Radiographic Evaluation
of the Wrist: A Vanishing Art

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The intricate anatomy and compartmentalization of structures in the wrist are somewhat daunting. As in other joints, the radiographic appearance of disease processes affecting the wrist is very much dependent on the articular and periarticular soft tissue and osseous anatomy. Therefore, abbreviated discussions of the pertinent anatomy are included within the introduction with more specific anatomic discussions within the text as a prelude to certain conditions affecting the wrist.

Anatomy of the Wrist

Osseous Anatomy

The osseous structures of the wrist are the distal portions of the radius and ulna, the proximal and distal rows of carpal bones, and the bases of the metacarpals (Fig. 1). The proximal row of carpal bones consists of the scaphoid, lunate, triquetrum, and the pisiform. The distal row of carpal bones contains the trapezium, trapezoid, capitate, and hamate bones. The distal row of bones articulates with the metacarpal bases. The bases of the metacarpals articulate with the distal row of carpal bones and with each other. The proximal carpal row is termed an intercalated segment because forces acting on its proximal and distal articulations determine its position. This aspect of the osseous anatomy becomes important when considering the pattern of collapse that occurs in the different types of wrist instability.

Articular Compartmental Anatomy

The wrist joint is separated into a number of compartments by the many ligaments that attach to the carpal bones (Fig. 2). These compartments are of considerable significance for the interpretation of standard or MR arthrograms and for identifying various patterns of arthritic involvement. The compartments are as follows:

1. Radiocarpal compartment
2. Midcarpal compartment
3. Pisiform-triquetral compartment
4. Common carpometacarpal compartment
5. First carpometacarpal compartment
6. Intermetacarpal compartments
7. Inferior (distal) radioulnar compartment

In daily clinical practice, the most important compartments are the radiocarpal, midcarpal, and distal radioulnar compartments. The radiocarpal compartment (Fig. 2) lies between the proximal carpal row and the distal radius and the triangular fibrocartilage, which is fibrocartilaginous tissue that extends from the ulnar side of the distal aspect of the radius to the base of the ulnar styloid. A meniscus attaches to the triquetrum and is located between the radiocarpal and pisiform-triquetral compartments, in most cases. In the coronal plane, the radiocarpal compartment forms a C-shaped cavity bordered by the radial collateral ligament on the radial side and the point at which the meniscus is attached to the triquetrum on the ulnar side. On its ulnar side, two projections are noted from the joint space, a proximal prestyloid recess between the meniscus and the triangular fibrocartilage and a distal recess that extends to the triquetrum; these latter projections form a Y-shaped area toward the ulnar wrist. The prestyloid recess abuts the ulnar styloid and, on its radial aspect, the radiocarpal compartment contacts the “bare area” (area unprotected by articular cartilage) of the scaphoid and the radial styloid. These relationships become important when articular diseases such as rheumatoid arthritis affect the wrist.

The midcarpal compartment (Fig. 2) includes articulations between the proximal and the distal carpal rows. The distal pole of the scaphoid articulates with the two trapezial bones, termed the trapeziocapitate space. The proximal end of the scaphoid combines with the lunate and triquetrum to form a concavity that articulates with the combined capitate and hamate.

The inferior radioulnar compartment (Fig. 2) lies between
the cartilage-covered surfaces of the radius (sigmoid notch) and the ulnar head, surrounded by a loose capsule. When the articulating surface between the ulna and the sigmoid notch is intact, the radius translates on the seat of the ulnar head. The synovial cavity of this compartment is described as L-shaped in coronal section, as it extends between the distal radius and ulna and then across the distal ulna. This compartment is separated from the radiocarpal joint by the triangular fibrocartilage.

Ligamentous Anatomy

Detailed review of the ligamentous anatomy of the wrist is beyond the scope of this article. Rather, the discussion will be limited to the scapholunate ligament, lunotriquetral ligament, and the triangular fibrocartilage complex. The ligaments of the wrist have been classified into intrinsic ligaments because they arise and insert on carpal bones and extrinsic ligaments because they connect the distal portion of the radius and the carpal bones. Two intrinsic ligaments join the bones of the proximal carpal row, the scapholunate interosseous ligament (joining the proximal surfaces of the scaphoid and lunate) and the lunotriquetral interosseous ligament (joining the proximal surfaces of the lunate and triquetrum) (Fig. 3). These ligaments connect the bones from their palmar to dorsal surfaces. The intrinsic scapholunate ligament complex and the lunotriquetral complex each consist of dorsal, palmar, and proximal (membranous) components. When intact, they separate the radiocarpal and midcarpal compartments of the wrist.

The ulnar ligamentous complex (ulnocarpal ligaments) is largely synonymous with the triangular fibrocartilage complex (TFCC), comprising the triangular fibrocartilage (TFC) proper (the articular disk) and the dorsal radioulnar ligament, volar radioulnar ligament, ulnotriquetral ligament, ulnar collateral ligament, and the meniscus homologue. The literature includes the sheath of the extensor carpi ulnaris tendon in the description of the TFCC.

The distal radioulnar joint is stabilized by the TFCC. The complex arises from the medial margin of the distal radius to insert in the fovea at the base of the ulnar styloid process. From the ulnar side, the ulnocarpal ligaments arise and insert strongly on the triquetrum (the ulnotriquetral ligament) and weakly on the lunotriquetral interosseous ligament and on the lunate (the ulnolunate ligament). Further ulnarly, the TFCC becomes thickened again as it is joined by fibers of the ulnar collateral ligament to form the meniscus homologue, and it courses distally to insert on the triquetrum, hamate, and base of the fifth metacarpal bone (meniscus reflection). On its dorsolateral side, the TFCC is incorporated into the floor of the sheath of the extensor carpi ulnaris tendon.

**Figure 1** Gross anatomic section through the wrist illustrating the osseous anatomy. The proximal row consists of the scaphoid (S), lunate (L), triquetrum (tq), and pisiform (not shown). The distal row includes the trapezium (tm), trapezoid (tz), capitate (C) and hamate (H). R = radius, U = ulna, 1st = base of thumb metacarpal, 5th = base of small finger metacarpal. (Color version of figure is available online.)

**Figure 2** Articular compartmental anatomy. The wrist is separated into compartments by ligaments that attach to carpal bones. The radiocarpal, midcarpal, pisiform-triquetral, common carpometacarpal, first carpometacarpal, intermetacarpal, and inferior radioulnar compartments are shown. (Reproduced with permission.)

**Figure 3** Intrinsic ligaments. Joining the proximal surfaces of the scaphoid (S) and lunate (L) is the scapholunate interosseous ligament; and, joining the proximal surfaces of the lunate (L) and triquetrum (T) is the lunotriquetral interosseous ligament. They separate the radiocarpal and midcarpal compartments. In the distal carpal row, three intrinsic ligaments unite the trapezium (TR) and trapezoid (TZ) bones, the trapezoid and capitate bones, and the capitate with the hamate bones. These distal interosseous ligaments do not prohibit midcarpal and common carpometacarpal compartment communication. (Reproduced with permission.)
TFC may be fenestrated centrally, especially in middle-aged and elderly persons. It functions as a cushion between the ulna proximally and the carpus, primarily the triquetrum, distally. It is a major stabilizer of the distal radioulnar joint.\(^2\),\(^5\)

**Imaging of Osseous and Articular Structures**

**Radiographic Views**

In most situations, standard radiographic evaluation of the wrist includes posteroanterior, oblique, and lateral radiographs (Fig. 4). Additional exams may include radial or ulnar deviation views, carpal tunnel view, carpal bridge view, special scaphoid views, or other specialized techniques.\(^1\),\(^6\) To avoid diagnostic errors, the routine and specialized techniques and significant points of plain film evaluation are reviewed.

**Posteroanterior Projection**

The posteroanterior (PA) projection (Fig. 5) is obtained with the arm abducted 90° from the trunk and the forearm flexed at 90° to the arm.\(^6\) With the forearm in this pronated position, the ulnar styloid is seen in profile. When views are taken in supination, the ulnar styloid overlaps the central portion of the distal ulna. With the wrist in the neutral position, one-half or more of the lunate should contact the distal radial articular surface.\(^1\)

**Normal Arcs of the Wrist**

Three smooth carpal arcs are formed on the neutral PA view along the radiocarpal and midcarpal joints (Fig. 6). Arc 1 follows the proximal surfaces of the scaphoid, lunate, and triquetrum; arc 2 is along the distal surfaces of these same carpal bones, and arc 3 follows the curvature of the proximal surfaces of the capitate and hamate.\(^7\) In the normal situation, on a neutral PA view, these curvilinear arcs are roughly parallel, without disruption, and the interosseous spaces are nearly equal in size. Disruption of these arcs or abnormal overlapping of adjacent bones on the PA view commonly indicates carpal subluxation or dislocation. There are, however, two common normal variants that mimic step-offs within the carpal arcs (Fig. 7): (1) a triquetrum shorter in its proximal-distal dimension than the adjacent lunate creates a

![Figure 4 Standard radiographic evaluation of the wrist. The routine radiographic evaluation includes (from left to right) posteroanterior, lateral, and oblique radiographs.](image-url)
lunotriquetral step-off of the first carpal arc and a normal second carpal arc and (2) a proximally prominent hamate with an apposing hamate facet on the lunate (type II lunate) that produces a bilobate second and third carpal arc using the capitate (C) facet and hamate (H) facet along the distal lunate articular surface to create the second carpal arc and the proximal capitate and hamate facets to create the third carpal arc (shown).

**Normal Scapholunate Joint Space**

The normal scapholunate joint space width is the same as the width between pairs of the other carpal bones. It is measured at the center of the scapholunate joint with the beam angled from the dorsal ulnar aspect of the wrist approximately 10°. In its midportion, this space normally measures 2 mm or less and usually remains constant even within the normal range of radial or ulnar deviation of the wrist.

**Ulnar Variance**

Changes in the length of the ulna relative to the length of the radius, designated ulnar variance (Fig. 8), alter the distribution of compressive forces across the wrist. Ulnar variance is found by extending a line along the distal articular surface of the radius toward the ulna and measuring the distance from this line to the distal ulna (Fig. 8A). Normally, the radius and ulna are almost the same length, although wrist and forearm position and centering of the x-ray tube have been noted to influence the measurements obtained. When the ulna is shorter than the radius, the term negative ulnar variance is used.

![Figure 5](image5.jpg) **Figure 5** Posteroanterior (PA) views. (A) With the forearm in a pronated position, the ulnar styloid is seen in profile. (B) When views are taken in supination, the ulnar styloid overlaps the central portion of the distal ulna. With the wrist in a neutral position, one-half or more of the lunate (L) should contact the distal radial articular surface.

![Figure 6](image6.jpg) **Figure 6** PA view illustrating the normal three arcs of the wrist. Arc 1 spans the proximal articular surfaces of the scaphoid (S), lunate (L), and triquetrum (tq). Arc 2 connects the distal concave surfaces of these same bones. Arc 3 outlines the proximal articular surfaces of the capitate (C) and hamate (H).

![Figure 7](image7.jpg) **Figure 7** Two common normal variants that mimic step-offs within the carpal arcs: (A) a triquetrum (tq) shorter in its proximal-distal dimension than the adjacent lunate (L) creating a lunotriquetral step-off (arrow) of the first carpal arc and a normal second carpal arc, and (B) a proximally prominent hamate (H) with an apposing hamate facet on the lunate (L = type II lunate) that produces a bilobate second and third carpal arc using the capitate (C) facet and hamate (H) facet along the distal lunate articular surface to create the second carpal arc and the proximal capitate and hamate facets to create the third carpal arc (shown).

![Figure 8](image8.jpg) **Figure 8** Ulnar variance on PA wrist views. (A) Normal or neutral variance. Perpendicular to the long axis of the radius, tangential lines are drawn along the ulnar-most extent of the subchondral white line of the distal radius and the distal-most extent of the articular surface of the ulnar dome. The shortest distance between these two lines is the measure of ulnar variance. (B) Negative ulnar variance or ulna minus variance (measurement of dotted line). (C) Positive ulnar variance (measurement of dotted line).
used (Fig. 8B). The consequences of negative ulnar variance are increased force applied to the radial side of the wrist and to the lunate bone, which may explain the association of negative ulnar variance and Kienböck’s disease. With such variance, the TFC is thicker, and abnormalities of the TFCC are uncommon. A consequence of a long ulna, or positive ulnar variance, is the ulnar impaction or ulnar abutment syndrome, with resulting limitation of rotation. The TFC is thinner in instances of positive ulnar variance, and degenerative perforation of this structure (as well as disruption of the lunotriquetral interosseous ligament) may be observed.

Carpal Height
Carpal height is the distance between the base of the third metacarpal and the distal radial articular surface as determined on a PA radiograph of the wrist (Fig. 9). Measurement of carpal height allows comparative quantification of carpal collapse in an individual patient over time. The carpal height ratio allows comparison between individuals and it is the carpal height divided by the length of the third metacarpal. Similarly, a carpal height index may be obtained by dividing the carpal height ratio of the diseased wrist by that of the normal hand. Some investigators believe the carpal height index to be the most sensitive for detection of abnormal carpal height in a specific hand.

Lateral Projection
On a true lateral view of a normal wrist (Fig. 10), the long axis of the third metacarpal should be coaxial (parallel) with the long axis of the radius. Another clue to a true lateral view is that the pisiform projects directly over the dorsal pole of the scaphoid.

Longitudinal Axes of the Radius, Lunate, and Capitate
In neutral position, the longitudinal axes through the third metacarpal, the capititate, the lunate, and the radius all fall on the same line (Fig. 11A). This ideal situation is actually uncommon, but in most cases the axes are within 10° of this line. The axis of the radius is constructed as a line parallel to
the center of the radial shaft (Fig. 11A). The axis of the lunate can be drawn through the midpoints of its proximal and distal articular surfaces (Fig. 11A). The axis of the capitale is drawn through the centers of its head and its distal articular surface (Fig. 11A). The axes of the radius, lunate, and capitale should superimpose, with 0 to 30° described as the capitulunate angle in normal patients.1

Longitudinal Axis of the Scaphoid
The long axis of the scaphoid is represented by a line drawn through the midpoints of its proximal and distal poles (Fig. 11B).1 Another method, proposed by Gilula and Weeks, consists of connecting the ventral convexities of the scaphoid that are visible on the lateral view.10 Normally, the angle formed between the long axis of the radius, the lunate, and the capitale that of the scaphoid (the scapholunate angle) ranges between 30 and 60° and averages 47°.1

Distal Radial Measurements on Lateral and Posteroanterior Views
There are three radiographic measurements that are commonly used to assess the anatomy of the distal radius, namely, palmar tilt, radial inclination, and radial length (Fig. 12).1,11 The normal palmar or volar tilt of the radius can be measured on lateral views by noting the angle of intersection between a line drawn tangentially across the most distal points of the radial articular surface and a perpendicular to the midshaft of the radius. Normal range is 11° of volar tilt to 4° of dorsal tilt. (B) Radial inclination is measured on PA radiographs and averages 22° (range = 13 to 30°). (C) Radial length is the distance between the tip of the radial styloid and the ulnar head articular surface. Radial length averages 11 to 22 mm.

Oblique View
The standard oblique view (Fig. 13) is taken in the PA position, with the hand in partial pronation. This view is helpful in detection of scaphoid tuberosity and waist fractures and dorsal margin triquetral fractures. It profiles the scaphotrapezial, trapeziotrapezoidal, and capitulunate joints and will show the first carpometacarpal and the scaphotrapezoidal joints to best advantage.12

Radial and Ulnar Deviation Views
Radiographs obtained with radial and ulnar deviation of the wrist (Fig. 14) are useful for visualizing the carpal bones, particularly the scaphoid, and for assessing carpal mobility. As the wrist is radially deviated, palmar flexion of the proximal carpal row occurs and the distal pole of the distal scaphoid rotates into the palm. This causes the normal scaphoid to appear foreshortened and exhibit a ring-like appearance of its distal pole as the distal aspect of the scaphoid is seen end-on. As the wrist is placed in ulnar deviation, the scaphoid rotates its distal pole dorsally and ulnarly and it appears to elongate.1 The distances between the carpal bones are normally equal throughout and are unchanged by radial or ulnar deviation. Although widening of the scapholunate distance to between 2 and 4 mm may be abnormal, more than 4 mm is definitely abnormal.1,6

Radiocarpal Joint View
Radiographs obtained by angulating the beam along the axis of the radiocarpal joint (Fig. 15) allow better visualization of
this articulation; a PA roentgenogram may be obtained with the beam angulated 10° proximally, and a lateral radiograph from the radial side of the joint may be obtained with the beam angulated 15° proximally. The PA view elongates the scaphoid and shortens the capitate, and it may provide better visualization of abnormalities of the scaphoid.12

**AP Projection**

To more reliably profile the scapholunate and lunotriquetral interspaces, an AP view can be obtained. The dorsum of the hand and wrist are flat against the cassette and the central beam is perpendicular to the cassette, centered over the head of the capitate. The ulnar styloid projects over the ulnar head on an adequate examination.6,9

**Semisupinated Oblique View**

In some cases, oblique projections are taken in both a semipronated oblique and a semisupinated oblique position (Fig. 16). The latter is an anteroposterior oblique view that is taken in partial supination. Synonymous names for this view include the Norgaard view, the “ball-catcher’s” or “You’re in good hands with Allstate” view. It shows the pisiform, palmar aspect of the triquetrum, palmar ulnar surface of the hamate, and it profiles the pisiform-triquetral joint. The Norgaard view is optimal for evaluation of early erosive changes in the hands and wrists of patients with inflammatory arthritides.1,12,13

**Lateral Flexion and Extension Views**

These views demonstrate extension and flexion at the radiocarpal and midcarpal joints in normal wrists (Fig. 17). They can be used in evaluation of carpal instability patterns. In particular, these views can assist in distinguishing between a true instability pattern versus normal variance.12 Extension and flexion of the wrist is recognized by observation of the long axis of the third metacarpal extended dorsally and flexed volarily, respectively, relative to the long axis of the radius and ulna. In extension, the pisiform remains closely apposed to the triquetrum and projects over the scaphoid as in the neu-
In flexion, the pisiform moves away from the triquetrum, projecting anterior to the scaphoid.

**Carpal Boss View or Off-Lateral View**

A slightly supinated off-lateral view (Fig. 18) shows the dorsal carpal boss on a tangent and enables distinction of (1) a separate os styloideum, (2) a bony prominence attached to the second or third metacarpal base or apposing surface of the trapezoid or capitate bones, (3) degenerative osteophytes, or (4) a fracture of the dorsal prominence.

The view is taken with the ulnar side of the wrist on the cassette, in slight ulnar deviation and with approximately 30° supination. The central beam passes tangent to the dorsal prominence.

**Scaphoid Views**

The standard pronated oblique view generally shows fractures of the scaphoid tubercle. However, the detection of non-displaced scaphoid fractures can be significantly improved with the use of dedicated scaphoid views. These may include magnification views or any combination of the following: PA or AP ulnar deviation view, semipronated oblique view with ulnar deviation, lateral scaphoid view, “stecher position” view, ulnar oblique scaphoid view, 30-degree semipronated oblique PA view, 60-degree semipronated oblique PA view, and elongated oblique view. For a more detailed technical discussion of these projections, the reader is referred to standard imaging texts that detail the position and technique for obtaining these views.

**Carpal Tunnel View**

The carpal tunnel view (Fig. 19) is obtained with the wrist dorsiflexed and either the ventral aspect of the wrist (inferosuperior view) or the palm (superoinferior view) placed on the film cassette. The x-ray beam is angled to profile the carpal tunnel. This view shows the palmar soft tissues and the palmar aspects of the trapezium, scaphoid tuberosity, capitate, hook of the hamate, triquetrum, and the entire pisiform. It should be noted that the carpal tunnel view obtained using the inferosuperior projection, the Gaynor–Hart method, may create a confusing ring artifact representing an end-on view of the fifth metacarpal.
superimposed on the carpal bones, with the central radiolucent area corresponding to the medullary canal.6

Carpal Bridge View
This view profiles dorsal surface fractures of the scaphoid, chip fractures of the dorsum of other carpal bones, and it demonstrates calcifications and foreign bodies in the dorsal soft tissues. On an adequate examination, there is tangential view of the dorsal aspect of the scaphoid, lunate, and triquetrum (Fig. 20). The superimposed capitate should be visible.12

Clenched Fist View
The clenched fist view (Fig. 21) is used to widen the scapholunate joint in cases of scapholunate joint diastasis. It can be obtained in a PA or AP position as the central beam passes through the center of the capitate head. With a tight fist, the contracting tendons and muscles create a force within the wrist that drives the capitate proximally toward the scapholunate joint.3,12 In wrists with a lax or disrupted scapholunate ligament, the joint will widen.

Distal Tilt View
If there is suspicion of a capitate waist fracture that is not demonstrated on the standard PA view, the distal tilt view (Fig. 22) may be utilized. It is a PA projection with the central beam angled 25 to 30° toward the fingers, centered on the capitate.12

First Carpometacarpal Joint View
A dedicated anteroposterior projection with beam angulation has been used to define changes in the first carpometacarpal joint (Fig. 23).12 Coned frontal and lateral views of the first carpometacarpal joint allow a more precise analysis of arthritis and traumatic lesions, such as the Bennett’s fracture.6
Radiographic Evaluation of Soft Tissues

Deep and Superficial Fat Planes

There are two deep fat planes that are useful in the radiographic evaluation of wrist trauma: the pronator quadratus fat pad and the scaphoid fat pad. The pronator quadratus fat pad (Fig. 24) lies between the pronator quadratus muscle and the volar tendon sheaths. It is seen on the lateral radiograph of the wrist as a linear or crescent-shaped lucency just anterior to the distal radius and ulna. Fractures involving the distal radius or ulna often show volar displacement, blurring, irregularity, or obliteration of this fat plane.

The scaphoid fat plane or fat stripe (Fig. 25) is a triangular or linear collection of fat that is bounded by tendons of the abductor pollicis longus and the extensor pollicis brevis and by the radial collateral ligament. This fat plane is seen on the PA radiograph as a lucent stripe extending from the radial styloid to the trapezium and almost paralleling the lateral aspect of the scaphoid. Fractures of the scaphoid, the radial styloid, and the first metacarpal often result in displacement or obliteration of this fat stripe.

On the ulnar aspect of the wrist, fat along the extensor carpi ulnaris tendon is often visible. Inflammatory processes such as rheumatoid arthritis may obliterate this fat stripe and thicken the tendon shadow, increasing the amount of soft-tissue density along the ulnar styloid.

Wrist Pain — Differential Diagnosis

Many wrist disorders are readily identified during the initial clinical evaluation. Alternatively, the patient’s history may be pathognomonic of a certain injury, such as acute volar ulnar wrist pain in a golfer after a “dubbed swing”, this being a history that is typically associated with fracture of the hook of the hamate. However, some disorders such as carpal instabil-
ity and ulnar-sided wrist pain are less specific; and these conditions are conclusively diagnosed only after careful examination supported by appropriate imaging studies. There are many varied causes of wrist pain and methods of radiographic evaluation, as will be discussed throughout the following pages of this writing.

**Traumatic**

**Fractures of the Radius and Ulna—Patterns of Injury**

Fractures of the distal aspect of the radius are one of the most common skeletal injuries treated by orthopedic surgeons and they account for 17% of all fractures seen in emergency departments. A multitude of classification systems have been devised based on extraarticular or intraarticular involvement, fracture complexity (degree of displacement and angulation), management issues, mechanism of injury, and treatment options. Intraarticular fractures of the distal portion of the radius have been described as two-, three-, four-, or five-part (or more) fractures. Based on stability and reducibility of the fracture, consistent radiographic observations have led to a more universally accepted description of articular injuries (discussion of fracture parts), whereby analysis of the fracture pattern and creation of a subset of articular injury classification has facilitated their treatment.

Despite frequent comminution, there are four basic components or parts of an articular fracture: (1) the radial shaft, (2) the radial styloid, (3) a dorsal medial fragment, and (4) a palmar medial fragment (Fig. 26). The two medial fragments, along with their ligamentous attachments to the carpus and the ulnar styloid, are termed the medial complex. Anatomic preservation of this medial complex is recognized as an absolute requirement for optimal fracture reduction and management. Displacement of these strategically positioned medial fragments also forms the basis for categorizing articular fractures into a classification system (type I, II, III, IV), taking into account features of previous classification systems.

Type I fractures are minimally displaced, stable after closed reduction, and effectively treated by a short period of cast immobilization (Fig. 27). More commonly, an articular fracture is Type II, which is the dorsally displaced “die-punch fracture.” In such a fracture, the lunate selectively impacts the dorsal medial component, resulting in an unstable fracture characterized by varying degrees of comminution of the dorsal metaphysis, marked dorsal tilting, and considerable shortening of the radius. In the majority of type II fractures, the medial complex components are neither widely separated nor rotated (Type IIA), and they are generally amenable to closed reduction and skeletal fixation (Fig. 28). Less commonly, a more comminuted and displaced pattern of dorsal or palmar displacement, the type IIB fracture (Fig. 29), is seen, irreducible by closed methods.

A third type of pattern, the type III “spike fracture,” demonstrates articular disruption similar to that in type II injuries with added displacement of a “spike fragment,” from the volar metaphysis (Fig. 30). Displacement of the spike fragment may occur at the time of injury or during fracture ma-

**Figure 26** Basic components of an articular fracture of the radius. The basic fracture parts are (1) the radial shaft, (2) the radial styloid, (3) a dorsal medial fragment, and (4) a palmar medial fragment.

**Figure 27** Type I fractures are minimally displaced and stable after closed reduction.
Manipulation, which worsens fracture stability and may cause injury to adjacent nerves and tendons.\textsuperscript{15}

The type IV fracture pattern is characterized by wide separation or rotation of the dorsal and palmar medial fragments with severe disruption of the distal radius articulations\textsuperscript{15} (Fig. 31). A more violent injury accounts for the occurrence of the type V explosion fracture. This severe injury results from an enormous force, composed of both axial compression and direct crush, with resultant severe comminution often extending from the articular surface of the radius to the diaphysis.\textsuperscript{15} The latter two patterns usually occur in association with severe surrounding soft-tissue trauma.
The classification system described above is not meant to replace the common fracture descriptions and use of their eponyms; it is a method of discussion that increases understanding of fracture reducibility, stability, and ultimate management. Common eponyms are consistently used to describe fractures of the distal end of the radius. Examples include Colles’ fracture (fracture of the distal aspect of the radius with dorsal displacement), Smith’s fracture (fracture of the distal portion of the radius with palmar displacement), Barton’s fracture (fracture of the dorsal rim of the radius), palmar or reverse Barton’s fracture (fracture of the palmar rim of the radius), and Hutchinson’s or chauffeur’s fracture (fracture of the radial styloid process).

Colles’ Fracture
The well-known Colles’ fracture (Fig. 32) is the most common injury to the wrist caused by a fall on an outstretched hand causing axial compression together with a bending moment. The combination leads to dorsiflexion of the joint. The frequency of this fracture increases with advancing age of the patient. The classic Colles’ fracture is a transverse fracture, with or without comminution, with or without intraarticular extension, accompanied by impaction and dorsal displacement of the distal surface of the radius.

Complications of Colles’ fractures are diverse and fairly common. Such complications include unstable reduction, articular incongruity, subluxation or dislocation of the distal radioulnar joint, median nerve compression resulting in carpal tunnel syndrome, ulnar nerve injury, entrapment of flexor tendons, reflex sympathetic dystrophy, carpal malalignment or fracture, posttraumatic osteolysis of the ulna, and malunion, delayed union, or nonunion. Therefore, measurement of such parameters as radial tilt, radial inclination, and ulnar variance on routine radiographs assumes some importance in evaluation of fracture stability.

Markers of fracture instability are (1) radial shortening in excess of 6 to 10 mm, as this predisposes to further collapse, resulting in distal radioulnar instability and ulnocarpal joint impaction (Fig. 33); (2) angulation or tilting of the radial articular surface exceeding 20° in the sagittal plane, which causes a serious disturbance of radiocarpal collinear alignment as well as incongruity of the distal radioulnar joint; and (3) metaphyseal comminution involving both the volar and the dorsal radial cortices as this eliminates an intact bony buttress on which a stable reduction must hinge. Recognition of these radiographic signs of instability is essential for satisfactory management of these injuries.

Smith’s Fracture
The less common Smith’s fracture is a fracture of the distal radial metaphysis or epiphysis, with or without articular involvement, demonstrating palmar displacement or angulation. The mechanism of injury is hyperflexion from a fall on the palmar-flexed wrist (Fig. 34). Complications of Smith’s fractures are similar to those of Colles’ fractures and may include injury to the extensor tendons.

Barton’s Fracture
A Barton’s fracture is a marginal fracture of the dorsal rim of the radius that displaces along with the carpus, producing a fracture-subluxation (Fig. 35). The fracture results from a fall causing dorsiflexion and forearm pronation on a fixed wrist. A variant of the Barton’s fracture involves the palmar rim of the distal end of the radius (Fig. 36) and may be more common than its dorsal counterpart. It is sometimes referred to as a reverse Barton’s or a palmar Barton’s fracture. Complications of fractures of the dorsal or palmar rim of the radius are...
similar to those of a Colles’ fracture with increased difficulty in maintaining stable reduction.\textsuperscript{15}

**Hutchinson’s or Chauffeur’s Fracture**

Fracture of the styloid process of the radius is often referred to as a Hutchinson’s fracture or a chauffeur’s fracture (originally described as a fracture that occurred when the starting crank of an engine suddenly reversed during an engine backfire) (Fig. 37). It is an avulsion injury related to the sites of attachment of the radiocarpal ligaments or the radial collateral ligament. It may also result from a direct blow.\textsuperscript{18} Because the fragment is most often non-displaced, this fracture is often difficult to visualize. The fracture is best identified on a PA radiograph and may not be apparent on a lateral radiograph. On the PA view, it should not be confused with the normal irregularity along the lateral surface of the radius at the expected site of previous physeal closure. The fracture line may enter the space between the scaphoid and lunate fossae, thereby causing scapholunate dissociation and lesser arc injury of the wrist.\textsuperscript{10}

It is critical to restore the articular surface to anatomic congruency following the described various fracture patterns.
to prevent the development of instability and late posttraumatic arthritis. In addition to diagnostic PA, lateral and oblique plain x-rays, thin-section computed tomography (CT) scans with multiplanar reconstruction of images can be used to assess the intraarticular extent and fracture fragment morphology in preparation for percutaneous pinning and other methods of reduction. In particular, coronal and sagittal images are especially helpful in measuring cortical depression or offset. MR imaging has been useful in evaluation of ligamentous, nerve, tendon, and surrounding soft-tissue pathology associated with wrist fractures.

**Ulna Styloid Fracture**

When an ulnar styloid fracture is present, another fracture should be sought (Fig. 38A), because only 6% of ulnar styloid fractures occur alone.19 In isolation, an ulna styloid fracture is perhaps related to an avulsion produced by the ulnar collateral ligament or triangular fibrocartilage complex. The resulting ossific fragment should not be confused with the anatomic variant appearance of the normal ossification center (lunula) that may appear in the meniscus homologue of the wrist. The irregular contour of the fracture fragment, as well as the irregularity of the donor site along the styloid process, generally allows accurate diagnosis of the fracture. Hypertrophy of the fragment with fracture nonunion is encountered infrequently and may be a source of chronic wrist pain16 (Fig. 38B).

**Childhood Fractures**

In children, injuries may result from acute trauma or chronic overuse. Due to the fact that the capsule and ligaments are two to five times stronger than the growth plate, the growth plate is more often involved. Acute fractures typically involve the radial and ulnar physes; in younger children, torus fractures commonly occur (Fig. 39). The radiographs of children should be inspected carefully in at least two orthogonal planes in an effort to avoid misdiagnosis or incomplete diagnosis of fractures. Physeal fractures are usually Salter–Harris type II (Fig. 40).

**Occult Wrist Fractures**

There are a number of common and not-so-common carpal bone fractures that are more often missed than others. Increasing awareness of these injuries and more consistent use of CT scanning and MR imaging have improved their diagnosis.
The majority of fractures of the wrist involve the scaphoid (65%). However, radiographic diagnosis may be difficult. Seventy percent of these fractures occur through the waist; 20% involve the proximal third, and 10% occur in the distal pole. In children, avulsion fractures of the distal portion of the scaphoid are typical. Unusual patterns of scaphoid injury include dorsal avulsion fractures and fractures of the osteochondral interface in young children.16

Radiographically, multiple views of the wrist are indicated in patients with suspected scaphoid fractures. In addition to PA, lateral and oblique projections, angled and magnification views, and views with the wrist in ulnar deviation will show the waist of the scaphoid to best advantage. Soft-tissue signs of fracture include dorsal swelling and scaphoid fat pad changes. Obliteration, distortion, or displacement of the “scaphoid fat stripe” may occur (Fig. 25B). In the case of a displaced scaphoid fracture or suboptimal healing, there may be dorsal tilting of the lunate (“humpback deformity”) simulating that occurring in dorsal segmental instability.16

The major factor leading to nonunion of scaphoid fractures is delayed or inadequate immobilization. Therefore, treatment is often begun even when radiographic confirmation is lacking. Individuals without radiographically demonstrable fractures who are clinically suspected of having non-displaced scaphoid fractures are immobilized in a cast for several weeks and then reexamined. Ganel and coworkers, who noted that a negative bone scan 24 to 72 hours after injury excludes fracture at this site, have suggested an alternative course.20 In clinically suspicious cases with negative radiographs, a bone scan (with the cast on) is performed and, if this is negative, immobilization is discontinued.

Complications of a scaphoid fracture (Fig. 41) include avascular necrosis of the proximal pole, delayed or nonunion, and an unusual form of osteoarthritis, termed scaphoid nonunion advanced collapse (SNAC). Due to the fact that the entire blood supply to the scaphoid enters through its distal pole, avascular necrosis (AVN) may occur following fractures through the waist of the scaphoid and it is an expected sequela of proximal pole fractures. Increased density of the proximal fragment, indicating avascular necrosis, has been noted on radiographs in about 30% of patients.1 However, sclerosis alone does not indicate inevitable nonunion, and both the fracture and the avascular area may go on to heal.

Nonunion of scaphoid fractures is due primarily to a delay in diagnosis or lack of adequate immobilization, or both.21 Contributing factors include anatomical features such as the presence of articular cartilage covering five of the six scaphoid surfaces, healing by endosteal reaction only, failure to achieve anatomical reduction, and a tenuous blood supply in some cases.21,22

Radiographic abnormalities of scaphoid nonunion include bone sclerosis, cyst formation, widening of the scapholunate space, bone resorption, and, subsequently, osteoarthritis. Tendon ruptures may occur as a complication of scaphoid nonunion, and CT may reveal hypertrophy of Lister’s tubercle in the dorsum of the radius, which may predispose to tendon disruption.16

Figure 41 Scaphoid fracture avascular necrosis (AVN) and nonunion. (A) Avascular necrosis of the proximal fragment (arrow) is more prevalent in fractures that involve the proximal third of the scaphoid and less frequent with fractures that involve the middle third. (B) A PA view of the wrist demonstrates a chronic fracture through the waist of the scaphoid, consistent with nonunion (arrow).

Figure 42 Triquetral dorsal avulsion fracture. A lateral view shows a dorsal-avulsion fracture of the triquetrum (ellipse).
Fractures of Other Carpal Bones

The triquetrum is the second most commonly injured carpal bone (3 to 4% of all carpal bone injuries). The dorsal fracture (Fig. 42) may be caused by forceful contact of the triquetral with the hamate or ulnar styloid process or to avulsion of the dorsal radiotriquetral ligaments. The dorsal-avulsion type of injury is not often missed on the lateral or oblique projections. However, a less common triquetral fracture that is often missed involves the body of the triquetrum (Fig. 43), caused by a direct blow in most cases. This rare type of triquetral injury may be missed on conventional radiography and better diagnosed with CT.

Fractures of the hamate make up 2 to 4% of all carpal fractures. Sagittal or coronal fractures through the body may occur and these may be detected on plain x-ray or with CT. CT scans are often necessary to define the fracture plane. It is more difficult to clinically and radiographically detect the more common fracture involving the hook of the hamate (Fig. 44). Therefore, this injury deserves attention. Fractures of the hook often occur in association with a dubbed golf swing or in sports that use rackets or bats. The grip may place the end of the club handle or bat against the hook, thereby predisposing the hook to direct trauma. These injuries may also result from a fall on a dorsiflexed wrist, with the force transmitted through the transverse carpal and pisohamate ligaments. Aside from standard radiographs, a carpal tunnel view, computed tomography, or a bone scan may be helpful in detecting fractures of the hook of the hamate, as is MR imaging (Fig. 45). Complications of these fractures include nonunion, osteonecrosis, injuries to the ulnar or median nerve, tenosynovitis or tendon rupture, and chronic pain. A bipartite hook or os hamuli proprium (incomplete fusion of the ossification center of the hook) may mimic a fracture. On an MR imaging study, it is recommended that the axial and sagittal images be completely reviewed before excluding a fracture of the hamate.

Fractures of the pisiform (Fig. 46) are usually the result of a direct blow to the volar surface of the wrist. The fracture may be transverse (usually a chip fracture of the distal end of the bone) or longitudinal. Occasionally, the fracture is comminuted. The fracture is best visualized on a 30° supinated AP view, carpal tunnel view, lateral oblique view, or a radial deviation PA view. When no other soft-tissue swelling is seen, paraulnar fat pad swelling suggests a pisiform fracture. A complication of fractures involving the pisiform is ulnar nerve damage.

Isolated fractures of the capitate, trapezium, and trapezoid are infrequent. Capitate fractures (Fig. 47) usually involve the neck of the bone and may be associated with metacarpal fractures, scaphoid fractures, and trans-scaphoid perilunate dislocations, at times resulting in the scaphocapitate syndrome (Fig. 48). In scaphocapitate syndrome, the head of the capitate may be dislocated from the scaphoid, resulting in chronic pain. The triquetrum may also be involved in these fractures, leading to a triquetral impaction syndrome.
the capitate is fractured and rotated 180°. Difficulty interpreting the radiographs in this situation can result in improper treatment of a fracture fragment that is considerably displaced or a fracture fragment that is markedly rotated. Proper radiographic interpretation often requires multiple projections, including PA, lateral, and oblique views, often supplemented with CT scan images. When interpreting the films, the “squared-off” appearance of the proximal end of the capitate, best seen on a PA view, is the key to making the proper diagnosis.24

The trapezium may fracture in various places, the vertical body, dorsoradial tubercle, dorsoulnar tubercle, and anterior (palmar) ridge.25,26 The vertical split fracture of the body of the trapezium is associated with lateral subluxation of the first metacarpal, which remains attached to the lateral trapezial fragment. The fracture of the palmar trapezial ridge, although rare, is important to recognize as these fractures are prone to nonunion27 if not promptly diagnosed and treated. The anatomy is such that a portion of the transverse carpal ligament attaches to this ridge and extends across the carpal tunnel to the hook of the hamate. In a setting of trauma, an avulsion fracture of the trapezial ridge may be produced26 (Fig. 49). Because the ridge is not well visualized on routine radiographs, the diagnosis can be easily overlooked. Trapezial ridge fractures can best be seen on the carpal tunnel view (Fig. 49B). CT scans also are very useful in evaluation of these fractures.

Carpometacarpal Injuries

Anatomically, the osseous structures of the wrist include the bases of the metacarpals. Within the first carpometacarpal compartment of the wrist, relatively common injuries include the Bennett’s fracture-dislocation and Rolando’s fracture that occur at the base of the thumb metacarpal (Fig. 50). The Bennett’s fracture and Rolando’s fracture are two-part and three-part (or comminuted) fractures, respectively, and they are usually well recognized on radiographs. A more challenging diagnosis is that of a beak ligament avulsion fracture.

The beak ligament avulsion fracture (Fig. 51) occurs at the level of the thumb carpometacarpal joint. At this articulation,
there is a major strong ligament that connects the beak of the metacarpal base to the anterior tubercle of the trapezium. This ligament has been referred to as the anterior oblique, the ulnar, the ulnar-volar, and the beak ligament. Two other ligaments in the capsule include the lateral ligament beneath the abductor pollicis longus tendon insertion, and the posterior oblique ligament that is under the extensor pollicis longus. Although rare, pure dislocation of the first metacarpal without fracture can occur. The dislocations are always dorsal and the beak ligament strips subperiosteally along the metacarpal. The ligament is lax in the dislocated position, but it becomes tight again if the thumb is reduced. Chronic instability can result if unrecognized and not treated with rigid reduction (pinning) for a 6- to 8-week time interval. Careful radiographic examination may demonstrate the tiny avulsed fragment(s) adjacent to the metacarpal base unless there is pure ligamentous avulsion.

Stress Fracture of the Radial Epiphyseal Plate

In the skeletally immature, a stress reaction can develop primarily at the distal radial growth plate and to a lesser degree in the distal end of the ulna. Gymnastics is the major cause of this injury; hence it bears the name, “gymnast’s wrist” (Figs. 52 and 53). The condition is due to chronic compression and rotational forces that are applied as the upper extremity becomes the weight-bearing limb during this sport activity. Radiographically, the changes at the physis resemble those seen in rickets. The physeal plate shows irregularity, cystic change, and widening, consistent with a Salter–Harris type I or II injury. There may be adjacent bone fragmentation. If not treated, the condition can lead to early physeal closure and positive ulnar variance with dysfunction of the distal radio-
ulnar joint and abnormalities of the triangular fibrocartilage complex.29

Wrist Instability
Carpal instability occurs when there is symptomatic mal-alignment between the rows of carpal bones and between the carpal bones and the radius. Figuratively speaking, the proximal carpal row is termed an intercalated segment because forces acting on its proximal and distal articulations determine its position.30 Collapse is normally prevented by linkage of the proximal and the distal carpal rows by the scaphoid and its connecting ligaments.1 When the system is compressed, a zigzag pattern of collapse occurs, analogous to what happens to cars in a train if the first car stops short. The resultant instability may be due to traumatic injuries (fractures or ligamentous disruption) or to inflammatory conditions such as rheumatoid arthritis. When the term carpal instability was first coined, it was almost synonymous with scapholunate instability. Since then, descriptions of progressive perilunate instabilities have evolved with scapholunate instability representing the first stage of perilunate injuries.3

Perilunate Dislocation
Most wrist injuries, including dislocations, result from forced dorsiflexion of the wrist. The resultant lesions are predictable as they are all progressive stages of the same injury pattern. A stage I injury is secondary to scapholunate ligamentous failure and dissociation with rotatory subluxation of the scaphoid.16 Stage II injury is characterized by perilunar instability resulting from capitulunate failure of the palmar radioscaphocapitate ligament or a fracture of the radial styloid process, leading to perilunate dislocation16 (Fig. 54). The stage III injury results from lunotriquetral partial or complete failure or avulsion of the volar and dorsal radiotriquetral ligaments.24 The final stage IV injury is associated with disruption of the dorsal radiocarpal ligaments, which frees the lunate and allows it to become volarly displaced (lunate dis-
When the perilunate dislocation pattern is associated with fractures, these injuries are then called greater arc injuries as the arc of injury passes through the scaphoid, capitate, hamate, and/or triquetrum. The lesser arc injuries affect the ligaments and joint spaces about the circumference of the lunate and begin with scapholunate injury.16

Scapholunate (SL) Instability

Scapholunate instability or scapholunate dissociation may accompany tears of the palmar radiocarpal ligaments and scapholunate interosseous ligament complex. Scapholunate dissociation (rotatory subluxation of the scaphoid) may occur as a complication of lunate or perilunate dislocation, rheumatoid arthritis, and other articular diseases, or as an isolated injury.16 Although characteristic abnormalities are typically identified on routine radiographic examination, patients who are suspected of having ligamentous instability may require additional views. The full series may include (1) PA views in neutral, ulnar deviation, and radial deviation; (2) AP clenched fist view; (3) an oblique view; (4) lateral views with the wrist in neutral, flexion, and extension; and (5) lateral view in neutral position with the fist clenched.1 The views in flexion and extension and in radial and ulnar deviation help to demonstrate the dynamics of wrist motion. The clenched-fist views compress the wrist, tending to force the capitate into the space between the scaphoid and the lunate, and to rotate the scaphoid toward the palm, thus revealing any tendency for abnormal scaphoid rotation or scapholunate separation.1,3

Abnormal findings on standard radiographic views or on the additional views include the following1 (Fig. 56):

1. A wide scapholunate distance (“Terry Thomas sign”). Normally, the scapholunate distance is less than 2 mm. Ligamentous disruption is suggested when the distance between the scaphoid and lunate is greater than 2 mm and can be diagnosed almost unequivocally when this distance is 4 mm or more.1,16

2. Foreshortened appearance of the scaphoid. On a PA view, this appearance is due to rotation of the distal pole of the scaphoid toward the palm. In contrast to the normal wrist, this foreshortening does not appear on ulnar deviation.

3. Ring sign. This sign refers to the density produced by the cortex of the distal pole of the scaphoid seen end-on because of the abnormal scaphoid rotation. Normal individuals may exhibit this finding on PA views taken with the hand in radial deviation; however, this appearance should not persist when the hand is in ulnar deviation.1

4. Dorsiflexion instability. On a continuum of progressive severity of scapholunate injury or dissociation is the occurrence of secondary changes such as capsular contracture, scaphoid and midcarpal fixation, dorsal intercalary segment instability (DISI), scapholunate advanced collapse (SLAC), and pancarpal degenerative arthritis.1,16 Radiographic findings of DISI include (1) on a PA view, overlap of the lunate and the capitate and (2) on a lateral view (Fig. 57), scapholunate angle >80°.
Lunotriquetral Instability

Lunotriquetral instability may be seen after sprain or disruption of the lunotriquetral intersesous ligament, with ulnar injury, excision of the triquetrum, sprains of the midcarpal joint that attenuate the extrinsic ligaments, with ulnar positive variance associated with degenerative lunotriquetral membrane tears, and in patients using wheelchairs.\textsuperscript{16,23} Patients with this injury usually progress from minimal symptoms to ulnar wrist pain and the sensation of instability. They develop ulnar nerve paresthesias and eventual midcarpal instability. A similar pattern of instability is seen as a normal variant in persons with ligamentous laxity and in those with various articular disorders, including rheumatoid arthritis and calcium pyrophosphate dihydrate crystal deposition disease.\textsuperscript{14}

Standard radiographs may appear normal in patients with lunotriquetral tears or sprains and in those with lunotriquetral dissociation and dynamic instability.\textsuperscript{16} Stress radiographs, ie, clenched-fist AP view in pronation or ulnar deviation or the clenched-fist lateral view, may be necessary to elicit the abnormality in patients with dynamic instability. The abnormalities encountered include disruption of the normal smooth convexity of the proximal carpal row with the triquetrum displaced proximally on the AP radiograph. Disruption of the normal arc is particularly pronounced with ulnar deviation, producing overlapping of the lunate and triquetrum.\textsuperscript{31} On the lateral view, the lunate is tilted volarly, capitate directed dorsally, and the triquetrum dorsi-flexed in relation to the lunate compared with the other wrist.\textsuperscript{1,18,31} With progressive instability, volar intercalated segment instability (VISI) deformity occurs and radiographic findings include the following: (1) PA views show that the lunate overlaps the capitate and (2) lateral views (Fig. 58) demonstrate a scapholunate angle <30° (normal = 30 to 60°), increased capitolunate angle to >30° (normal = 0 to 30°), lunate tilted volarly, capitate directed dorsally, and the triquetrum dorsi-flexed in relation to the lunate compared with the other wrist.\textsuperscript{1,16,30}

Standard arthrography is probably the most helpful diagnostic aid in the evaluation of lunotriquetral tears (sprains). Sequential injection of the midcarpal and radiocarpal spaces has been shown to be the best method of evaluation.\textsuperscript{16} A positive study demonstrates communication between the midcarpal and radiocarpal joints through the lunotriquetral space. Patients with isolated lunotriquetral tears need to be differentiated from those with ulnar impaction syndrome. Ulnar impaction syndrome is discussed more extensively elsewhere in this writing.

Midcarpal Instability—Intrinsic to Carpus

In midcarpal instability, laxity of certain carpal ligaments results in lack of support for the proximal carpal row and
midcarpal joint, which in turn leads to a loss of the normal joint reactive forces between the proximal and distal carpal rows. The proposed etiology is injury to—or laxity of—the ulnar arm of the arcuate ligament (a major stabilizer of the midcarpal joint) and laxity of the dorsal radiolunotriquetral (RLT) ligament.32 A dynamic flexion deformity (VISI) occurs in the proximal row as the distal row translates palmarly owing to the lax ligament. As the wrist moves from radial to ulnar deviation, there is no longer the normal coupled rotation of the carpus and smooth transition from flexion (VISI) to extension (DISI). Instead, the proximal row remains flexed in a “VISI-like” pattern for a period with “the head of the capitate [subluxed] volarly into the space of Poirier.”32,33 As the distal row/capitate abruptly reduces, the proximal row snaps into extension in a “DISI-like” pattern creating the clinical finding called the “catch-up clunk.” This is accentuated by increasing the load on the capitolunate joint when the fist is clenched and relieved by either splints which apply pressure in a dorsal direction to the pisiform or by surgery to strengthen the volar arcuate ligament and dorsal ligaments or by fusion of the lunate-triquetrum-capitate-hamate bones.33

The dynamic pattern of instability described above is named “palmar midcarpal instability (PMCI)” because of the palmar translation of the distal row. In earlier reports, this entity was termed “ulnar midcarpal instability.”34 Dorsiflexion injury, compression, rotation, and distraction injuries and ulnar minus variance have been associated with PMCI.35 PMCI is the most common pattern of midcarpal instability.36 A much less common variant of midcarpal instability, in which the proximal carpal row is extended (DISI) and the distal carpal row is subluxed dorsally when the wrist is in neutral, is termed dorsal midcarpal instability (DMCI).32

The radiographs may be normal as PMCI is a dynamic condition. Lateral radiographs in neutral, radial, and ulnar deviation may demonstrate VISI deformity and mild palmar translation of the distal carpal row. Videofluoroscopy in PA and lateral planes may show the dynamic palmar flexion instability (VISI) with wrist motions from radial to ulnar deviation.32 CT scan and MR image findings include VISI deformity with volar tilt of the scaphoid and the lunate, palmar translocation of the distal row, sclerosis between the distal lunate and proximal capitate, and dorsal tilting of the distal pole of the capitate. The T2-weighted MR images show an attenuated or disrupted lunotriquetral ligament with hyperintense fluid extending across the lunotriquetral (LT) or scapholunate (SL) interval. There may be hyperintense synovitis versus ligament attenuation associated with the ulnar arm of the arcuate ligament and the dorsal radiotriquetral (or radiolunotriquetral) ligament. MR arthrography will show contrast directly communicating across the SL or LT interval.32

The natural history of midcarpal instability is that the dynamic instability becomes a fixed VISI deformity with loss of the normal physiologic VISI to DISI wrist motion with wrist motion from radial to ulnar deviation. Louis and associates37 have described the capitolunate instability pattern (CLIP wrist) where there is laxity of the palmar radioscapohamate ligament in patients in whom dorsal subluxation of the capitate on the lunate and the scaphoid on the scaphoid fossa of the radius could be demonstrated. These patients have features similar to those of patients with DMCI.17

Midcarpal Instability—Extrinsic to Carpus
Extrinsic midcarpal instability is often associated with reversal of the normal volar tilt of the distal articulating surface of the radius. This is most often observed in patients with malunion of a distal radial fracture. Subsequently, the lunate and capitate are tilted dorsally; however, they maintain a collinear relationship with each other on neutral lateral views. With ulnar deviation, the capitate rotates volarly and becomes parallel and slightly dorsally displaced, relative to the shaft of the radius on the lateral view. However, the lunate remains dorsally tilted. The inability of the lunate to rotate volarly with the capitate is thought to cause the pain and clunk associated with extrinsic midcarpal instability.32

Radiocarpal or Proximal Carpal Instabilities
Although a rare occurrence, proximal carpal instabilities are characterized by subluxation or dislocation of the entire carpus in a dorsal, palmar, ulnar, or radial direction relative to the distal radius. Dorsal and palmar instabilities are most commonly related to trauma and ulnar dislocations are related to ligamentous laxity. Radiocarpal translocations have not been reported.32

Dorsal carpal instabilities may appear as an isolated finding or in association with Colles’ or Barton’s fractures, which result in either dorsal tilt of the distal radial articular surface or dorsal displacement of the dorsal lip. Palmar carpal instabilities are less common, as one might expect, given their association with the rare palmar or reverse Barton’s fracture. This results in increased palmar tilt or displacement of the articular surface. Both are treated with osteotomy to correct the malalignment.38,39

Ulnar carpal instabilities are generally from capsular injury or any type of synovitis, such as rheumatoid arthritis resulting in weakening and laxity of the extrinsic ligaments.33 This allows the carpus to “migrate down the inclined plane of the distal radius in an ulnar direction”33 (Fig. 59). A diagnostic feature is an abnormally wide space between the radial styloid process and the scaphoid29 as the carpus begins to slide ulnarly along the radius. The scapholunate angle is less than 30°. PA views show that the lunate overlaps the capitate. Shift of the entire carpus dorsal to the midpoint of the distal radial articular surface is seen.1

Distal Radioulnar Joint Instability
Anatomically, in full supination, the ulnar head rests on the palmar aspect of the notch, and in full pronation, it rests against the dorsal lip of the notch.2 Acute injuries of the distal radioulnar joint (DRUJ) frequently go undiagnosed or misdiagnosed. Early recognition of DRUJ injury is crucial to effective treatment because chronic DRUJ conditions are much more difficult to manage.30 Injuries to the DRUJ can involve trauma to the bone, joint, and the surrounding soft tissues.
DRUJ Dislocation/Subluxation

DRUJ dislocations have been reported as isolated injuries as well as with Galeazzi fractures, Essex-Lopresti injuries, both bone forearm fractures, distal radius fractures, fracture-dislocation of the elbow, and in plastic deformation of the forearm. DRUJ dislocation can be categorized as simple (reduces spontaneously or with minimal manipulation), or complex (irreducible, incomplete reduction, or interposition of soft tissue or bone). Isolated dislocations of the inferior radioulnar joint are uncommon, usually resulting from significant rotatory force applied to the forearm about a fixed hand, as in a fall or twisting injury. At the distal radioulnar articulation, dislocations of the ulna most often occur in a distal, dorsal, and medial direction; volar dislocation is less frequent. Most dislocations of this articulation occur in conjunction with Galeazzi fractures, short oblique, or transverse fractures that occur at the junction of the middle and distal third of the radius accompanied by dislocation of the DRUJ. An Essex-Lopresti injury is a fracture or fracture-dislocation of the radial head associated with disruption of the interosseous membrane between the radius and ulna and dislocation of the DRUJ. DRUJ injuries also occur with distal radius fractures. Poor results following treatment of distal radius fractures with symptoms at the distal radioulnar joint are typically from chronic disruption of the TFCC, ulnar abutment due to radial shortening, posttraumatic arthritis of the distal radioulnar joint, and/or persistent instability or dislocation of the DRUJ.

Radiographic findings of distal radioulnar dislocation include (1) abnormal rotation of the ulna with the ulnar styloid overlying the central portion of the distal ulna on the PA radiograph; (2) widening of the radioulnar distance on the PA view in ulna dorsal dislocations; (3) superimposition of the radius and ulna on the PA view in ulna ventral dislocations; and (4) posterior or anterior (less common) displacement of the ulna on lateral radiographs. Unfortunately, detection of subluxation on radiographs may be quite difficult because slight variations in wrist position alter the relationship of the radius and ulna. Because of the difficulty in demonstrating the anatomy of the distal radioulnar joint on routine radiographs, the associated complex injuries that occur, and the infrequent occurrence of isolated subluxations or dislocations, CT of the bilateral wrists in neutral, pronated, and supinated positions may be utilized to confirm the diagnosis.

Due to the fact that DRUJ dislocation or subluxation may not occur until the patient reaches the extremes of pronation or supination, most institutions study the DRUJ in full pronation, neutral position, and in full supination. The asymptomatic wrist is included in the same positions. On transaxial views, DRUJ dislocation is confirmed when the ulna is displaced posteriorly or anteriorly, or rotated volarly or dorsally. The ulnar styloid process is no longer in line with the midportion of the distal radius. On coronal views, DRUJ dislocation is confirmed when the ulna is displaced posteriorly or anteriorly, or rotated volarly or dorsally. The ulnar styloid process is no longer in line with the midportion of the distal radius. On sagittal views, DRUJ dislocation is confirmed when the ulna is displaced posteriorly or anteriorly, or rotated volarly or dorsally. The ulnar styloid process is no longer in line with the midportion of the distal radius.
ial images, there are methods of objective CT or MR evaluation of the position of the ulna relative to the radius. The methods (Fig. 61) require construction of a number of lines that are drawn along the radius and ulna. In one method, a line is drawn through the dorsoulnar and dorso-radial aspects of the radius and another line is drawn through the palmoulnar and palmaradial aspects of the radius; the congruent ulnar head should lie between these two divergent lines.\(^5\)\(^6\) (Fig. 61A). If the ulnar head crosses the respective dorsal or palmar line, subluxation in a dorsal or palmar direction is diagnosed. Another method is the epicenter method.\(^4\) In this method, with the DRUJ in supination, a perpendicular line is drawn from the midpoint between the center of the ulnar head and the ulnar styloid (center of DRUJ rotation) to the chord of the sigmoid notch falls in the center of the sigmoid notch. (C) With the arm in pronation, the arcs of the sigmoid notch and the ulnar head should be congruous. (Reprinted with permission.)\(^5\)

In equivocal cases, arthrography of the radiocarpal joint can be helpful in establishing the diagnosis, as disruption of the inferior radioulnar joint requires injury to one or more components of the TFCC, the major stabilizing structure of the distal portion of the ulna.\(^1\) On arthrographic images, contrast opacification of the radiocarpal joint will be associated with filling of the inferior radioulnar joint as a result of perforation or detachment of the intervening articular cartilage (Fig. 62).

**Triangular Fibrocartilage Complex Tears**

Pathologic conditions affecting the TFCC can be categorized as traumatic or degenerative and Palmer has devised a system for categorizing the abnormalities\(^4\)\(^2\) (Table 1). Lesions of the TFCC are variable in location; they may be confined to the horizontal, or flat, portion of the TFCC (referred to as the TFC or articular disc) or involve one or more components of the TFCC with or without instability of the distal radioulnar joint.

| Table 1 Palmer Classification of TFCC Abnormalities\(^4\)\(^2\) |
|-----------------|-------------------------------------------------|
| **Class 1. Traumatic**              |  |
| A. Central perforation |  |
| B. Ulnar avulsion |  |
| C. Distal avulsion |  |
| D. Radial avulsion |  |
| **Class 2. Degenerative (ulnocarpal abutment syndrome)** |  |
| A. TFCC wear |  |
| B. TFCC perforation (lunate +/or ulnar chondromalacia) |  |
| C. TFCC perforation (lunate +/or ulnar chondromalacia) |  |
| D. TFCC perforation (chondromalacia + lunotriquetral ligament perforation) |  |
| E. TFCC perforation (chondromalacia, ligament perforation, ulnocarpal arthritis) |  |

Traumatic and degenerative TFCC abnormalities/tears exist and are listed according to the most often used classification system described by Palmer.\(^4\)\(^2\)
Degenerative lesions of the TFCC are more common than traumatic lesions and are thought of as chronic injuries resulting from load on the ulnar side of the wrist. Anatomic studies have shown that perforation of the TFCC occurs in approximately one-third to one-half of cadaveric specimens, perhaps due to degenerative changes.

Radiography is not useful in characterization of TFCC abnormalities. However, there are radiographic findings that are associated with abnormalities of the complex, such as positive ulnar variance, the presence of an ulnar base fracture associated with proximal detachment of the TFCC, and avulsion fracture of the fovea of the ulna indicating injury at the site of attachment of the proximal lamina of the TFCC.

The role of arthrography in the diagnosis of TFCC defects is well established, although there is some disagreement regarding the optimal technique for compartmental injection. Nonetheless, the terms communicating (full-thickness) and noncommunicating (partial thickness) defects are used in discussion of TFCC abnormalities. The presence of contrast material in the DRUJ after radiocarpal opacification or in the radiocarpal compartment after DRUJ injection is diagnostic of a communicating defect in the TFC (articular disc) (see Fig. 62). Noncommunicating, or partial, defects involving the proximal and distal aspects of the TFC can be demonstrated following injection of the DRUJ and radiocarpal joint, respectively. Other traumatic abnormalities that involve the TFCC attachments, as described by Palmer, may be associated with distinctive arthrographic findings. At this time, arthrography and state-of-the-art MR imaging can be considered equally accurate in assessment of defects of the TFCC.

Ulnar Abutment Syndrome

The ulna abutment syndrome, also termed ulnocarpal abutment, ulnar impaction syndrome, and ulnolunate impaction syndrome, is a degenerative condition related to excessive load-bearing across the ulnar side of the wrist. It is most often due to altered mechanics from ulnar elongation relative to the radius (positive ulnar variance). Patients present with ulnar wrist pain, swelling, crepitus, and limited wrist motion. The condition is caused by chronic impaction of the ulnar head against the TFCC and ulnar-sided carpal bones resulting in progressive deterioration of the TFCC, chondromalacia of the lunate and ulna, and attrition of the lunotriquetral interosseous ligament. The ulnar impaction syndrome is almost always associated with a positive ulnar variance. Positive ulnar variance is often idiopathic but can be caused by malunion of a distal radial fracture, premature physeal arrest of the distal radius, or an Essex-Lopresti injury. Although the ulnar impaction syndrome has been identified in patients with neutral or positive ulnar variance, it is not associated with negative ulnar variance.

A routine PA radiograph may demonstrate positive ulnar variance (Fig. 63) and degenerative changes such as joint space narrowing, subchondral sclerosis, or cystic changes in the ulnar head, sigmoid notch, lunate, or triquetrum. An excellent radiographic study for ulnar abutment is to obtain a PA view with the fist clenched in addition to the routine PA view. With a load across the wrist, the ulna moves distal relative to the radius, and this change is often quite noticeable on plain radiographs. Videofluoroscopy can be used to determine whether there truly is an abutment between the distal ulna and the carpus in ulnar impaction syndrome. MR imaging may demonstrate chondromalacia or degenerative arthritis of the ulnar head or carpus, and the lunotriquetral ligament may be perforated.

The syndrome of ulnar abutment or impaction should
be differentiated from the syndrome of ulna impingement, which is generally associated with negative ulnar variance (Fig. 64). Impingement at the level of the DRUJ can occur following surgical resection of the distal ulna, following fracture of the ulnar head or secondary to a malunited sigmoid notch as a sequela of a distal radius fracture.5 The syndrome of impingement may be seen in chronic instability of the DRUJ, infection, inflammatory arthritis, crystalline disease, and primary osteoarthritis.7,46 Ulna impingement syndrome is a degenerative process that leads to DRUJ pathology and pain with supination.

Posttraumatic/Postinstability Arthrosis (SLAC)

A wrist with scapholunate advanced collapse (Fig. 65) has a pattern of osteoarthritis, occurring either spontaneously or after trauma, characterized by narrowing of both the radioscapoid and the capitulonate spaces. Some investigators believe that it is one of the most common patterns of degenerative joint disease in the wrist. The most common etiology of SLAC wrist is rotary subluxation of the scaphoid (RSS) due to scapholunate or periscaphoid dissociation. In addition to RSS, SLAC wrist may be caused by other conditions such as Kienbock’s disease, scaphoid fracture nonunion or malunion, radioscapoid and capitulonate intraarticular fractures, Preiser’s disease (spontaneous osteonecrosis of the scaphoid), and crystalline pyrophosphate deposition disease (CPPD).3 The presence of chondrocalcinosis or other types of intraarticular calcification, the absence of a history of injury, or the presence of radiolunate joint space narrowing, alone or in combination, strongly suggests the diagnosis of CPPD crystal deposition disease.

Triscaphe Arthritis

Triscaphe arthritis (Fig. 66) occurs as a result of load changes and articular abnormalities analogous to those in the SLAC wrist. The destruction of the trapezioscaphoid and trapezoidoscaphoid joints results from disruptions in the ligamentous support of the scaphoid distally. The radial column collapse allows the trapezium and trapezoid to migrate proximally and come to rest on the nonarticular dorsum of the distal scaphoid, immediately proximal to the distal articular cartilage. This, along with any rotational changes and lateral displacement of the distal scaphoid, leads to abnormal shear stresses that result in the degeneration observed.

Congenital/Developmental Conditions

The following topics are congenital or developmental conditions that may lead to wrist pain. The discussion of each entity is brief, and interested readers may consult standard reference textbooks for more detailed information.

Carpal Coalition

Coalition, or carpal fusion, is relatively common and may occur as an isolated phenomenon or as part of a generalized congenital malformation syndrome. As a rule, isolated fusions involve bones in the same carpal row (proximal or distal); fusions related to syndromes may affect bones in different rows (proximal and distal) and massive carpal fusion is usually associated with congenital malformations and anomalies.31 Coalition may be fibrous (Fig. 67) or bony (Fig. 68).

The most common type of isolated fusion is between the triquetrum and the lunate bones, occurring in 0.1 to 1.6% of the general population. The condition is bilateral in approximately 60% of cases.31 The scapholunate interosseous space is frequently widened in cases of lunotriquetral coalition, and, although the SL ligament is generally intact,31 abnormal
widening to more than 3 to 4 mm suggests a scapholunate ligament tear or laxity. Less common isolated fusions have been described in almost all possible combinations, including two or more bones.

Bone cysts adjacent to the coalition are sometimes seen. The changes can usually be differentiated from the acquired ankylosis that may accompany infection, certain arthritides such as juvenile chronic arthritis, and rheumatoid arthritis, trauma, and surgery.

**Osteonecrosis and Osteochondrosis**

**Kienböck’s Disease**

The various synonyms used for this condition (lunatomalacia, aseptic necrosis, avascular necrosis, osteochondritis, traumatic osteoporosis, osteitis) are most likely a reflection of the fact that its exact etiology remains unclear. Early descriptions of Peste and, later on, Kienböck, supported the belief that the lesion is a fracture with a traumatic etiology. Kienböck believed that repeated sprains, contusions, or subluxations led to ligamentous and vascular injury resulting in loss of blood supply to the lunate. Since then, numerous authorities have described the pathologic changes as avascular necrosis. The exact cause and pathogenesis is not definitively known. However, there is the finding of ulna minus variance that has been associated with Kienbock’s disease. Theoretically, a short ulna causes increased shear forces on the ulnar side of the wrist and particularly on the lunate. This is thought to be a contributing factor in the development of avascular necrosis.

Early in the course of Kienböck’s disease, the radiographs may appear normal to slightly dense (Fig. 69). However, a linear or compression fracture can be delineated with CT scanning and MR imaging. Subsequently, increased density of the lunate is noted, followed by altered shape and diminished size of the bone. Eventually, the lunate may collapse and fragment. Later on, complications may develop such as disruption of carpal architecture, scapholunate separation, or dissociation, with disruption of the scapholunate interosseous ligament, ulnar deviation of the triquetrum, and secondary degenerative joint disease in the radiocarpal and midcarpal compartments of the wrist. Tendon rupture resulting from erosion by the irregular and collapsed lunate has been reported.

Many classification systems of Kienböck’s disease have
been proposed. The most popular is a four-stage system described by Lichtman and coworkers that is based on radiographic abnormalities. In stage I, radiographs are usually normal except for possible visualization of a fracture. Unless a compression fracture is visible, this stage is clinically indistinguishable from a wrist sprain. Stage II is when there are abnormalities of radiodensity that are not accompanied by changes in size, shape, and relationships of the carpal bones. In stage III, the lunate bone is collapsed on the PA or AP view and is elongated in the lateral view with abnormalities in carpal bone relationships. The capitate migrates proximally secondary to scapholunate dissociation. To assess the extent of collapse in stage III, the carpal height ratio can be measured (normal ratio = 0.54 ± 0.03). Carpal height ratio is becoming more important, because the results of treatment in stage III are related to the extent of collapse. Stage III is divided into stage IIIA (lunate collapse without fixed rotation of the scaphoid) and stage IIIB (lunate collapse with fixed rotation of the scaphoid and other secondary derangements). Stage IV is when there are changes of osteoarthritis.

Madelung Deformity

Madelung deformity is a developmental growth disturbance of the distal radial physis that manifests clinically during adolescence. The primary deformity is a bowing of the distal end of the radius typically in a volar direction while the ulna continues to grow in a straight fashion. The result is a short radius and a long ulna. It predominantly affects females and is usually bilateral, although one side may be symptomatic. Clinically, the carpus and hand appear to be displaced anterior to the forearm and the distal ulna is dorsally subluxed, forming a prominence that is most marked in pronation. Potential causes of Madelung deformity include dyschondroplasia, enchondromatosis, hereditary multiple exostoses (HME) (Fig. 70), mesomelic dwarfism, and Turner syndrome.

Degenerative Osteoarthritis

Osteoarthritis (OA) is the most common arthropathy seen today. In primary osteoarthritis, the radiographic features include normal mineralization, nonuniform loss of joint space, subchondral new bone formation, osteophyte formation, cysts, subluxation, absence of erosions, and unilateral or bilateral asymmetrical distribution. Primary OA is virtually limited to the first carpometacarpal and the trapeziocapitate joints. Characteristic findings are seen (Fig. 71) as follows: (1) at the first carpometacarpal joint, there is radial subluxation of the metacarpal base; (2) osteophyte formation occurs between the base of the first and second metacarpals; and (3) at the trapeziocapitate area, joint space narrowing and eburnation may be the only findings.

Osteoarthritic changes involving any other joint in the wrist should be considered secondary to another arthropathy or to accidental or occupational trauma. In the posttraumatic setting, more widespread involvement of the wrist may be observed. Abnormalities of the radiocarpal and midcarpal compartments can follow a scaphoid fracture or Kienbock’s disease; changes at the DRUJ can appear following subluxation or dislocation, and abnormalities of the radiocarpal and midcarpal areas can be observed in pneumatic tool operators or professional athletes. As the degenerative joint disease worsens and becomes more widespread, there may be eventual development of SLAC.

In secondary osteoarthritis, the joint space loss is uniform as this type of arthritis develops secondary to an underlying cartilage problem. The uniform involvement distinguishes...
secondary osteoarthritis from primary OA where there is nonuniform joint space loss.

Infectious Diseases

Bacteria Soft-Tissue Infection

Infection may be derived from hematogenous seeding, spread from a contiguous source, direct implantation, or operative contamination. An infection can gain access to the wrist through the hand. Three routes of wrist extension of infection are via tendon sheaths, fascial planes, or lymphatics, with the tendon sheaths being the primary route of contamination.\textsuperscript{19} Particularly in the first and fifth digits, the synovial sheaths surrounding the flexor tendons of the hand allow extension of infection to the radial and ulnar bursae. As a result of contamination of the fifth finger, ulnar bursa, radial bursa, and first finger, a characteristic “horseshoe abscess” may develop.\textsuperscript{19} In the dorsum of the wrist, infection usually occurs in the subcutaneous or subaponeurotic space. However, the less frequent occurrence of infected extensor tenosynovitis can contaminate the wrist\textsuperscript{19} (Fig. 72). On radiographs, diffuse soft-tissue swelling (Fig. 73), osteoporosis, and articular and osseous destruction are evident.

Infections in the fascial planes of the hand are numerous. However, they result in wrist joint or bone alterations less frequently than those via the synovial sheaths.\textsuperscript{19} Lymphangitis may result from superficial injuries with rapid extension producing widespread swelling. In some cases, tenosynovitis, septicemia, osteomyelitis, and septic arthritis may result.

Bacterial Osseous Infection

In acute hematogenous osteomyelitis, males are affected more commonly, and a history of trauma or recent infection is often obtained.\textsuperscript{51} In the neonate or infant, \textit{Staphylococcus aureus}, group B streptococcus, and \textit{Escherichia coli} are the bone isolates recovered most frequently; in children older than 1 year of age, \textit{S. aureus}, \textit{Streptococcus pyogenes}, and \textit{Haemophilus influenzae} are responsible for most cases of hematogenous osteomyelitis. Gram-negative organisms assume importance as pathogens in bone and joint infections in adults and in intravenous drug abusers. An acute or chronic

Figure 72. Abscess and tenosynovitis demonstrated with MR imaging. (A) Coronal T2-weighted MR image of the hand and wrist demonstrating heterogeneous high signal intensity tenosynovitis (circle) with synovial sheath extension of synovitis and infection from the hand into the wrist (arrows). (B) Sagittal T1-weighted MR image following intravenous administration of a gadolinium compound shows rim-enhancing flexor synovial sheath and adjacent abscess (box).

Figure 73. Dorsal hand infection. (A) Lateral view of the hand in a patient with dorsal soft-tissue cellulitis demonstrated as dorsal soft-tissue swelling (asterisks). (B) In a different patient, an infection has progressed to involve the extensor carpi ulnaris with associated soft-tissue swelling (asterisks) identified on a PA view. Osteopenia of the ulnar styloid is consistent with early osseous destruction (arrow).

Figure 74. Radiographic findings in osteomyelitis and septic arthritis. A PA wrist view shows soft-tissue swelling and obliteration of tissue planes. Joint space loss, osteolysis, and marginal and central osseous erosions involve the distal aspect of the radius and ulna and multiple carpal bones.
respiratory tract infection is important in the pathogenesis of tuberculous, fungal, and pneumococcal osteomyelitis. The route of hematogenous bacterial seeding very much depends on the age of the patient. In a child, a metaphyseal focus is frequent as the growth plate acts as a barrier. From this site, cortical penetration can result in a subperiosteal abscess in those locations in which the growth plate is extraarticular or in a septic joint in those locations in which the growth plate is intraarticular. Because the distal radial and ulnar metaphyses are extraarticular, secondary joint involvement does not occur as a rule. In children, the radius and ulna are affected in 5 to 9% of cases. In the infant (<1-year-old), a metaphyseal focus may be complicated by epiphyseal extension owing to the vascular anatomy in this age group. In the adult, a subchondral focus in an epiphysis is not unusual owing to the vascular anatomy in this older age group (Fig. 74). In general, carpal bone osteomyelitis is extremely rare.

The radiographic findings of osteomyelitis (Figs. 74 and 75) (including abscess, involucrum, and sequestration), septic arthritis (including joint space loss and marginal and central osseous erosions), and soft-tissue suppuration (including swelling, radiolucent streaks, and periostitis) are generally delayed for a variable period after the clinical onset of infection. Radiographs are nonspecific in the early stages, showing soft-tissue swelling and obliteration of tissue planes. After 10 days or so, diffuse or focal osteopenia, periostal elevation, and new bone formation are seen. Localized cortical and medullary abscesses may be seen as single or multiple radiolucent cortical or medullary lesions with surrounding sclerosis. Cortical necrosis and sequestra formation may occur followed by sinus tract formation. Other diagnostic techniques, including scintigraphy and MR imaging (Fig. 76), allow accurate diagnosis at an earlier stage of the process.

Atypical Infections
The wrist is the most commonly affected site in atypical mycobacterial infections. Children are affected less frequently than adults. The usual presentation is as a chronic extensor or flexor tenosynovitis, with joint involvement in some cases. There is a firm or boggy swelling with minimal tenderness and inflammation. Diagnosis may be delayed for several months. Infection with Mycobacterium fortuitum can occur following penetrating wounds and steroid injections, whereas infection with Mycobacterium marinum or Mycobacterium terrae may occur following exposure to a marine or farm environment, respectively. Mycobacterium kansasii and Mycobacterium aviumintracellularare appear to be the most commonly isolated pathogens in deep mycobacterial infections. Mycobacterium tuberculosis infection occurs less commonly at the wrist than at other sites, such as the spine and hip, although the clinical presentation is similar. In cases of wrist involvement, dactylitis involving the metacarpals may present as a swollen wrist. Successful treatment of mycobacterial infection consists of surgical debridement in conjunction with long-term antibiotic therapy.

Besides atypical mycobacterial infections, cutaneous, tendon sheath, and joint infection may be caused by Sporothrix schenckii. Bacteroides infection may follow a human bite wound. In the immunocompromised patient, a variety of unusual bacterial, mycobacterial, and fungal infections may occur and are often difficult to eradicate (Fig. 75).

Chronic recurrent multifocal osteomyelitis is an inflammatory disorder of unknown origin affecting the skeletally immature. It is characterized by repeated episodes of fever, local pain, and swelling over the metaphyseal region of tubular bones and the clavicle. The radiographic appearance is similar to that of osteomyelitis (Fig. 77). Antibiotics produce no response. The condition is treated with anti-inflammatory agents and it usually shows eventual spontaneous remission.
Tumors and Tumor-like Diseases

With the exception of ganglion cysts, tumors and tumor-like conditions of the wrist are uncommon. As is true of the hand, most tumors that occur in or about the wrist are benign, although malignancies do appear on occasion. All ages may be affected and the size of the lesion is not a clue as to whether the lesion is benign or malignant. Tumor-like lesions may be associated with a generalized metabolic disorder, such as in gout or xanthomatosis; or may develop following trauma as in a foreign body reaction or granuloma.59

Osseous—Benign

Lytic lesions are very common in the carpal bones. If cystic, radiographically, they usually appear as rounded lucencies that are sharply demarcated by a thin margin of sclerosis. They usually contain mucinous material and probably represent degenerative cysts. Occasionally, they are called “intrasosseous ganglia” because they originate in the same location as the routine ganglia and represent remodeling of the bone and capsular tissues.60 Cartilaginous lesions, such as enchondromas, are relatively common (Fig. 78) and are often seen in conjunction with enchondromas in the hand.

A variety of bone lesions occur in the radius and ulna. The distal aspect of the radius is one of the more common locations for occurrence of a giant cell tumor; the ulna is somewhat less common. Radiographically, extensive osteoclastic resorption and remodeling is seen with an irregular, thin shell of expanded bone and periosteum (Fig. 79). Osteochondromas can occur in the wrist and may involve the radius, ulna, or carpal bones. Multiple osteochondromas may be seen in the heritable condition of osteochondromatosis (Fig. 70). Rarely, epiphyseal osteochondromas (Trevor’s disease) may be a source of wrist pain (Fig. 80).

Osteoblastic lesions vary from the benign bone island or osteoma to aggressive, fortunately rare, osteosarcoma. Bone islands (enostoses) are common, can occur in any carpal bone, are usually asymptomatic, and are picked up as incidental findings. Occasionally, one may show increased radioisotopic uptake on a bone scan. However, more commonly, increased uptake represents a more active process, such as an osteoid osteoma.

Osteoid osteoma (Fig. 81) is not an infrequent finding in the wrist area. It usually manifests as pain that is relieved by salicylates. Conventional radiography, CT scanning, or MR
imaging may delineate the nidus. It is not unusual for symptoms to be present for a year or more before a diagnosis is made. Radiothermal ablation of the nidus is curative.

**Osseous—Malignant**

Primary skeletal malignancies of the carpus are rare. As in malignancies elsewhere, control of the primary tumor is usually surgical. However, due to the central location of the wrist, in terms of structures passing from the forearm to the hand, a localized limb-sparing resection is seldom feasible. 59 MR imaging has become essential in staging of primary malignancies to determine whether the tumor is retained within a compartment or if metastasis is present.

Although reports of metastatic tumors of the bones of the wrist and hand are quite uncommon, a large number of malignant tumors of the wrist are metastatic. 61 There is no specific predilection for any given primary tumor to metastasize to the bones of the wrist. The incidence of any type tends to match that of the tumors that metastasize to bone (ie, breast, lung, kidney). When tumors do metastasize to the carpus, they tend to cause destruction in several bones simultaneously, which is often a clue to the aggressive nature of the process. Generally, the tumor is treated systemically, although occasionally, a local approach may be necessary for diagnostic reasons and for stabilization or pain relief. 59

**Soft Tissue—Benign**

In all reported series, the dorsal wrist ganglion cyst arising from the capsule over the scapholunate joint is the most common tumor of the hand/wrist. It may appear as a painless mass in patients of any age; however, it tends to occur during the third to fifth decades. Women are more commonly affected and there may be a history of prior trauma. On the volar side, most ganglia originate from the joint capsule (Fig. 82) and some originate from the trapezioscaphoid joint. Fre-

![Figure 80](image1) Trevor’s disease. PA wrist view shows enlargement and sclerosis/calcification of the radial epiphysis due to the presence of an osteochondroma (arrow).

![Figure 81](image2) Osteoid osteoma. A PA view illustrates a focal sclerotic nidus of an osteoid osteoma within the capitate (arrow), surrounded by dense-appearing bone. C = capitate, H = hamate.

![Figure 82](image3) Volar soft-tissue ganglion cyst. (A) Lateral and (B) PA views of the wrist depict a volar, radial side soft tissue mass (arrows).
quently, they appear near the radial artery and cause compression of the artery or distort its path. These lesions may be found in the carpal tunnel or in Guyon’s canal.59 The exact etiology of ganglia is still unknown. The most commonly accepted theory involves remodeling of the fibrous capsular tissue of the joint. Collagen fiber breakdown products and intercellular mucin collect and as these collections coalesce, expand, and dissect their way toward the subcutaneous tissues, a fibrous pseudocapsule is created.63

Lipomas may involve the wrist by way of extension from the hand or the forearm and appear as deep or superficial lesions (Fig. 83). Not uncommonly they may be found during carpal tunnel release procedures. There are reports of large lipomas in the median nerve.64 Radiographically, lipomas in the wrist have the typical density of fat, unless they undergo metaplastic change and appear as a mixture of fat and myxoid material, or undergo osseous metaplasia following trauma.59

Giant cell tumors of the tendon sheath are slow growing, painless masses that may arise in association with synovial tissue of the joints or tendon sheaths on the flexor or extensor side of the wrist (Fig. 84). These benign growths contain numerous histiocytes and foreign body giant cells adjacent to hemosiderin deposits from minor bleeding episodes secondary to trauma.59

Vascular lesions more commonly include hemangiomas (Fig. 85), arteriovenous shunts (congenital or acquired), thromboses (after intravenous infusions or following trauma), or aneurysms (following repetitive trauma).99 Glomus tumors have been described in the carpal area.62

One of the more common lesions in the wrist is a neuroma caused by trauma following operative section of a nerve, presenting as a tender mass. Neuromas of the superficial radial and palmar cutaneous branch of the median nerve are particularly problematic.59 A neurofibroma or a neurilemoma may occur in any of the nerves at the wrist. Neurilemomas arise from Schwann cells and are composed of two types of tissue; a cellular type and a myxomatous or cystic type, and they are easily removed. On the other hand, neurofibromas originate from the fibrous tissue of the epineurium or endoneurium, are more infiltrative between nerve bundles, and are difficult to remove without causing damage to the nerve of origin.59

Fibrous lesions can occur in the skin or subdermal soft tissues. They are relatively common lesions, may be single or multiple, and are locally invasive. They may or may not have fine stippled calcifications.59 A not-so-common, but interesting le-
Fibrolipomatous hamartoma (Fig. 86), is a hamartomatous enlargement of the median nerve. It has been associated with macrodactyly of the fingers or overgrowth of portions of the hand, a condition known as, "macrodystrophia lipomatosa." 65,66

Synovial/Inflammatory Diseases: Arthritis

Imaging modalities that may be utilized for the evaluation of articular disease include conventional radiography, computed tomography, scintigraphy, ultrasonography, and magnetic resonance imaging. Evaluation of articular disease should always begin with conventional radiography. If quality films are obtained (appropriate patient positioning in at least two orthogonal planes), the extent and severity of joint involvement, and the disease progression or regression may be documented. In some cases, special views may be utilized to evaluate for specific joint involvement. Although PA and AP oblique (Norgaard) radiographs of the hands are the most informative for evaluation of arthritis, the wrist may show characteristic changes on these views as well. The PA view provides for evaluation of mineralization and soft-tissue involvement. In the Norgaard view of the wrist, the pisiform and the hamate are well demonstrated, and this view profiles the triquetrum-pisiform joint. 13,50

Rheumatoid Arthritis

In rheumatoid arthritis, the earliest radiographic changes are symmetric periarticular soft-tissue swelling and juxta-articular osteoporosis. Although these changes are nonspecific, they help support any clinical suspicion of an underlying inflammatory problem. On the PA view, early erosions in the wrist may be seen in specific locations, namely, the waist of the navicular, the waist of the capitate, the articulation of the hamate with the base of the small finger metacarpal, the articulation of the thumb metacarpal with the trapezium, the radial styloid, and the ulnar styloid.13

As the disease progresses (Fig. 87), there is pancompartmental loss of cartilage and joint spaces of the wrist; the soft-tissue swelling decreases, and the juxta-articular osteoporosis becomes diffuse. The initial subtle marginal erosions eventually become large subchondral erosions. Subcutaneous rheumatoid nodules may develop in 25% of the patients, without bone destruction.13 As arthritis mutilans develops (Fig. 88), there is lack of any recognizable joint space as bone ankylosis occurs.

One interesting finding that occurs at the wrist in patients with rheumatoid arthritis is the “caput ulnae syndrome.” The syndrome consists of pain, limited motion, and dorsal prominence of the distal end of an eroded ulna. The eroded and abnormally located ulnar head impinges into the extensor tendon compartments on the dorsum of the wrist. This produces fraying of the surfaces of the tendons in association with tenosynovitis, a situation that leads to weakening of the tendons with subsequent rupture of the tendons beginning on the ulnar side of the wrist.67

In evaluation of the wrist, MR imaging has not yet replaced quality conventional radiography, although rheumatoid ar-

Figure 86 Fibrolipomatous hamartoma in a 22-year-old male. (A) A T1-weighted axial MR image shows marked enlargement of the median nerve with multiple intermediate and low signal intensity longitudinal tubular regions (arrows), creating the appearance of a cable. (B) The corresponding T2-weighted axial image demonstrates the tubular regions as high signal intensity (arrows) with interspersed areas of low signal intensity. (C) A gadolinium enhanced axial image shows inhomogeneous bright enhancement of the lesion (arrows). (Courtesy of Donald Resnick, MD San Diego, CA.)

Figure 87 Progressive changes in rheumatoid arthritis. A PA view of the wrist in a patient with RA shows progressive marginal erosions that progressively involved more and more of the articular surface to become large subchondral erosions.
Arthritis has been the arthropathy most extensively studied by MR imaging. MR imaging can demonstrate synovitis, tenosynovitis, erosion, synovial cyst formation, bursitis, tendon rupture, and fibrocartilaginous degeneration associated with rheumatoid arthritis. The literature states that MR imaging may show erosions earlier than plain films and offers the potential of directly demonstrating the extent of synovial hypertrophy and cartilage destruction. The MR image demonstration of the synovium may be very important to the rheumatologist, if the physical examination is equivocal in determining the effect of a particular treatment regimen. Synovium may demonstrate intermediate signal intensity on T1-weighted images relative to the low signal intensity of adjacent fluid and show intermediate signal intensity on T2-weighted images compared with the relatively high signal of an effusion. However, frequently, synovium cannot be differentiated from effusion without use of intravenous gadolinium. Active synovitis enhances following the administration of gadolinium. However, the affected joint must be imaged immediately, as gadolinium will diffuse into the joint if imaging is delayed.

Psoriatic Arthritis

In the hands or wrists, the hallmarks of this disorder are bilateral asymmetrical distribution of soft-tissue swelling, normal mineralization (following the initial stage of the disease), joint space loss (sometimes dramatic), bone proliferation (adjacent to erosions, along shafts, across joints, and at tendon and ligament insertions), and erosions (usually DIP or PIP joints). In the wrist, psoriatic arthritis may appear in the carpal bones in conjunction with ray involvement or it may appear only in the wrist in a pattern similar to that observed in rheumatoid arthritis. In the latter pattern, other features will distinguish psoriatic arthritis from rheumatoid arthritis (ie, usually DIP and/or PIP involvement and/or evidence of bone proliferation in psoriatic arthropathy).

Reiter’s Disease

The classic radiographic features of Reiter’s disease (Fig. 90) are identical to those of psoriatic arthritis with the erosive disease and bone formation being the predominant findings. However, the hands and wrists are less frequently involved in Reiter’s than in psoriatic arthropathy. When the upper extremity is affected, the hand is the most common area of involvement.
Crystal-Induced and Related Diseases

CPPD crystal deposition disease is a common disorder and the most common crystal arthropathy. CPPD crystals deposit in hyaline and fibrous cartilage, producing a radiographic picture of calcified cartilage (chondrocalcinosis). It is seen most frequently in the knee, pubic symphysis, and wrist, with the hips, shoulder, and elbow involved in decreasing order of frequency. The radiographic diagnosis can be made when two or more different joints (one wrist and one knee, not two wrists or two knees) in the skeleton demonstrate chondrocalcinosis. The radiographic picture varies from chondrocalcinosis alone to severe arthropathy (Figs. 91 and 92). When arthropathy occurs, the radiographic picture of CPPD crystal deposition disease resembles that of osteoarthritis. The arthropathy of the wrist most commonly affects the radiocarpal joint. There is typically uniform joint space loss, subchondral new bone formation, and cyst formation, with the changes in distribution different from that of primary OA. Normal mineralization, variable osteophyte formation, cyst formation (more prominent than in OA), and bilateral distribution are other typical features of the arthropathy. The wrist arthropathy is found in 70% of patients with the disease and chondrocalcinosis is found in 65% of the patients. Chondrocalcinosis is most frequently encountered in the triangular fibrocartilage and/or the hyaline cartilage between the lunate and the triquetrum. This may lead to SL ligamentous disruption with subsequent SL disassociation. If there is SL dissociation, there may be associated narrowing of the capitolunate joint space. The characteristic appearance of these latter findings has been described as a “stepladder” configuration. The only other two diseases known to cause deposition of CPPD crystals in cartilage, other than idiopathic CPPD crystal deposition disease, are hyperparathyroidism and hemochromatosis.

In the wrist, gout affects the bone, joint, or soft tissue in a sporadic, asymmetrical fashion. The radiographic changes of the disease occur in response to urate crystals that deposit in tissues such as cartilage, tendon sheaths, and bursa. If the urate crystals deposit in cartilage, the primary radiographic picture is that of osteoarthritis. Mineralization is maintained. There may be pancompartmental involvement of the wrist; however, frequently there is preferential involvement of the carpometacarpal joints with erosive change (Fig. 93). Many of the erosions have sclerotic borders and often there are overhanging edges of cortex (Fig. 94). The joint space may or may not be preserved, although gout is one of the few arthropathies that is known for causing significant changes around the joint while maintaining the joint space.

Figure 91. Chondrocalcinosis in CPPD. Chondrocalcinosis is most frequently encountered in the triangular fibrocartilage (arrow) and/or the hyaline cartilage between the lunate and the triquetrum (double arrow) and that between the scaphoid and lunate (hatched arrow). scaphoid = S, lunate = L, triquetrum = tq, capitate = C.

Figure 92. Calcium pyrophosphate dihydrate (CPPD) crystal deposition disease. There is typically uniform joint space loss, subchondral new bone formation, and cyst formation (arrows), with the changes in a distribution different from that of primary OA.

Figure 93. Gout. There is preferential involvement of the carpometacarpal joints with erosive changes (arrows) seen in this patient with longstanding gout.
may see irregular bone spicules at sites of tendon and ligamentous attachment. Enlargement of ends of bones may also occur. If urate deposits in soft tissue, chronic tophaceous gout will result (Fig. 94). A tophus deposited on the extensor aspect of a joint may cause significant erosive change of the dorsal aspect of the joint while preserving the flexor side.13

Hydroxyapatite depositional disease is an extremely common disorder that primarily causes periarticular disease. The wrist is involved more frequently than the hand. There may be bilateral, polyarticular involvement. Calcium hydroxyapatite crystals may deposit in bursae, tendons, musculotendinous junctions, ligaments, and within soft tissues of the wrist producing bursitis, tendinopathy, or carpal tunnel syndrome.70,71 Calcific deposits may be seen, most commonly, in or about the tendon of the flexor carpi ulnaris (adjacent to the pisiform) (Fig. 95).72 Deposits also occur in or near the tendons of the flexor carpi radialis (on the volar side of the radiocarpal joint), common flexors (near the volar aspect of the wrist), and the extensor carpi ulnaris (adjacent to the distal end of the ulna).70 The crystals may be poorly defined or well defined. Calcific deposits are often described in various systemic diseases, such as scleroderma, dermatomyositis, renal osteodystrophy (Fig. 96), hypervitaminosis D, and milk-alkali syndrome.13 When there is no underlying systemic disease, the entity is known as hydroxyapatite deposition disease (HADD). In the triangular fibrocartilage complex, hydroxyapatite deposition may simulate the appearance of CPPD crystal deposition.70 Possible complications of calcium hydroxyapatite deposition within the tendon sheaths or tendons include tendon rupture and intraarticular extension of the calcification, resulting in articular disease, on rare occasion.13

Rare deposition diseases that may affect the wrist are hemochromatosis and Wilson’s disease. These disorders have all been associated with chondrocalcinosis. Whether or not it is true that CPPD crystal deposits in the hyaline or fibrous cartilage or some other substance, degeneration and secondary osteoarthritis occur.13 Radiographically, each of the diseases has distinguishing features.

Hemochromatosis, a rare disease leading to marked iron deposition throughout the body, is almost identical to that of CPPD crystal deposition in that there is osteoarthritis in atypical sites compared with primary OA. Characteristic findings in the hand specifically involve the second and third metacarpophalangeal joints. There may or may not be involvement of the wrist. However, if the wrist is involved (Fig. 97), there is usually involvement of the common carpometacarpal, midcarpal, and/or the first carpometacarpal compartments, with sparing of the radiocarpal compartment.13 The changes observed are those of atypical OA or CPPD crystal deposition disease.

Wilson’s disease is extremely rare. Copper is the substance that is abnormally deposited in various tissues. Radiographically, chondrocalcinosis may be observed. However, it remains unclear whether the calcification seen is secondary to true CPPD crystals or bone fragmentation in the joint.13 In approximately 50% of patients, an arthropathy occurs. The arthropathy is distinctive as there is marked irregularity of
the cortex and subchondral bone giving a “paint brush” appearance.\textsuperscript{15} Due to significant subchondral bone fragmentation, the condition may appear as osteochondritis dissecans. Ossicles may be seen in the joint (Fig. 98).\textsuperscript{13} The arthropathy otherwise resembles primary osteoarthritis in an atypical distribution.

**Erosive Osteoarthritis**

Erosive osteoarthritis (OA) is an inflammatory condition that is superimposed on underlying osteoarthritic changes. It is most often described in postmenopausal females. Radiographically, erosive osteoarthritis is similar to primary OA in distribution in the wrist. However, the inflammatory component of erosive OA causes periarticular soft-tissue swelling (during the acute phase) and central gull wing erosions. Eventual ankylosis may ensue.

**Connective Tissue Disorders**

The collagen vascular diseases (connective tissue diseases) are a group of conditions that have multisystem involvement. For the most part, the articular symptoms play a minor role in each condition. However, there are distinctive features in each disease.

**Systemic Lupus Erythematosus**

Systemic lupus erythematosus (SLE) is the most common of the collagen vascular diseases and it is associated with articular symptoms in 75 to 90% of affected individuals.\textsuperscript{13,73} Most often, this disease is described as a bilateral deforming nonerosive arthritis (Fig. 99). Soft-tissue swelling may be seen early in the disease, followed by soft-tissue atrophy. Juxtaarticular osteoporosis is observed with eventual diffuse demineralization. Reducible subluxation and/or dislocation without erosions are the hallmark of SLE.\textsuperscript{13,73}

Osteonecrosis is a feature of SLE, whether or not the patient is receiving or has received steroid treatment. It usually occurs bilaterally and asymmetrically.\textsuperscript{13} As in osteonecrosis secondary to other etiologies, the radiographic findings are similar. Initial osteoporosis may or may not be appreciated radiographically. The first radiographic change that may be observed is an ill-defined increased bone density surrounded by osteoporosis creating a “smudgy” appearance.\textsuperscript{13} As the condition progresses, a subchondral lucency is seen due to subchondral fragmentation. This is followed by articular sur-
face deformity, collapse, and eventual secondary osteoarthritis.

Calcification is the third typical but nonspecific feature of SLE. It may be present in the subcutaneous tissues and may appear as linear and streaky density.

Scleroderma and Dermatomyositis

Approximately 46% of patients with scleroderma have articular symptoms. The radiographic findings appear to be limited primarily to the hands and secondarily to the wrist. In the wrist, the findings are resorption of soft tissue and amorphous subcutaneous calcification (Fig. 100).

Dermatomyositis is most commonly associated with the radiographic abnormality of soft-tissue calcification. The calcification is usually along the intermuscular fascial planes and may be seen within the subcutaneous tissues and about joints. At times, transient osteoporosis may be seen.

Mixed Connective Tissue Disease

Mixed connective tissue disease (MCTD) is a disease that is made up by a combination of collagen vascular diseases, such as SLE, scleroderma, and/or rheumatoid arthritis. The radiographic features of this combined disorder are an “overlap” of findings observed in each condition. To make the radiographic diagnosis, one should identify at least one feature of a specific arthritis and one feature of another type of arthritis. Some patients display a unique feature of preferential ankylosis of the capitate to the trapezoid.

Juvenile Chronic Arthritis

Juvenile chronic arthritis (JCA) includes juvenile-onset ankylosing spondylitis, psoriatic arthritis of inflammatory bowel disease, juvenile-onset adult-type (seropositive) rheumatoid arthritis, and Still’s disease (seronegative chronic arthritis). All of these disorders, except for Still’s disease, tend to occur in older children and therefore usually behave like their adult counterpart. Juvenile-onset adult-type (seropositive) rheumatoid arthritis differs from adult rheumatoid arthritis in two ways. First, a periostitis is frequently present in the metaphyses of the phalanges, metacarpals, and metatarsals. Second, there is significant erosive disease without joint space loss.

Still’s disease (seronegative chronic arthritis) makes up 70% of the cases of JCA. The radiographic changes are those of chronic inflammation and hyperemia in a joint that is undergoing growth and change; the radiographic changes are as follows:

1. Periarticular soft-tissue swelling
2. Osteoporosis—juxta-articular, metaphyseal lucent bands, and/or diffuse.
3. Periostitis
4. Overgrown or ballooned epiphyses
5. Advanced skeletal maturation—premature fusion
6. Late joint space loss
7. Late erosive disease
8. Ankylosis
9. Bilateral and symmetrical distribution in polyarticular disease; sporadic in pauciarticular or monoarticular disease
10. Distribution in hand and wrist, foot, knee, ankle, hip, cervical spine, and mandible, in decreasing order, in polyarticular disease; distribution in knee, ankle, elbow, and wrist in pauciarticular or monoarticular disease.

The wrist is more often involved than the hand. Early in the disease there is juxta-articular osteoporosis, soft-tissue swelling secondary to synovitis, and a loss of complete wrist extension. With persistence of the disease process, there is acceleration of growth maturation in the wrist, as seen by increase in the number and size of the carpal bones. The carpal bones become irregular in their contour secondary to erosions occurring at a young age and repairing with growth. Nineteen percent of patients demonstrate ankylosis at the wrist with relative sparing of one of the three compartments. Most frequently the common carpometacarpal and midcarpal compartments are ankylosed, with total sparing of the radiocarpal compartment. Spontaneous intercarpal or radiocarpal fusion occurs more commonly in children with JRA than in adults.

Secondary changes may occur in the distal radial epiphysis consisting of wedging and fragmentation (Fig. 101). With time, an ulnar deviation of the wrist and radial deviation of the digits appear. The wrist deformity is in contrast to the usual pattern of radial deviation seen in adults. It may be related in part to shortening of the ulna secondary to premature physeal arrest. This, in conjunction with attenuation of the volar wrist ligaments, results in ulnar and volar translocation of the carpus, leading to a bayonet deformity. Involvement of the basal joint of the thumb may lead to dorsal
References


Figure 101 Secondary changes of JCA. The radial epiphysis shows wedging and fragmentation (arrow).
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