a small depression. This depression marks the space between the radius and the capitate and the scapholunate joint. As the wrist is flexed, the lunate is palpable as it rises out of this depression. This is one of the easiest places to palpate a wrist effusion, traumatic or otherwise. (This is also the best place to tap a wrist.) Moving toward the ulna just distal to the ulnar styloid is the TFC; distal to that is the triquetrum.

On the volar side of the wrist, the scaphoid tubercle is palpable just distal to the palmar margin of the radial styloid, at the base of the thenar eminence. Across the wrist crease, at the base of the hypothenar eminence, is the pisiform. Just distal and radial to this, the hook of the hamate is palpable in the meat of the hypothenar eminence. The volar wrist crease marks the base of the proximal row of carpals.

Because of its ubiquity and high complication rate when missed, a diligent search for signs of scaphoid injury is useful. Snuffbox tenderness is the most familiar sign, but tenderness of the scaphoid tubercle is also an important finding.[14] Supination of the forearm against resistance exerts shear forces across the scaphoid, and pain with this maneuver suggests fracture. To perform this test, ask the patient to "shake hands" with you and tell them not to let you twist their wrist. In the presence of a scaphoid injury, they will complain of pain in the snuffbox when you try to twist their rigid hand. An alternative test involves axial loading of the thumb. By pushing directly down the axis of an extended thumb, pressure is applied directly to the scaphoid.

Waeckerle examined these three signs in 85 patients (with 40 fractures identified acutely or on follow-up) and found snuffbox tenderness had a sensitivity of 100% and a specificity of 98% for ultimate detection of fracture (either on immediate radiography or at two-week follow-up). Supination against resistance had a sensitivity of 100% and a specificity of 98%. Longitudinal compression of the thumb had a sensitivity of 98% and a specificity of 98%.[15]

In a separate prospective study, other authors evaluated four clinical signs believed to be useful in the diagnosis of scaphoid fracture.[16] They examined 215 consecutive patients with suspected scaphoid fracture on two separate occasions for the following clinical variables: tenderness in the anatomical snuffbox; tenderness over the scaphoid tubercle; pain on longitudinal compression of the thumb; and the range of thumb movement. At the initial examination, tenderness in the snuffbox, tenderness over the scaphoid tubercle, and longitudinal compression of the thumb were all 100% sensitive for detecting scaphoid

fracture. However, their specificities were dramatically lower than those in Waeckerle's study, with specificities of only 9% for snuffbox tenderness, 30% for tubercle tenderness, and 48% for pain with axial compression of the thumb. Abnormalities in the range of thumb movement had 69% sensitivity and 66% specificity. However, the authors found that the *combination* of snuffbox and tubercle tenderness along with pain on compression of the thumb was 100% sensitive and 74% specific within the first 24 hours following injury. Unfortunately, this algorithm has never been revalidated. Note also that in this study, six of the 56 scaphoid fractures were reported as nontender in the snuffbox at the 24-hour follow-up.[16]

While most injuries occur on the radial side of the wrist, do not neglect the ulnar aspect during the examination. The ulna can displace dorsally or volarly. Pain and deformity in the area of the ulnar styloid are the hallmarks of a radial ulnar dislocation, but this finding is difficult to interpret when associated with other wrist injuries. With disruption of the radioulnar joint, rotation of the forearm will be exquisitely painful.

A final caveat: When examining the wrists, always take advantage of the fact that the wrist is a paired structure. To detect subtle findings, have the patient hold both arms out together and compare both sides.

"You can observe a lot by just watching."—Yogi Berra

Radiology

The Ottawa rules provide an excellent guide to determine when to order ankle films. However, the anatomy of the wrist is more complex, with a wider range of injuries, and radiographs harbor more subtle findings. There have been attempts to develop an algorithm that defines criteria for radiography in the injured wrist or extremity among children,[17-19] but none have been validated or are powerful enough to influence clinical practice. In fact, the authors of one orthopedic text summarize current practice by stating, "With rare exceptions…imaging is an absolute requirement in the diagnosis of injury or disease involving the wrist."[20]

Algorithms and recommendations for imaging in wrist trauma come from the orthopedic and hand literature, and many are impractical for the emergency physician. They start with x-rays, move to special views, and get progressively more expensive (MRI, bone scan, or CT) or invasive (arthrogram and arthroscopy).[21,22] Several studies in the emergency literature examine x-ray strategies for specific wrist injuries, but they are predicated on determining the specific wrist injury in question before obtaining the imaging studies. It should be stressed that the literature about missed injuries is far more abundant than guidelines attempting to curtail x-ray use.[23-28] In general, any victim of wrist trauma who has point tenderness of the wrist or a test suggesting a scaphoid injury should have an x-ray. Beyond this, the literature on who needs a film is silent.

Wrist films can be intimidating. The 14 bones have subtle relationships that change with wrist positioning. Therefore, it's essential to have a system or mental checklist to evaluate wrist films.[29] (See **Table 1**.) First, assess the adequacy of the film; then look at the alignment and angles of the bones; and, finally, note the bone shape.

Adequacy Of Films

The standard wrist series includes both a posterior-anterior (PA) and lateral view. Although controversial, some hospitals routinely include an oblique view. In one prospective study that examined the utility of oblique views in extremity trauma, the addition of the oblique view changed the interpretation in 70 (4.8%) of the 1461 examinations as well as increasing diagnostic confidence.[30] Films should include the carpometacarpal joint to the distal 5-6 cm of the radius. When taking the film, the patient's elbow should rest on the x-ray table in 90˚ flexion, with the shoulder in 90˚ abduction. The beam is centered on the carpals. *For this reason, hand films, although they include the carpals, are inadequate for wrist assessment.* Deviation or rotation of the hand will alter the appearance and alignment of the carpal bones and their relation to the ulna and radius. Therefore, the emergency physician should first assess the positioning of the hand on radiographs using the following guidelines.

Table 1. Systematic Assessment Of The Wrist Radiograph.

Adequacy:
- Carpal-metacarpal junction to distal 5 cm of radius is included.
- Hand is neutral in both the PA and lateral views. The axis of the middle metacarpal lines up with the middle of the radius.
- Rotation (PA view): There is a gap between the two bones at the radioulnar joint. The ulnar styloid projects laterally.
- Rotation (lateral view): The radius and ulna are superimposed or within 3 mm dorsally. The pisiform should overlie the head to the scaphoid.

Alignment and angles:
- The three smooth articulating cortical lines of the carpals are visible.
- There is no more than 2-3 mm between individual carpal bones.
- The radius articulates with at least half the lunate.
- Radial inclination is 16-28˚ on PA view.
- Radial volar (or palmar) tilt is 0-22˚ on lateral view.
- Scapholunate angle is < 65˚ on lateral view.
- The radial length is 11-12 mm.

Bony shape:
- The scaphoid shows a cortical ring when dislocated on the PA view.
- The lunate should be quadrangular on PA view; triangular shape implies rotation or displacement.
- The pisiform is the last carpal to ossify up to age 12 years.

Special views:
- Scaphoid: Views the long axis of the scaphoid.
- Carpal tunnel: Views the pisiform and hamate.
- Semi-pronated: Views the radial elements (trapezium and scaphoid tuberosity).
- Semi-supinated: Views the ulnar elements (pisiform and hamate).

Posterior-anterior View

The hand should be in neutral position with the axis of the middle metacarpal (MC) lining up with the axis of the radius. While the distal radius and ulna should not touch at the radioulnar joint, the gap should be less than 2 mm. The ulnar styloid should project laterally from the end of the ulna in a true PA. Superimposition of the styloid on the ulna suggests rotation or improper positioning.[31,32]

Lateral View

On the lateral view, the axis of the middle metacarpal should continue through the capitate, lunate, and radius. The dorsal surface of the ulna should be overlying, or less than 3 mm posterior to the dorsal surface of the radius. The four ulnar metacarpals should overlap one another (see **Figure 1** and **Figure 2**), and the pisiform should overlie the head of the scaphoid.

Alignment And Angles

On the PA view of a normal wrist, the radius and ulna are the same length at the radioulnar joint. The radial styloid projects 11-12 mm farther—a distance known as "radial length." There is a "radial inclination" (the slope of the radius from the styloid down to the radioulnar joint) of 16-28°.[33] The carpal bones line up as two arches, with up to 2 mm between the individual carpals and between the two rows. Three smooth radiographic arcs should be recognizable. (See **Figure 3** on page 7.) The first follows the proximal cortexes of the scaphoid, lunate, and triquetrum; the second outlines the distal surfaces of this proximal carpal row; and the third outlines the proximal surfaces of the capitate and hamate.[34]

On the lateral view of the normal wrist, the radius has a "volar tilt" of 9-13° and the scaphoid should be palmar flexed, with a normal scapholunate angle of 30-60° from the axis of the carpals.

Bony Shape

In addition to fracture lines and displacement, the shape of the carpal bones provides valuable clues to pathology. On the PA projection, the scaphoid length is seen, and it will gently cup the capitate. If it rotates, as in some dislocations, it will be foreshortened, and the cortex of the distal pole will superimpose over the body, projecting the illusion of a "signet ring." The properly aligned lunate will be generally trapezoidal on the PA view. As it rotates volarly, as in dislocations, it will look more like a triangle. (See **Figure 4** and **Figure 5** on page 7.)

Special Views

Special views are generally ordered when a specific injury is suspected. In the *pronated oblique view*, the radial palm is lifted 45°, leaving the ulnar palm on the cassette. This view offers a better view of the trapezium and scaphoid tuberosity as well as the bases of the first two metacarpals. The

Figure 1. PA view of the wrist. It should be obvious that the bones are all there; however, they're difficult to delineate individually, which is why a system of assessment is so necessary when looking at the wrist.



Reproduced with permission from: Harris JH, Harris WH, eds. *The Radiology of Emergency Medicine.* 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:377. Fig. 6.2B.

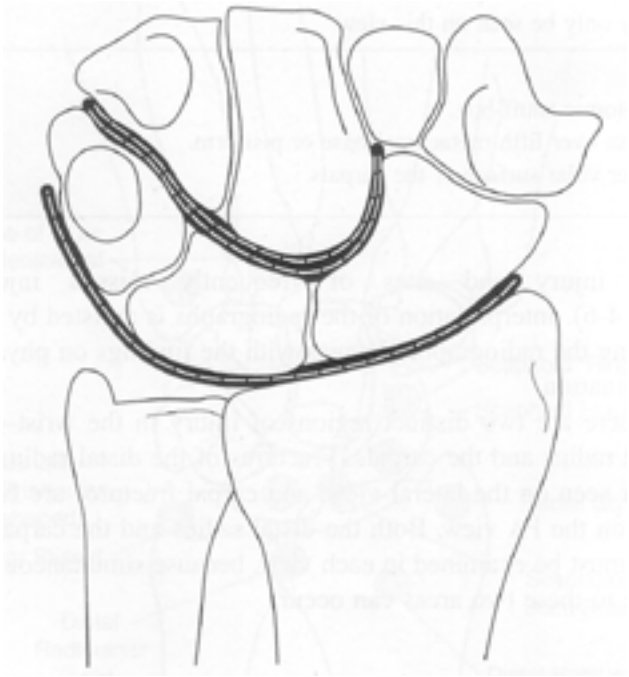
Figure 2. Lateral view of the wrist.



scaphoid view, or *ulnar deviated PA*, is shot with the palm flat and in ulnar deviation. It projects the length of the scaphoid better than the routine views. (See **Figure 6** on page 8.) The *supination oblique* view is an anterior-posterior (AP) rather than PA view. It is shot with the radial side lifted 45° and the ulnar side of the dorsum of the hand on the cassette. This gives better exposure to the pisiform and hamate. (See **Figure 7** and **Figure 8** on page 8.) The *carpal tunnel view* is shot through the carpal tunnel with the wrist maximally extended. It provides a look at the bones forming the tunnel, mainly the hamate and pisiform.[35]

The literature is rife with reports trumpeting the limitations of plain radiography in wrist injury. But do we have an imaging alternative? One interesting study compared plain films and MR imaging in 67 patients with acute wrist trauma. Three radiologists evaluated both the standard x-rays and MR images in a blinded fashion in all patients. One-third of the 37 fractures (n= 13) observed on MR images were missed on the radiographs. The authors recommended that MR imaging be considered in acute wrist trauma when: "1) There is a clear discrepancy between the clinical status and a negative radiography and when splint treatment would increase cost by causing occupational restrictions; and 2) Healing of trauma diagnosed as contusion or distension does not occur within the expected time."[36] However, the cost, implications, and utility of this recommendation have not been prospectively examined.

Figure 3. Diagram of the alignment and spacing of the carpal arches.



Reproduced with permission from: Schwartz DT, Reisdorff EJ, eds. *Emergency Radiology.* New York: McGraw-Hill Professional Publishing; 2000:56. Fig. 4-7.

Figure 4 and **Figure 5**. In the PA view (Figure 4; left), the lunate has taken on a more triangular shape, and the carpal arcs are completely disrupted. The lateral view (Figure 5; right) shows the capitate outside of the cup of the lunate, but the lunate is essentially in normal position.





Scaphoid Fractures

Scaphoid fractures comprise 60%-80% of all carpal fractures. Because the scaphoid forms a bridge between the carpal rows, it must withstand dramatic forces across its waist during forced extension of the wrist. Although common, scaphoid fractures can be difficult to visualize on film. In many series, 10%-20% of scaphoid fractures are not visible on the initial x-rays.[37,38] However, a significant percentage of these missed fractures may be obvious on films taken two weeks post injury.[39] (See **Figure 9** and **Figure 10** on page 9.)

Some studies suggest that multiple views may enhance radiographic visualization. In one study of 90 ED patients, 44 individuals had evidence of scaphoid fracture on a four-view series (PA, lateral, PA with ulnar and radial deviation).[37] When the authors added 25° supination and pronation views, they detected an additional 11 scaphoid fractures, making the six-view radiography series 100% sensitive for scaphoid fracture.[37] However, these results have not been reproduced by other researchers.

In addition to special views, inspection of the soft tissues may provide clues to scaphoid injury. The scaphoid fat stripe lies parallel and just radial to the scaphoid on the PA view. It should be slightly bowed inward toward the bone; obliteration or outward deviation of the stripe may suggest occult fracture. However, false-negative rates of

Figure 6. The scaphoid view allows a better view of the length of the scaphoid; compare with the PA or the oblique views.



Reproduced with permission from: Harris JH, Harris WH, eds. *The Radiology of Emergency Medicine.* 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:379. Fig. 6.4.

Figure 7 and **Figure 8**. The pronated view (Figure 7; top) presents an alternative view of the radial side bony elements, whereas as the supinated view (Figure 8; bottom) presents the ulnar elements.





Reproduced with permission from: Harris JH, Harris WH, eds. *The Radiology of Emergency Medicine.* 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:377. Fig. 6.2c and Fig 6.2d.

15%-30% and false-positive rates of 12%-32% limit the utility of this sign.[40-43]

Missed Scaphoid Fractures

A single artery that enters the distal end supplies the scaphoid bone; thus, a fracture can easily interrupt this tenuous blood supply. Inappropriate treatment due to a missed scaphoid fracture can result in an avascular necrosis of the proximal fragment. Unfortunately, even in recognized fractures that are treated appropriately, the chance of non-union or necrosis resulting in persistent pain and loss of mobility is 5%-12%.[109-111] The complication rate increases to 40%-88% when the fracture is not recognized and immobilized.[109-111] These grim odds have prompted some authors to suggest prolonged immobilization for all patients with scaphoid tenderness, regardless of radiographic findings.[73]

On the other hand, aggressive immobilization is not without consequences. Only 6%-20% of patients placed in plaster for a presumed occult scaphoid fracture actually prove to have a fracture at follow-up.[44] Furthermore, six weeks of immobilization can represent a significant inconvenience for the patient.

Imaging Strategies

Scaphoid fractures are often undetectable on initial radiographs. The incidence of occult scaphoid fracture at initial exam has been estimated to be 4%-26%.[16] Because of this, researchers formerly suggested immobilizing all patients with scaphoid tenderness and obtaining a repeat x-ray at two weeks post-injury.[44] Such recommendations were commonly made prior to the widespread availability of magnetic resonance imaging (MRI) or even bone scans. This begs the question, "Can early use of these technologies supplant prolonged immobilization?"

Bone Scans

Bone scanning became a popular tool soon after it was introduced. The timing of the scan in cases of potential scaphoid fracture is an important consideration. Scans obtained too soon (1-3 days) after injury yield false-positives due to periosteal reaction, edema, bone bruising, and other conditions. Scans obtained 14 days after injury are more sensitive than conventional radiography, but this mandates a two-week period of immobilization prior to the scan.[45,46] In one series of 100 patients, scans obtained on day 4 were 100% sensitive and 92% specific (and had a positive predictive value of 65%).[45] Despite the value of early bone scans in this study, many hand surgeons use nuclear studies at 2-4 weeks and limit them to cases in which the x-ray and clinical picture remain ambiguous.

Magnetic Resonance Imaging

MRI has become standard in the evaluation of suspected scaphoid fractures. It is nearly 100% sensitive, provides good anatomic detail, and is accurate in the acute setting.

Studies of MRI within seven days of injury have yielded sensitivity rates of 100% compared with six-week radiologic follow-up using plain films.[47,48] In one prospec-

Figure 9 and **Figure 10**. The PA view (Figure 9; left) appears normal. On the pronated view (Figure 10; right), the fracture line is clearly visible, though subtle. It is also visible on the scaphoid view (not shown).





tive, randomized study, the combination of repeated clinical examination and plain radiography was as sensitive as MRI in the detection of occult scaphoid fracture—only the injury was diagnosed by day 3 in the MRI group vs. day 38 in the group managed using clinical examination and plain film.[49] On the downside, MRI is expensive, and no one has analyzed the cost/benefit ratio of routine MRI in the setting of suspected scaphoid injury. However, some argue that early MRI will prevent unnecessary immobilization.[50,51]

Determining Which Study To Choose

One study compared MRI and bone scans performed an average of 19 days after suspected scaphoid fracture. Both were extremely accurate. The nuclear studies had one false-positive vs. none in the MRI group; on the other hand, two people were unable to complete the MRI due to claustrophobia.[52] Other studies also confirm that either bone scan or MRI delivers accurate information in the setting of suspected scaphoid fracture. While MRI seems to have the advantage of earlier reliability and better anatomic detail, bone scans are probably more widely available and less expensive.

One 1995 study (published in a nuclear medicine journal) examined the cost of various diagnostic strategies in suspected scaphoid fractures.[53] The authors suggest that the most efficient approach to the evaluation of patients with suspected scaphoid fractures consists of x-rays on day 1 followed by delayed bone scintigraphy in patients with initially negative scaphoid x-rays.

Treatment

What remains alarming about these studies is the number of scaphoid and other carpal fractures missed on plain film but identified using advanced imaging techniques—an incidence ranging from 20%-30% and even higher.[38,45,47,52-55] Moreover, all of these data are probably moot vis-à-vis emergency practice. When patients have clinical signs of scaphoid fracture (snuffbox tenderness, pain with axial compression of the thumb, pain on palpation of the tubercle, and so on), treat them as if they have a fracture—even in the presence of a negative x-ray. This means immobilization and orthopedic follow-up in 7-10 days. The consultant may then determine the appropriate study—whether it be MRI, bone scan, clinical examination, or simple radiography. Failure to immobilize these injuries in the emergency setting contributes to the already high incidence of malunion and avascular necrosis.

There is persistent controversy about the ideal immobilization for scaphoid fractures. Virtually all of the studies addressing this issue have significant weaknesses, the most common being failure to define inclusion criteria other than snuffbox tenderness. Most studies are small, so that one or two misreads considerably alter the statistical outcome.

The basis of the controversy is that rotation of the forearm applies shear to the scaphoid.[56] Long arm casts prevent rotation of the forearm, but they are significantly more limiting and uncomfortable than short arm casts. Clinical studies are scarce and contradictory. At least one clinical study (randomized, 100 nondisplaced scaphoid fractures, long vs. short casts) showed significantly shorter times to union when a long arm spica (which includes immobilization of the thumb) was used.[57] Another study showed no difference in outcome; however, this study included displaced fractures, which tend to do poorly anyway.[58] A review of the literature suggests using a long arm spica for displaced fractures (> 1 mm displacement) and a short arm spica for nondisplaced fractures.[59] A thumb spica splint as opposed to a cast is probably adequate in the acute setting.

"Orthodox medicine has not found an answer to your complaint. However, luckily for you, I happen to be a quack."
—Richter cartoon caption

Other Carpal Fractures

Triquetral Fractures

Triquetral fractures, the second most common type of carpal fracture, occur with both direct trauma and with FOOSH injuries. Dorsal chip fractures are due to hyperextension when the ulnar styloid is jammed into the dorsum of the triquetrum. This produces tenderness just distal to the ulnar styloid. These fractures require splinting and generally do well. Transverse fractures are less frequent and more ominous. Fracture through the body of the triquetrum is associated with perilunate, scaphoid, and ligamentous injury. Patients with triquetral fractures require a long arm splint and early referral.

Hamate Fractures

Hamate fractures, which account for 2%-4% of carpal fractures, are becoming more common due to the popularity of racket sports and golf.[60] The hook of the hamate projects from the body into the palm and defines the ulnar wall of the carpal tunnel as well as serving as a pulley for the extrinsic flexors of the ring and small fingers. The hook can break with direct impact, as in a fall on the palm or crush injury, or mechanisms where the extrinsic flexor tendons are forced through the hook, such as in racket, bat, or club sports. (The hamate is at particular risk when a golfer firmly strikes the sod in a futile attempt to gain an additional 30 yards.)

Hamate fractures can be difficult to visualize on standard views. If you suspect this injury, order a carpal tunnel view (although this is often difficult to perform in the painful acute setting) or a supinated oblique view.[24,60] One recent study of 16 patients with a fracture of the hook of the hamate examined the value of various radiographic views.[61] The routine PA view raised the suspicion of fracture in four of 13 patients (31%); the carpal tunnel view demonstrated the fractures in six of 14 patients (43%); but the supine oblique radiographic view was the most valuable of the plain films. It showed fractures in eight of 10 patients (80%). However, in this small series, computerized tomography proved to be the most accurate study of all.

Missed injuries may lead to non-union, stress or rupture of flexor tendons, and potential ulnar neuropathy. Immobilization and early referral are adequate treatment in the ED. While no one has compared the various splints and their effect on outcome, an ulnar gutter splint should reduce

pain if it immobilizes the wrist as well as the fourth and fifth fingers (whose tendons course beneath the hamate hook).

Lunate Fractures

Lunate fractures are uncommon. The mechanism is usually a fall, and patients may complain of diffuse or central wrist pain. Palpation of the bone distal to Lister's tubercle should elicit pain. Lunate fractures can be difficult to visualize on radiographs. As with the scaphoid, suspicion of lunate fracture mandates immobilization until it is ruled out at follow-up. Problems due to a tenuous blood supply threaten the lunate. Long-term complications include avascular necrosis (Kienbock's disease). This leads to long-term disability, collapse of the carpal space, migration of the capitate and scaphoid, and disruption of the normal wrist mechanics. Acutely, these fractures (or suspected fractures) need to be splinted and referred to an orthopedist.

Capitate Fractures

Capitate fractures are rare because of the bone's protected location in the center of the wrist. They occur in dorsiflexion injuries, especially when radial deviation forces the radius into the capitate, which can lead to fracture or dislocation. Displaced fractures need referral and reduction, while nondisplaced fractures require simple immobilization and referral.

Trapezium Fractures

Trapezium fractures are rare and occur most often through direct trauma. Movement of the thumb will be limited. A thumb spica splint is adequate until the orthopedic consultant sees the patient at follow-up.

Ligamentous Injuries

Ligamentous wrist injuries can lead to significant long-term sequelae; unfortunately, they are frequently overlooked. This may be due to lack of familiarity in how to detect these injuries on physical exam and because x-ray findings may be subtle. Disruption of these wrist stabilizers can lead to migration of the carpal bones, disruption of the normal mechanics, arthritis, and chronic pain. Once chronic sequelae develop, the outcome is usually poor despite surgical treatment.[23] Orthopedists often discuss ligamentous injuries in terms of the injury location—that is, dorsal intercalated segment instability (DISI) and volar intercalated segment instability (VISI).

The wrist has no inherent architectural stability; no ball and socket, mortise, or hinge is involved. Without the ligaments, the carpi are nothing more than a clattering bag of bones. In extension, the volar ligaments progressively tighten between the radius and the carpal rows. At maximal extension, the volar extrinsic ligaments are taut and the space of Poirier (located between the proximal and distal volar extrinsic ligaments) is open.[62] As the distal row slides dorsally over the proximal row, the scaphoid sustains greater stress. Ultimately, the dorsal rim of the radius crashes into the scaphoid waist. Forced extension beyond this breaking point will damage ligaments, bones, or both. The amount of radial or ulnar deviation, rotation, and the location of impact and duration of load will determine the nature of the structural failure.

While the most familiar manifestation of this sequence is the scaphoid fracture, a wide range of ligamentous injuries, dislocations, and fracture-dislocations can be overlooked. Delay in diagnosis may allow the ligaments to fibrose and will limit repair options. Physical examination is useful for diagnosing ligamentous wrist injuries (as described later in the text). Plain films may be inadequate, yet a number of other imaging techniques may fill this diagnostic void. These include computed and tri-spiral tomography, arthrography, video-fluoroscopy, and MRI.[63,64]

Scapholunate Injury

The mechanics of ligamentous wrist injury have been described and staged by several authors,[62,65-68] including Mayfield, who vividly describes the process: "In essence, the scaphoid and distal carpal row are progressively peeled away from the lunate."[65] The first ligamentous complex to rupture is the scapholunate, causing what is variably described as scapholunate instability, scapholunate dislocation, or rotary subluxation. These descriptive names invoke various degrees of damage to the scapholunate and radioscaphoid ligaments, but the principle is essentially the same.

The degree of instability will dictate the findings. Physical findings may include tenderness at the scapholunate joint, just ulnar to the snuffbox, or instability of the scaphoid elicited by the scaphoid shift or Watson's test. To perform this test, apply upward pressure to the scaphoid tubercle (push from palmar toward dorsal) while moving the hand from ulnar to radial deviation. With scapholunate instability, the scaphoid may sublux dorsally, reproducing pain and movement of the bone. However, there are several drawbacks to Watson's test. Not only is it painful in the acute setting, but it also seems to have low specificity. In one study, 36% of normal individuals had positive findings on the scaphoid shift test.[69]

Radiology

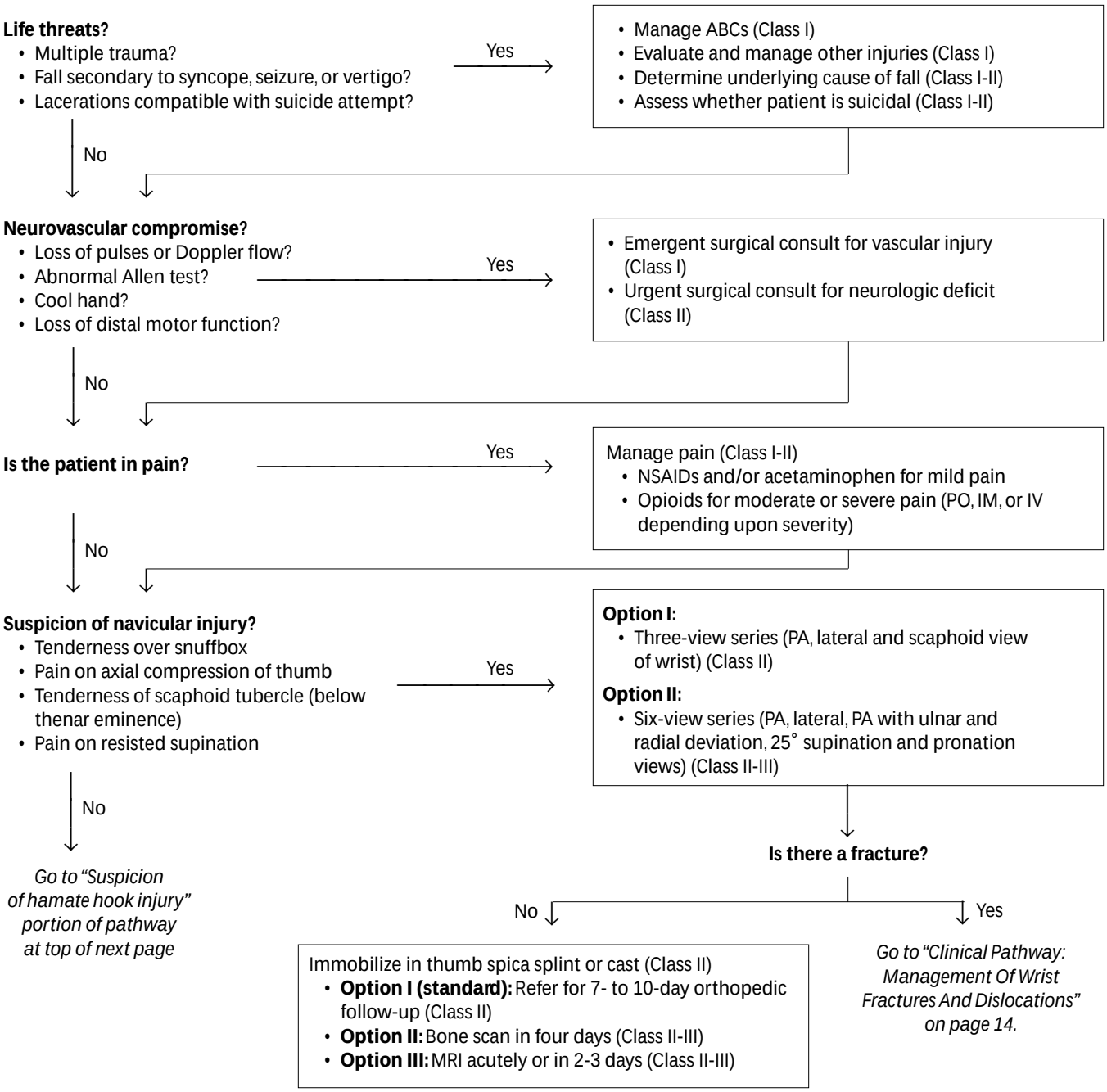
The expected radiographic findings of scapholunate injury on the PA view include a widened scapholunate gap, and a *cortical ring (*or *signet ring) sign* as the lunate foreshortens and the tubercle is viewed on end. (See **Figure 11** and **Figure 12** on page 16.) The lateral view may show an increase in the scapholunate angle. (See **Figure 13** on page 17.) Routine films may miss signs of this injury. A *clenched fist view* may show widening of the scapholunate space as the capitate is forced proximally between the scaphoid and lunate.[67,70]

Lunate And Perilunate Dislocations

If the scaphoid suffers fracture or ligament damage, it can no longer stabilize the wrist. At this point, further damage to the radiocapitate ligament, part of the volar extrinsic group, allows the capitate to slip out of its position in the lunate cup, leading to perilunate dislocation. Progressive

Continued on page 15

Clinical Pathway: Evaluation Of Wrist Injuries

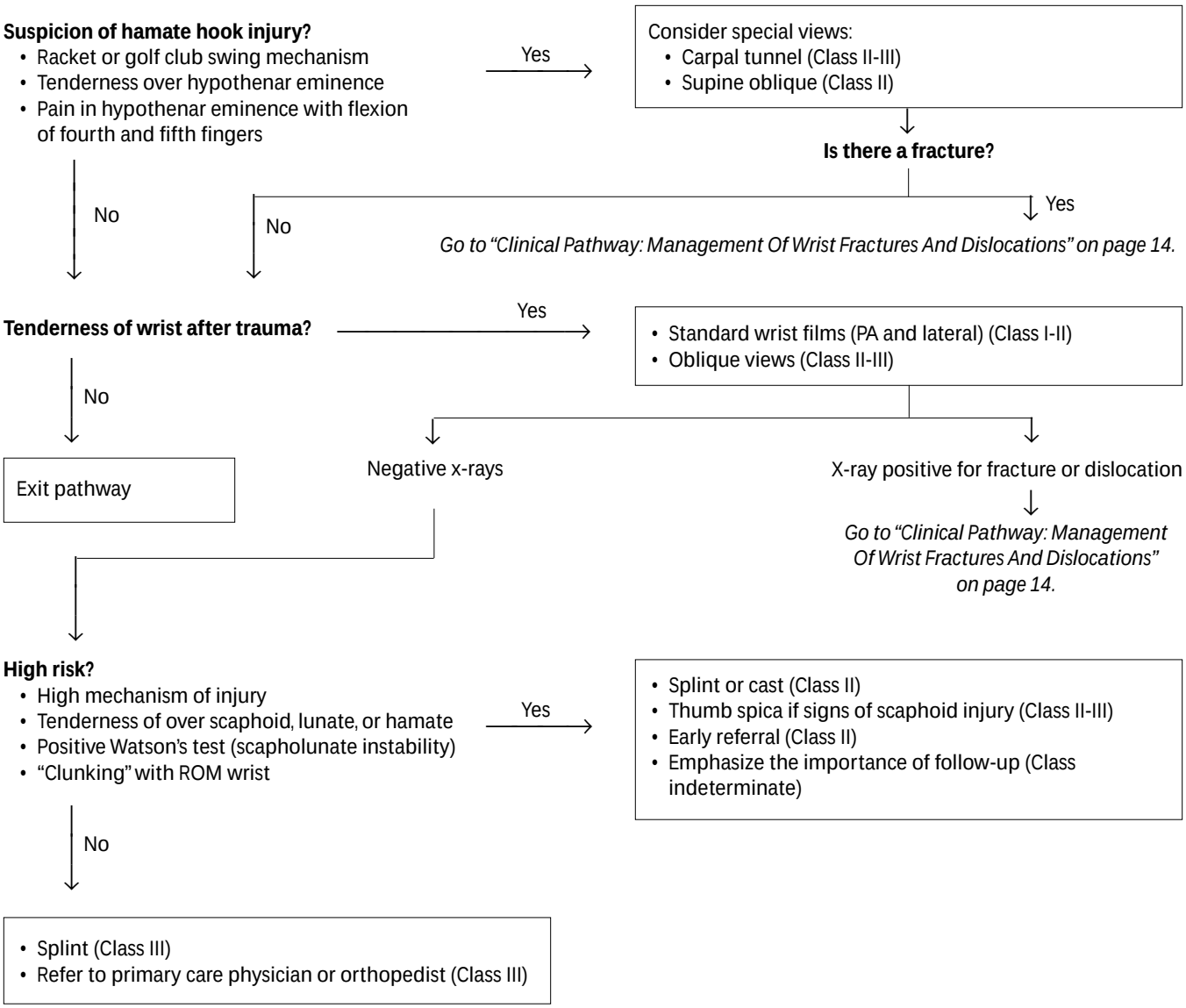


The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Clinical Pathway: Evaluation Of Wrist Injuries (continued)



The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

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Clinical Pathway: Management Of Wrist Fractures And Dislocations

Lunate or perilunate dislocation → Emergent/urgent surgical consult (Class II)

Radius fracture

High risk?
- Angulation of > 20˚
- Ulnar separation
- Dorsal comminution
- Shortening of the radius > 5-10 mm
- > 2 mm of articular step-off
- Median nerve dysfunction

High risk → Urgent surgical consultation (within hours) (Class II-III)

Not high risk → Splint and refer (Class II-III)

Scaphoid fracture →
- **Displaced fractures** (> 1 mm): Long arm spica splint or cast (Class II-III)
- **Non-displaced fractures**: Short-arm spica splint or cast (Class II-III)
- Refer all

Other carpal fractures →
- Immobilize:
  - Volar splint for most carpal fractures (Class indeterminate)
  - Ulnar gutter splint for hamate fractures (Class indeterminate)
- Early referral (Class II-III)

Carpal instability or **Scapholunate disruption** (widened scapholunate gap and cortical ring [or signet ring] sign on x-ray) →
- Immobilize:
  - Volar splint (Class indeterminate)
- Early referral (Class II-III)

The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Continued from page 11

shearing forces lead to rupture of the scapholunate, capitate-lunate, and lunate-triquetral connections. This destabilization may also encompass fracture of the involved bones, usually the scaphoid or triquetrum, leading to a fracture-dislocation.

In spite of the forces involved and seemingly obvious radiographic findings, perilunate and lunate dislocations are commonly missed.[25,26] In one series of 166 perilunate injuries, 25% were missed initially, including both dislocations and fracture-dislocations.[71] Outcomes were worse when diagnosis and treatment were delayed by more than seven days.

Perilunate Dislocations

Unless there has been spontaneous reduction, fracture-dislocations should be evident on film. On the lateral view, the capitate will no longer sit in the same line with the

Ten Excuses That Don't Work In Court

1. "The splint/cast was put on by the [*choose one: ortho resident, PA, nurse, med student].* The patient was discharged by the [*choose one: nurse, PA, resident].* I thought he told the patient about signs of vascular compromise."

That's right—he should have. But it was under your authority and supervision; therefore, you should check the final product. Make sure the patient understands the warning signs of vascular compromise (change of color, sensation, pain, significant swelling) and has access to medical care should it occur. Document these instructions, and make sure the patient has access to follow-up. Untreated or undertreated wrist injuries can lead to lifelong complications.

2. "It was just a nick in the skin. I didn't think it was an open fracture."

Not every open fracture needs to be washed out in the OR. But that's a decision best made by a surgeon. Osteomyelitis is low on everyone's wish list.

3. "At the most, the guy will have some chronic pain in his wrist. I didn't think to ask if he was a *[choose one: cabinetmaker, aspiring concert violinist, wicked left-handed pitcher being scouted by the Cubs, emergency physician].*"

Think about it. How much chronic pain would you be willing to tolerate in your job? You might have disability insurance, but that's no substitute for your job. Treat wrist injuries with respect—immobilize and refer.

4. "I didn't document two-point discrimination. She wasn't complaining of numbness."

The pain from the fracture was more significant to her than the numbness. Maybe her two-point was intact at presentation—maybe not. But you didn't check, and the neurovascular exam wasn't documented.

5. "There was a lot of swelling. How was I supposed to feel the pulse?"

This is not an uncommon problem. If swelling obscures the pulse at the wrist, sometimes you can feel it in the snuffbox. Consider using a Doppler to detect the pulse. If these are absent, you still have access to capillary refill or the Allen test.

6. "It was late. I didn't want to wake my hand guy up for a wrist sprain, because I couldn't be sure that the lunate was dislocated."

By the time the hand specialist found out about the injury, it was the next afternoon. Wrist dislocations do better if reduced early. Not every wrist injury needs to be seen emergently, but it is critical to recognize the ones that do.

7. "There was no snuffbox tenderness, and the x-ray was negative. I was confident it wasn't a scaphoid fracture."

You were right. It wasn't a scaphoid fracture—the lunate was broken! You failed to do a complete examination and take adequate precautions (immobilization and referral). The patient went home with a "wrist sprain," never had short-term follow-up, and developed permanent disability because of Kienbock's disease (osteonecrosis of the lunate).

Examine the entire wrist. FOOSH mechanisms can result in a variety of different injuries. Identify the likely injuries by history and physical examination, and order any special views that will help you make a diagnosis.

8. "It was a simple Colles' fracture in a guy who fell off his bike in a race. I've treated dozens of radius fractures in elderly people over the past year just by splinting and getting a two-week follow-up."

Elderly women fall down after tripping on the sidewalk—low impact, brittle bones. They don't generally hit the ground at 30 MPH, like this cyclist did. The distal radius fracture has a much worse prognosis in high-energy injuries. They may be associated with carpal injuries, dislocations, or neurovascular damage. Perform a scrupulous examination of the wrist and the x-rays to detect high-risk findings.

9. "I didn't x-ray his wrist because he said that he didn't feel any glass in the wound. Plus, when I explored the wound, there was too much blood for me to see anything."

A patient who is cut by shattered glass can harbor a foreign body. The patient's testimony as to whether or not there is a foreign body is notoriously inaccurate. If you're unable to visualize the base of a wound, use a tourniquet or get an x-ray if glass is involved.[100]

10. "He could make a fist. That means the tendons were intact."

Not really. Patients with complete transection of a flexor superficialis tendon can still clench their fist using the deep finger flexors. The wrist flexors can be cut and the patient can still flex their wrist using the finger flexors. When performing the physical examination, isolate the deep from superficial tendons in order to be sure of proper function. When exploring the wound, look for tendon injury even if the patient can move his or her fingers. A patient with a 90% tendon rupture may still have finger movement. ▲

lunate, midshaft radius, and metacarpals; it will be outside the cup of the lunate. On the PA view, look for a triangular (as opposed to quadrangular) lunate and a disruption of the arcs of the carpal bones. (See Figure 4 and Figure 5 on page 7.) Also look for associated carpal fractures.[71]

Lunate Dislocations

Further disruption of the ligamentous support leads to lunate dislocation, when the lunate is torn from its normal position on the radius. This is most notable on the lateral view, where the lunate is "spilling over" toward the palm, rather than cupping the capitate. (See **Figure 14** and **Figure 15** on page 17; also see **Figure 16** on page 18.)

Like any dislocation, lunate and perilunate dislocations need to be reduced sooner rather than later (that is, within hours).[72] Once reduced, the patient may still require surgery at a later time. Specialty consultation is mandatory.

Radius Fractures

Distal radius fractures are the most common upper-extremity fracture and represent a large portion of the overall fractures seen in the ED. The older literature depicted these as simple injuries that enjoyed good outcomes. This is true in the set of patients originally defined by Colles in 1814, which consisted of older people who had reduced functional expectation and whose reduced life expectancy gave them less time to develop long-term complications. It may also be a relatively minor injury in the pediatric age group. In both the young and the old, the carpal bones are spared as the osteopenic or immature radius gives way under impact.[74]

Since the radius in young adults is neither immature nor osteopenic, these are almost by definition high-energy injuries. It is probably inappropriate even to call distal radius fractures in young adults "Colles' fractures," because they differ in terms of associated damage, prognosis, and treatment.[75] Young adults are more likely to have greater soft-tissue injury, as well as a higher incidence of intra-articular and complex fracture patterns, than children or the elderly.[76] They also have a higher expectation of good functional outcome over a long remaining life span.[77-80]

Other wrist injuries are often seen in association with distal radius fractures. In one study, 68% of patients requiring operative repair of a radius fracture had injuries to the soft tissues, including the TFC, the scapholunate, or the lunate-triquetral ligaments.[78] Pay special attention to median nerve function in patients with Colles' fractures. In one study, acute median neuropathy was present in 13% of 536 fractures, and chronic median neuropathy developed in 23%.[81]

Over the past decade, surgery has become more frequent in the treatment of these fractures, in an attempt to attain full anatomic correction. Surgery is generally indicated in those with so-called "high-risk fractures." "High-risk" criteria include fractures with an angulation of more than 20˚, ulnar separation, dorsal comminution, shortening

Figure 11. In the PA view, scapholunate injury may be detected when the gap between the bones widens. The finding may be subtle.



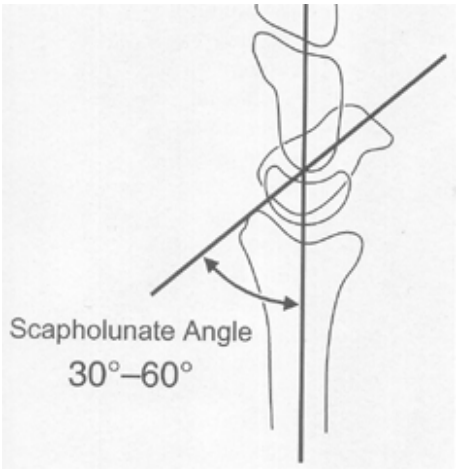
Figure 12. The only obvious abnormalities on this PA view is the projection of the scaphoid ring (or signet ring) and that the scaphoid is somewhat foreshortened, suggesting that it may be rotated out of its normal alignment.



of the radius more than 5-10 mm, and more than 2 mm of articular step-off.[20,79,80] There is significant controversy about how closely the anatomic configuration needs to be restored and whether this will prevent long-term complications[78,79] of carpal instability and hand weakness,[82] delayed rupture of finger flexors,[83] chronic pain,[84] neuropathy,[85] cosmetic deformity, or arthritis.[86]

Despite years of study, the best approach to distal radial fractures remains unclear. A Cochrane review examined randomized and quasi-randomized clinical trials in adults with fracture of the distal radius in order to determine the most appropriate conservative treatment. The authors included 31 trials totaling 3372 (mainly female and older) patients. The authors stated, "There remains insufficient evidence from randomized trials to determine which methods of conservative treatment are the most appropriate for the more common types of distal radial fractures in adults."[87]

Figure 13. The scapholunate angle. Acute injury to the ligaments that hold the scaphoid in relation to the other carpals may allow the scaphoid to rotate out of position.



Reproduced with permission from: Schwartz DT, Reisdorff EJ, eds. *Emergency Radiology.* New York: McGraw-Hill Professional Publishing; 2000:57. Fig. 4-8.

Other Fractures Of The Distal Radius

There are other named fractures of the distal radius, each associated with a specific mechanism. Rather than naming the fracture, it is more important to identify and describe the lesion in terms of location, displacement, angulation, and comminution, as these parameters determine treatment and prognosis.

Volar Angulation

The Smith's fracture (or reverse Colles' fracture) occurs with direct blow or fall on the dorsum of the wrist. It is often the result of a bicyclist or motorcyclist being thrown over the handlebars. By maintaining a fierce grip on the handlebars, the patient sustains a distal radius fracture with volar, rather than dorsal, angulation. Treatment criteria are similar to dorsally angulated fractures.

Radial Styloid Fracture

The chauffeur fracture (or Hutchinson fracture) is a break in the radial styloid. It is generally due to direct impact on the radial side of the wrist. (The archaic reference to the

Figure 14 and **Figure 15**. The lunate is now disoriented in relation to the radius on the lateral view (Figure 14; left), and the capitate is no longer coaxial. On the PA view (Figure 15; right), the lunate is triangular rather than its normal quadrangular appearance.





chauffeur involves a blow from the crankshaft handle of an antique car.) In this injury, the styloid is avulsed, including the attachment of the extrinsic ligaments of the wrist. Therefore, displaced fractures usually mandate open reduction and repair.[88]

"History teaches us that men and nations behave wisely once they have exhausted all other alternatives."—Abba Eban

Radioulnar Joint Injuries

The distal radioulnar joint includes the TFC and the radioulnar articulation. Injuries to this joint are commonly missed in the acute setting.[89-91] Dislocation of the ulna commonly occurs with distal radius fractures and can be an important component of some fracture-dislocations of the forearm. Occasionally, ulnar dislocation at the radioulnar joint occurs without bony injury. The injury can result from falls or axial distraction, as in sudden distraction or rotation (such as sudden lifting or grasping a fixed object, like a handrail or banister, against a fall). Radioulnar joint injuries can also result from crush- or wringer-type mechanisms.

In order to detect radioulnar dislocations radiographically, it is important to get true PA and lateral views (although this may be difficult in the suffering patient). Remember that the ulna has a fixed relationship to the radius in true PA and lateral films. On the lateral view, the dislocated ulna will project either dorsally or volarly to the radius. On the AP, it will overlap the radius, and close the radioulnar gap. Other suggestive signs of injury include fracture of the ulnar styloid base (which is associated with TFC injury) as well as radial shortening of 5 mm or more relative to the ulna.[92] In cases in which the diagnosis is suspected but radiographs are equivocal, CT of the wrist may be helpful.[90,93] This test, however, is usually left to the consultant.

Figure 16. The lunate is now disoriented in relation to the radius on the lateral view, and the capitate is no longer coaxial. On the PA view, the lunate is triangular rather than its normal quadrangular appearance.



Reproduced with permission from: Harris JH, Harris WH, eds. *The Radiology of Emergency Medicine.* 3rd ed. Baltimore: Lippincott Williams & Wilkins Publishers; 1993:417. Fig. 6.6A, 6.6B.

Treatment

Delayed diagnosis makes closed reduction difficult. The key is to identify the dislocation both in isolation and in association with non-displaced fractures. Reduction of associated fractures will often bring the ulna back into position. Once reduction is achieved, immobilize the arm with a long arm splint to prevent rotation at the injured joint. Damage to the TFC, which is the main stabilizer of the joint, or inability to reduce the joint usually mandates operative repair.[94-96]

Special Circumstances

Pediatric Issues

Carpal fractures are extremely rare in the very young. A recent review of pediatric carpal injuries describes carpal injuries in terms of case reports or small series.[97] The paucity of carpal injuries is due to the fact that these "bones" are more cartilaginous than calcified and are thus relatively resistant to injury. Because the radius growth plate is weaker than the joint capsule, energy transmitted from a fall leads to epiphyseal rather than carpal injury. This produces torus and greenstick fractures of the radius. Torus (doughnut-shaped) fractures are best appreciated as a tiny bump on the cortex of the distal radius on either the PA or lateral views.

As the child ages and growth plates close, injury patterns approach those of adults. In older children, carpal injury will occur, and in young adults, scaphoid fracture is the most common.

The most common pitfall in dealing with wrist injuries among children involves injury to the growth plates, especially in the radius. One study revealed that 87% of 38 children diagnosed with wrist "sprain" in fact had Salter type I injuries (see **Table 2**) of the distal radius.[28]

In children, fracture lines may be obscure, especially if the fracture occurs through the growth plate. Evaluating the fat stripes of the wrist can be helpful in detecting otherwise occult injury. The pronator quadratus muscle attaches at the

Table 2. Salter-Harris Classification.

- **Type I** involves the growth plate. Radiographs may be normal or show a displaced epiphysis. Often misdiagnosed as a "sprain."
- **Type II** involves the growth plate and a triangular piece of the metaphysis. It is the most common type of growth plate fracture and generally has a good outcome.
- **Type III** passes though the growth plate and the epiphysis. Surgery often indicated if fragments are displaced.
- **Type IV** involves the epiphysis, metaphysis, and growth plate. Surgery usually indicated and growth arrest can occur if alignment not restored.
- **Type V** represents a crush injury of the growth plate. Radiographic findings may be subtle. Growth arrest is common.

distal third of the radius and ulna and is associated with an overlying layer of fat. This fat stripe is best seen on true lateral projection (see **Figure 17** and **Figure 18**), and normally bows slightly toward the bone (as in Figure 18). Outward bulging or obliteration of the fat stripe can signify bleeding or edema in the underlying bone (as in Figure 17).[98] In one study, this sign was positive in 74% of Salter type I radius fractures.[28] Comparison views of the opposite wrist may also be helpful in evaluating epiphyseal injury.[28] Treatment outcomes are generally good.

Open Injuries Of The Wrist

The most significant open injuries of the wrist usually involve the volar aspect. Here is where the tendons, nerves, and vessels course. A careful distal examination of range of motion and neurovascular supply is essential. While foreign bodies may be detected upon wound exploration, consider the use of diagnostic imaging when the risk of foreign bodies is high. Plain films will detect glass and metals, whereas MRI and ultrasound are useful for non-radiopaque substances such as wood or plastic.[99-102]

Wounds requiring repair will need to be anesthetized, cleansed, and then explored to identify retained foreign bodies or tendon injuries. Because tendons can retract into the forearm, examine the wrist in full extension and look at the base of the wound during the full range of motion for the appearance of a tendon stub. The most superficial tendon in the wrist is the palmaris longus. This tendon is located in the middle of the volar wrist. It becomes very prominent when the wrist is partially flexed while the patient touches his or her thumb and fifth finger together. Interestingly, 16% of patients may be missing this tendon in either hand, and in an additional 9%, the absence may be bilateral.[103] Division of the palmaris longis tendon is rarely clinically significant except when there is injury to the median nerve, which lies beneath. Lacerations of other flexor tendons require surgical consultation.

The father of modern hand surgery, Sterling Bunnell, once suggested that trying to repair a hand wound without a tourniquet was like "trying to fix a Swiss watch in a bucket of ink."[104] When exploring the wrist, consider the use of a tourniquet to provide a bloodless field. Since most EDs

Figure 17 and **Figure 18**. The fracture shown in Figure 17 is subtle, as it can be in children. The comparison view (Figure 18) shows a normal pronator quadratus fat pad that is missing in the injured wrist. Along with a physical exam pinpointing the tenderness, there is little doubt of the diagnosis.





lack an automated pressure tourniquet, a blood pressure cuff will do. Have the patient lie on the gurney with the arm held directly overhead—that is, sticking straight up from the stretcher. Place a blood pressure cuff around the arm and wrap tape completely around the cuff to keep it from popping off. Have the patient forcefully pump, then clench his or her fist to exsanguinate the forearm (like Bruce Lee in "Fists of Fury"). Then inflate the cuff above systolic pressure and begin the wound exploration. Limit tourniquet time to 10 minutes to avoid ischemic injury and patient discomfort.

Pain Management

Pain management is an important and often overlooked aspect of wrist injuries. It may be of special significance in those with crush injuries, amputations, and fractures. Opioid analgesics are useful and may be given intravenously, intramuscularly, or orally depending upon the severity of the pain. The hematoma block is another valuable technique. It can provide rapid analgesia and is especially well-suited to those with distal radius fractures that require manipulation.[105,106] After identifying the fracture site by palpation and prepping the skin with iodine, insert a needle into the bony deficit and aspirate blood. Then infiltrate 5-10 cc of bupivacaine or lidocaine into the fracture site. Most patients achieve significant relief within 15 minutes. If the orthopedist is planning to come to the ED to reduce the fracture, coordinate the timing of the hematoma block appropriately.

Disposition

After an attentive exam and review of the x-rays, the vast majority of wrist injuries can be safely discharged from the ED. Most fractures or suspected fractures can be splinted and sent home. Provide clear instructions regarding splint care, and warn patients about any neurovascular changes that warrant a return to the ED.

Some injuries necessitate emergent orthopedic evaluation. These may include lunate and perilunate dislocations, open fractures, any fracture with neurovascular compromise, and grossly displaced fractures. These are injuries in which early reduction or surgery may improve outcome.[71,107,108] Notably, these are the same injuries that are most often missed on initial evaluation.

Most other wrist injuries, both fractures and ligamentous trauma, can be immobilized and then discharged with follow-up. This applies to both simple fractures and even to scapholunate separation that may ultimately need surgical repair.

Disposition may depend on factors other than the anatomic injury. Bilateral fractures, or a wrist fracture in an elderly person who is walker-dependent, may warrant admission until appropriate home help is ensured.

Summary

While wrist injuries rarely represent a threat to life, they remain a unique challenge for emergency physicians. The fact that they are more common but less urgent than other conditions seen in the ED can lull the unwary physician into a false sense of security. However, the complex anatomy of the wrist, combined with the high level of manual dexterity most people require, makes the management of wrist injuries a virtual minefield for emergency physicians. Vigilance is a must.

Mechanism of injury and other data obtained during the history and physical exam provide essential clues for the diagnosis and management of wrist injuries. Radiography is almost always required; physicians must insist on adequate films and order the proper views for the given scenario. Be systematic when evaluating the films. Furthermore, be aware that injuries to the ligaments, muscles, and soft tissue can also lead to long-term sequelae if not managed properly.

While it is neither cost-effective nor necessary to "splint and refer" all wrist cases, it is generally better to err on the conservative side. Be sure the patient understands the discharge instructions—especially the importance of follow-up with the appropriate consultant, if indicated. Provide written discharge instructions, and be sure to document each step of the patient encounter thoroughly.

The management of wrist injuries is rarely clear-cut. Fortunately, though, a thorough and systematic approach to the evaluation and disposition can lead to better outcomes for the patient and physician alike. ▲

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Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

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Physician CME Questions

65. Fractures at the radial or ulnar styloid are significant because:
a. they will be the most cosmetically apparent after healing.
b. the extrinsic ligaments that stabilize the carpals originate there.
c. they are most likely to become infected.
d. of the risk of avascular necrosis.

66. Transverse triquetral fractures should alert emergency physicians to look for:
a. scaphoid fracture.
b. radial styloid fracture.
c. perilunate dislocation.
d. elbow injury.

67. Supinated oblique views are useful for:
a. reviewing the scaphoid from a different angle.
b. checking the alignment of the radius and ulna.
c. alternative views of the hamate and pisiform.
d. alternative views of the trapezium.

68. What is the advantage of a long arm spica over a short arm spica?
a. It prevents rotation of the forearm in complex scaphoid injuries.
b. It makes it more likely that the patient will seek medical attention for splint removal.
c. It bills better.
d. It protects the elbow joint.

69. Which of the following is a common pitfall in the management of pediatric wrist injuries?
a. Not examining the wrist carefully to know what injury to suspect
b. Diagnosing a Salter injury at the distal radius as a "sprain"
c. Being intimidated by the absence of calcification in the carpi
d. All of the above

70. The cortical (or signet ring) sign signifies:
a. the sound that a healthy bone makes when tapped.
b. abnormal scaphoid alignment.
c. abnormal triquetral position.
d. artifact at mid-proximal fourth phalanx.

71. An injury sustained while swinging a bat or club to hit a ball should raise suspicion for which type of injury?
a. Scaphoid fracture
b. Triquetral injury
c. Dislocation around the lunate
d. Hamate hook injury

72. Severe pain at the wrist sustained in a fall from a third-floor scaffolding should raise suspicion for which type of injury?
a. A high-energy wrist injury
b. A shoulder dislocation
c. A life-threatening blunt abdominal injury
d. All of the above

73. Which of the following is the most common type of carpal fracture?
a. Scaphoid
b. Lunate
c. Hamate
d. Triquetrum

74. Most wrist injuries are caused by:
a. motor vehicle crashes.
b. a fall on an outstretched hand.
c. typing for long stretches of time.
d. sports and other pastimes.

75. The proximal arch includes all of the following *except:*
a. the hamate.
b. the scaphoid.
c. the lunate.
d. the triquetrum.
e. the pisiform.

76. The distal row includes all of the following *except:*
a. the trapezium.
b. the trapezoid.
c. the capitate.
d. the hamate.
e. the pisiform.

77. In patients with wrist injuries, which of the following should be determined as part of the patient history?
a. Pre-existing medical conditions such as rheumatoid arthritis
b. The time of the patient's last meal if emergent surgery is anticipated
c. Any current medications/allergies
d. All of the above

78. Bone scans are most effective in detecting occult scaphoid fractures when performed:
a. the same day as the injury.
b. within two days of the injury.
c. at least 3 but no more than 13 days after injury.
d. three weeks after injury.

79. Finding a distal radius fracture in a young adult roller hockey player should prompt the emergency physician to:

a. splint the wrist and send the patient home with a diagnosis of Colles' fracture.
b. perform a conscientious search for associated wrist injuries.
c. suspect a pathological fracture.
d. call for an immediate orthopedic consultation.

80. Which of the following is the best strategy for patients with clinical signs of scaphoid fracture?

a. Immobilization and orthopedic follow-up in 7-10 days, even in the absence of radiographic findings
b. Immobilization and orthopedic follow-up in 7-10 days if a fracture is detected on x-ray
c. Immediate surgical consult
d. Discharge the patient with instructions to return to the ED if symptoms worsen

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives an alpha-numerical score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case-control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA* 1992;268(16):2289-2295.

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