Systematic Checklist Approach to the Radiographic Interpretation of the Injured Wrist to Avoid Common Diagnostic Errors

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Key Words: Radiographic Evaluation of the Injured Wrist, Systematic Approach, Traumatic Wrist Injury

Radiography is the first-line imaging modality for the evaluation of traumatic wrist injury, which is encountered commonly in the daily practice of a diagnostic radiologist. Because of the complex anatomy and overlapping structures of the wrist on standard radiographic projections, abnormalities of the wrist can be subtle and easily overlooked. Therefore, it is essential for radiologists to be proficient at the interpretation of wrist radiographs. The use of a checklist approach, and recognition of common injury patterns, potentially can increase radiologists’ accuracy when interpreting standard wrist radiographs. The objective of this article is to present a simple but thorough method for accurate radiographic evaluation of the wrist and to review some common injury patterns of the wrist.

Introduction

Radiographs usually are sufficient for the diagnosis of common wrist injuries. A systematic approach to the evaluation of wrist radiographs is essential to avoid missing wrist fractures and ligamentous injuries, which can result in significant long-term morbidity, including carpal instability, late carpal collapse, and severe degenerative arthritis.

Radiographic Evaluation of the Wrist

Common views of the wrist include posteroanterior (PA), lateral, and oblique projections. With the PA view, the wrist
In the PA view of the wrist, half or more of the proximal lunate cortical surface should articulate with the distal radial articular surface. Should be in a neutral position, and half or more of the proximal cortex of the lunate should articulate with the distal radial articular surface¹ (Figure 1A). On the lateral view, a straight line should be able to be drawn through the axes of the distal radius, lunate, capitate, and third metacarpal, or the axes should be within 10 degrees of that straight line² (Figure 1B). For the oblique view, the wrist is pronated 45 degrees from the lateral, which improves evaluation of the radial corner of the wrist, the base of the thumb, the triscapho-trapeziotrapezoid joint, and the dorsal triquetral margin. More specific views include the PA projection with ulnar or radial deviation, carpal boss or off-lateral, dynamic anteroposterior (AP) clenched fist, specialized scaphoid carpal tunnel, and bridge. These specialized views serve as problem-solving projections for indeterminate cases, and each view has its advantages for viewing the complex anatomy of the wrist. For example, in the setting of a suspected scaphoid fracture, the clenched-fist AP and PA ulnar-deviated views allow for better visualization of the scaphoid and for the evaluation of scapholunate instability.¹³

Radiographic Anatomy of the Wrist

The complex anatomy of the wrist derives from the two rows of four carpal bones, extrinsic ligaments, and intrinsic ligaments. This article reviews key osseous anatomy and key ligamentous injuries that are implied by radiographic abnormalities. However, a thorough review of ligamentous anatomy is beyond the scope of this article.

The carpal bones and intrinsic ligaments form some of the most complex anatomy of the wrist, both on radiographs and cross-sectional images. Radiographic evaluation was somewhat simplified by Gilula in 1979 with the description of three normal carpal arcs on the PA view of the wrist. Three normal carpal arcs on the PA view of the wrist.¹ The proximal arc, or arc 1, silhouettes the proximal articular surfaces of the scaphoid, lunate, and triquetrum. The middle arc, or arc 2, silhouettes the proximal concave surfaces of the scaphoid, lunate, and triquetrum. The distal arc, or arc 3, silhouettes the proximal articular surfaces of the capitate and hamate. These arcs, as illustrated in Figure 1A, should be...
delimited by greater and lesser arcs\(^6\),\(^7\) (Figure 2). Greater arc injuries typically involve a perilunate dislocation and carpal fracture, the most common being a scaphoid fracture with perilunate instability. More severe injury can result in capitate, hamate, or triquetral fractures along the greater arc (Figure 3). Conversely, lesser arc injuries describe progressive stages of ligamentous injury, which result in rotatory subluxation of the scaphoid and eventually perilunate/lunate dislocations.\(^6\) Familiarity with injury patterns of the wrist can prompt a search for associated injuries, which are often subtle, can be missed easily, and are clinically important to prevent progressive instability of the wrist.

**Greater arc wrist injuries typically involve a perilunate dislocation and carpal fracture, usually the scaphoid.**

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**Systematic Checklist Approach to Evaluation of Wrist Radiographs**

In our opinion, a systematic checklist approach is essential to avoid errors when interpreting wrist radiographs. We provide a simple yet thorough checklist for use and review each component subsequently (Table 1).

**Frontal View**

**White Cortical Line Outlining All Bones.** On every wrist radiograph, the white cortical margins of the carpal bones, proximal metacarpals, and distal radius and ulna should be scrutinized for evidence of disruption. Disruption of the cortical white line is due most commonly to fracture, followed by erosions from arthritis (Figure 4). Less common causes include neoplasm and infection. Loss of the cortical white line also may indicate carpal coalition. The most common...
type of isolated carpal coalition is lunotriquetral, which is seen in 0.1% to 1.6% of the population. Carpal coalitions are commonly bilateral, and osseous fusions are much more common than fibrous fusions, which can be symptomatic. Typically, congenital fusions (e.g., arthrogryposis) involve bones from the same carpal row, and syndrome-related fusions (e.g., Ellis-van Creveld syndrome, Holt-Oram syndrome, and Turner syndrome) affect bones from different rows (proximal and distal).

On radiographs, loss of the cortical white line of a wrist bone most commonly is attributable to fracture, followed by erosions from arthritis.

**Joints.** The frontal view of the wrist allows for the best evaluation of the wrist articulations, including the distal radioulnar joint, the radiocarpal joint, and the carpometacarpal joints. Assessment of all joints should include alignment and the preservation of joint spaces and smooth articular surfaces. The carpal arcs of Gilula should be intact, and the normal lazy “M” contour of the carpometacarpal joints should be present (Figure 1A). Disruption of the arcs of Gilula or the lazy “M” can occur from fracture, dislocation, or both (Figures 5A and 5B).

**Contour of Ulna Parallels Contour of Radius.** On PA and lateral radiographs, the contour of the ulna should parallel the contour of the radius. Disruption of this relationship can signify fracture or dislocation. This is especially important in the pediatric population, as subtle cortical irregularity may indicate a buckle fracture (Figure 6).

**Cortical Rim of Hook of Hamate Should Be Visible.** The white cortical rim of the hook of the hamate deserves special attention. It always should be visible on the frontal view (Figure 4). PA view of the wrist demonstrates disruption of the cortical white line (arrow) of the radial articular surface, indicating an intra-articular fracture of the distal radius. (Figure 1A), and disruption implies fracture (most common) or destruction from infection or tumor (uncommon). Hook of hamate fractures occur with a fall on a dorsiflexed wrist, which results in force transmitted through the transverse carpal and pisohamate ligaments (Figure 7). These hook of hamate fractures also are associated with sports that use golf clubs, racquets, or bats. Complications include nonunion, osteonecrosis, injury to ulnar or median nerve, tenosynovitis, tendon rupture, or chronic pain. An important differential diagnosis is a bipartite hook of hamate (i.e., os hamuli proprium), which may mimic a fracture.

**Ulnar Variance.** The last osseous evaluation on the checklist for PA or AP views of the wrist is ulnar variance. The ulna and radius should align when the wrist is in the neutral position; however, some anatomic variation occurs, and the ulna may be longer or shorter than the radius. When the discrepancy between the lengths is greater than 2 mm, there is a predisposition to pathologic processes. Positive ulnar variance occurs when the ulna is longer than the radius, and negative ulnar variance occurs when the ulna is shorter than the radius. Positive ulnar variance may result in ulnar impaction of the lunate and can lead to early degenerative or cystic change in the lunate, termed ulnar abutment syndrome (Figure 8A). Positive ulnar variance also may be associated with triangular fibrocartilage tear. In the setting of negative
Capitolunate and Scapholunate Angles. As part of the lateral wrist radiographic analysis, the capitolunate and scapholunate angles should be evaluated. The capitolunate angle is formed by two lines drawn along the long axis and ulnar variance, the lunate is predisposed to avascular necrosis or Kienbock disease (Figure 8B).

**Positive ulnar variance occurs when the ulna is longer than the radius; negative variance when the ulna is shorter.**

**Lateral View.** Evaluation of the lateral wrist radiograph can be technically challenging secondary to multiple overlying osseous structures; however, a few key points need to be evaluated on every lateral wrist radiograph.

**Metacarpals, Carpals, and Radius Alignment.** On the lateral radiograph, the third metacarpal, capitate, lunate, and radius all should align. Disruption of the alignment of these key components is indicative of an underlying dislocation and possible carpal instability.

**Figure 5.** A: PA view of the wrist reveals disruption of the lazy “M” (*dotted line*) secondary to acute traumatic dorsal carpometacarpal dislocations. Also note the fifth metacarpal fracture (*arrowhead*). B: Lateral view of the wrist confirms the dorsal carpometacarpal dislocation (*arrow*).

**Figure 6.** PA view of the wrist of a skeletally immature patient with arm pain after a fall shows buckle fractures of the distal radius and ulnar metadiaphysis (*arrows*). Note the loss of parallelism between the ulna and radius.

**Figure 7.** PA view of the wrist shows disruption of the cortical white line of the hook of the hamate (*arrow*) in this patient who fell on an outstretched hand. A hook of hamate fracture was confirmed on CT (*not shown*).
through the center of the capitate and lunate. Similarly, the scapholunate angle is formed by two lines drawn along the long axis and through the center of the scaphoid and lunate. The normal capitolunate angle measures 0 to 30 degrees, and the normal scapholunate angle measures 30 to 60 degrees. Abnormal angles are important secondary signs for intercarpal ligamentous injury and intercalated segment instability, which can lead to advanced instability and destruction of the wrist (Figure 9). The lunate is attached to the scaphoid and triquetrum by the scapholunate and lunotriquetral ligaments, respectively. Tilting of the lunate is determined by the intrinsic ligaments, with the tendency of the scaphoid for volar tilt and the triquetrum for dorsal tilt. If both scapholunate and lunotriquetral ligaments are intact, the lunate is in neutral position because the scaphoid and triquetral actions counteract each other. When there is a scapholunate ligament tear, the scaphoid rotates volarly, causing rotatory subluxation of the scaphoid. Eventually, the lunate tilts dorsally because of the action of the triquetrum, resulting in dorsal intercalated segmental instability. Conversely, when the lunotriquetral ligament is torn, the lunate tilts volarly after the scaphoid, resulting in volar intercalated segmental instability. When both intrinsic ligaments are torn, the lunate becomes unstable, leading to lunate dislocation. Table 2 provides a summary of the most common patterns and associated ligamentous injuries.

Contour of Ulna Parallels Contour of Radius. As seen on the frontal view, the contours of the radius and ulna should parallel each other. Proper alignment on the lateral view is crucial, and disruption of this relationship can signify fracture or dislocation (Figure 10).

Fat Stripes. The last check of every wrist radiograph should be a soft tissue assessment to include evaluation of the scaphoid and pronator quadratus fat stripes. Obliteration, displacement, or irregularity of normal fat stripes is an important secondary sign of a potentially radiographically occult wrist fracture.

Mass. Hand masses are common, and radiography frequently is performed as an early step in assessment. Although radiographs are often negative in this setting, important information can be gained from radiography. Therefore, systematic

Figure 8. A: PA view of the wrist shows positive ulnar variance (dashed line) with cystic change in the ulnar base of the lunate (dashed arrow), suggesting ulnar abutment syndrome because of impaction on the lunate. B: PA view of the wrist shows negative ulnar variance (straight line) and sclerosis of the lunate (arrow), consistent with avascular necrosis or Kienbock disease.

Figure 9. Lateral view of the wrist demonstrates an increased capitolunate angle (CLA, 40 degrees) and volar tilt of the lunate in a patient with volar intercalated segmental instability.
evaluation of the soft tissues should include soft tissue density, mass effect, calcifications, and pressure erosion on adjacent bone (Figure 11). The presence of any one of these may prompt further analysis with MRI, as the differential diagnosis for a hand mass is broad and includes but is not limited to giant cell tumors of tendon sheath; fibromatosis; lipomas; benign nerve sheath tumors; and pseudotumors such as ganglions, De Quervain tenosynovitis, tophaceous gout or pseudogout, and hydroxyapatite deposition.15

Conclusion
The anatomy of the wrist is complex; therefore, a systematic approach to radiographic interpretation is essential. This article provides a simple yet thorough checklist for radiographic evaluation of the wrist. This CME activity emphasizes that use of a checklist approach and familiarity with injury patterns may aid in detecting direct and indirect radiographic signs of wrist injury, which can otherwise be difficult to diagnose.

References
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1. A fracture of which one of the following carpal bones is associated most often with a traumatic perilunate dislocation?
A. Lunate
B. Pisiform
C. Hamate
D. Scaphoid
E. Triquetrum

See Reference No. 6 for further study

2. Fractures of the hook of the hamate are least likely to occur in which one of the following athletes?
A. Baseball hitter
B. Recreational swimmer
C. Golfer
D. Tennis player
E. Cricketer

See Reference No. 9 for further study

3. Which one of the following carpal bones is at risk for ulnar impaction in the presence of positive ulnar variance?
A. Pisiform
B. Scaphoid
C. Lunate
D. Triquetrum
E. Capitate

See Reference No. 8 for further study

4. Which of the following carpal bones are involved in the most common carpal coalition in the wrist?
A. Lunate, scaphoid
B. Lunate, capitate
C. Triquetrum, pisiform
D. Lunate, triquetrum
E. Capitate, hamate

See Reference No. 8 for further study

5. All of the following carpal bones at the wrist articulate with the triquetrum, except
A. pisiform
B. capitate
C. lunate
D. hamate

See Reference No. 4 for further study

6. Which one of the following carpal bones is involved with Kienbock disease?
A. Hamate
B. Capitate
C. Scaphoid
D. Trapezium
E. Lunate

See Reference No. 11 for further study

7. Which one of the following ligaments is torn in a DISI pattern of instability?
A. Scaphocapitate
B. Lunotriquetral
C. Scapholunate
D. Ulnolunate
E. Radiotriquetral

See Reference No. 1 for further study

8. The PA radiograph of a young boy with a painful wrist after a fall reveals loss of parallelism and irregular metaphyseal cortical bulging of the distal ulna and radius. The most likely diagnosis is
A. buckle fractures of the radius and ulna
B. plastic bowing fractures of the radius and ulna
C. physal fractures of the radius and ulna
D. complete, undisplaced fractures of the radius and ulna
E. normal distal radius and ulna

See Reference No. 7 for further study

9. Initial imaging of the traumatized wrist comprises
A. CT
B. radiography
C. MRI
D. ultrasound
E. bone scintigraphy

See Reference No. 3 for further study

10. All of the following are part of systemic checklist radiographic evaluation of the injured wrist, except
A. intact cortical white line outlining all bones
B. contour of distal ulna parallels contour of distal radius
C. capitate, lunate, and distal radius align on the lateral view
D. scaphoid and pronator quadratus fat stripes
E. normal convexity of the carpal arcs

See Reference No. 12 for further study