American College of Radiology
ACR Appropriateness Criteria®
Chronic Wrist Pain

Variant 1: **Chronic wrist pain. With or without prior injury. Best initial study.**

Procedure	Appropriateness Category	Relative Radiation Level
X-ray wrist	Usually Appropriate	☢
MRI wrist without IV contrast	Usually Not Appropriate	O
MRI wrist without and with IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 2: **Chronic wrist pain. Routine radiographs normal or nonspecific. Persistent symptoms. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
MR arthrography wrist	May Be Appropriate	O
MRI wrist without and with IV contrast	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 3: **Chronic wrist pain. Routine radiographs normal or nonspecific. Suspect inflammatory arthritis. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without and with IV contrast	Usually Appropriate	O
MRI wrist without IV contrast	Usually Appropriate	O
US wrist	May Be Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 4: **Chronic wrist pain. Radiographs normal or show nonspecific arthritis. Exclude infection. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
Aspiration wrist	Usually Appropriate	Varies
MRI wrist without and with IV contrast	May Be Appropriate (Disagreement)	O
US wrist	May Be Appropriate (Disagreement)	O
MRI wrist without IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 5: **Ulnar-sided chronic wrist pain. Radiographs normal or nonspecific. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
MR arthrography wrist	Usually Appropriate	O
CT arthrography wrist	May Be Appropriate	☢
MRI wrist without and with IV contrast	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
X-ray arthrography wrist	Usually Not Appropriate	☢
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 6: **Radial-sided chronic wrist pain. Radiographs normal or nonspecific. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
MR arthrography wrist	May Be Appropriate	O
US wrist	May Be Appropriate	O
CT arthrography wrist	May Be Appropriate	☢
MRI wrist without and with IV contrast	Usually Not Appropriate	O
X-ray arthrography wrist	Usually Not Appropriate	☢
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 7: **Chronic wrist pain. Radiographs normal or nonspecific. Suspect Kienböck's disease. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
CT wrist without IV contrast	May Be Appropriate	☢
MRI wrist without and with IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 8: **Chronic wrist pain. Kienböck's disease on radiographs. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
CT wrist without IV contrast	May Be Appropriate	☢
MRI wrist without IV contrast	May Be Appropriate	O
MRI wrist without and with IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 9: **Chronic wrist pain. Palpable mass or suspected occult ganglion cyst. Radiographs normal or nonspecific. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
MRI wrist without and with IV contrast	Usually Appropriate	O
US wrist	Usually Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

Variant 10: **Chronic wrist pain. Suspect occult fracture or stress fracture. Radiographs nondiagnostic. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
CT wrist without IV contrast	Usually Appropriate	☢
X-ray wrist additional views	May Be Appropriate	☢
Tc-99m bone scan with SPECT/CT wrist	May Be Appropriate	☢☢☢
MRI wrist without and with IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢

<u>Variant 11:</u> **Chronic wrist pain. Radiographs show old scaphoid fracture. Evaluate for nonunion, malunion, osteonecrosis, or post-traumatic osteoarthritis. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI wrist without IV contrast	Usually Appropriate	O
CT wrist without IV contrast	Usually Appropriate	☢
MRI wrist without and with IV contrast	May Be Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
US wrist	Usually Not Appropriate	O
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

<u>Variant 12:</u> **Chronic wrist pain. Radiographs normal or nonspecific. Suspect carpal tunnel syndrome. Next study.**

Procedure	Appropriateness Category	Relative Radiation Level
US wrist	May Be Appropriate	O
MRI wrist without IV contrast	May Be Appropriate	O
MRI wrist without and with IV contrast	Usually Not Appropriate	O
MR arthrography wrist	Usually Not Appropriate	O
CT wrist without IV contrast	Usually Not Appropriate	☢
CT wrist with IV contrast	Usually Not Appropriate	☢
CT wrist without and with IV contrast	Usually Not Appropriate	☢
CT arthrography wrist	Usually Not Appropriate	☢
X-ray arthrography wrist	Usually Not Appropriate	☢
Tc-99m bone scan wrist	Usually Not Appropriate	☢☢☢

CHRONIC WRIST PAIN

Expert Panel on Musculoskeletal Imaging: David A. Rubin, MD[a]; Catherine C. Roberts, MD[b]; Jenny T. Bencardino, MD[c]; Angela M. Bell, MD[d]; R. Carter. Cassidy, MD[e]; Eric Y. Chang, MD[f]; Soterios Gyftopoulos, MD[g]; Darlene F. Metter, MD[h]; William B. Morrison, MD[i]; Naveen Subhas, MD[j]; Siddharth Tambar, MD[k]; Jeffrey D. Towers, MD[l]; Joseph S. Yu, MD[m]; Mark J. Kransdorf, MD.[n]

Summary of Literature Review

Introduction/Background

In patients with chronic wrist pain, imaging studies are an important adjunct to history, physical examination, laboratory testing, and electrophysiology studies. The choice of imaging modality depends on the patient's presentation and the clinical questions being asked. There are scenarios in which no imaging beyond baseline radiographs is necessary, but in other situations advanced imaging has added value for diagnostic evaluation and treatment planning.

Overview of Imaging Modalities

Radiographs

Imaging evaluation of the painful wrist should begin with radiographs [1,2]. This simple study may establish a specific diagnosis in patients with arthritis, complications of injury, infection, some bone or soft-tissue tumors, impaction syndromes, or static wrist instability. The standard radiographic examination consists of posterior-anterior (PA) and lateral views, ideally performed in neutral position and rotation, often supplemented by one or more oblique view [1,2]. The lateral view is important for demonstrating malalignments and soft-tissue swelling [3]. A variety of stress positions and maneuvers can be performed to elicit dynamic instability that is not visible on standard radiographs [4]. Other nonstandard projections may be indicated for specific suspected problems. Additionally, radiographs are necessary for accurate measurement of ulnar variance [5].

In the past, fluoroscopic observation was used to establish the diagnosis of dynamic wrist instability. However, in most practices, fluoroscopy is used either for guidance during wrist injections or as an adjunct to arthrography. Percutaneous aspiration of the wrist—which is indicated in cases of suspected septic arthritis or to assess for intra-articular crystals—can be carried out with either fluoroscopic or ultrasound (US) guidance if needed.

Scintigraphy

Bone scintigraphy has been used for diagnosing occult wrist fractures and as a screening procedure in patients with wrist pain and negative radiographs. However, while it is sensitive to bone abnormalities, scintigraphy suffers from a lack of specificity [6]. Furthermore, bone scans cannot detect soft-tissue abnormalities such as lesions of the ligaments, tendons, and cartilage, all of which are often responsible for chronic wrist pain.

Arthrography

Conventional (x-ray) arthrography can be performed with contrast injection into the radiocarpal joint alone or into the radiocarpal, midcarpal, and distal radioulnar joints (3-phase technique) for the diagnosis of triangular fibrocartilage complex (TFCC) tear and intrinsic ligament perforations. A recent meta-analysis found only moderate pooled sensitivity (76%) for the detection of full-thickness TFCC tears (82% for 3-phase technique and 72% for single-injection arthrograms) [7]. However, arthrography is unable to reliably show the size, shape, and stability of TFCC defects and is insensitive to partial-thickness tears. Similarly, while conventional arthrography can be used to diagnose full-thickness defects in the intrinsic intercarpal ligaments, it is unable to identify which components of those ligaments are affected, to distinguish degenerative from traumatic lesions, to find partial-thickness ligament tears, to demonstrate abnormalities of the extrinsic ligaments, or to show extra-articular

[a]Principal Author, Washington University School of Medicine, Saint Louis, Missouri. [b]Panel Chair, Mayo Clinic, Phoenix, Arizona. [c]Panel Vice-Chair, New York University School of Medicine, New York, New York. [d]Rush University Medical Center, Chicago, Illinois; American College of Physicians. [e]UK Healthcare Spine and Total Joint Service, Lexington, Kentucky; American Academy of Orthopaedic Surgeons. [f]VA San Diego Healthcare System, San Diego, California. [g]New York University Medical Center, New York, New York. [h]UT Health San Antonio, San Antonio, Texas. [i]Thomas Jefferson University Hospital, Philadelphia, Pennsylvania. [j]Cleveland Clinic, Cleveland, Ohio. [k]Chicago Arthritis, Chicago, Illinois; American College of Rheumatology. [l]University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania. [m]The Ohio State University Wexner Medical Center, Columbus, Ohio. [n]Specialty Chair, Mayo Clinic, Phoenix, Arizona.

Reprint requests to: publications@acr.org

abnormalities responsible for pain when there is no ligament or TFCC abnormality. Because of these limitations, arthrography has now largely been supplanted by cross-sectional imaging. Fluoroscopic-guided intra-articular injections are chiefly used as a first step when performing arthrographic computed tomography (CT) and magnetic resonance imaging (MRI) studies [8].

MRI

Wrist MRI accurately depicts abnormalities of the bones and bone marrow, articular cartilage, intrinsic and extrinsic ligaments, TFCC, synovium, tendons, and neurovascular structures, making it a powerful study for chronic pain caused by diverse etiologies.

A dedicated receiver coil or transmit-receive coil is necessary to provide the signal-to-noise ratio needed for high-resolution, high-contrast MRI of the wrist [9]. MR arthrography—either with direct contrast injection into one or more wrist compartments or performed indirectly after intravenous (IV) contrast administration—can enhance the yield of the study for diagnosing internal wrist derangements, especially abnormalities of the ligaments, articular cartilage, and TFCC of the wrist. MRI performed with a 3.0 T magnet and a dedicated coil provides better signal-to-noise ratio and better contrast compared with wrist MRI performed with 1.5 T or lower field strength systems [10,11].

CT

CT of the wrist is used primarily when high-detail imaging of bone cortex or trabeculae is needed. In patients with chronic wrist pain and prior fractures, CT is typically the study of choice to evaluate fracture healing and joint congruence. When a radiographically occult fracture is suspected as the cause of a patient's chronic pain, either CT or MRI can be used [12]. Advantages of CT over MRI for the wrist include its ability to obtain high-resolution images of both wrists simultaneously and the much shorter acquisition times for CT. These factors make CT the preferred examination for suspected distal radioulnar joint subluxation, where images of both wrists can be obtained in both supination and pronation [1,13]. A disadvantage of CT is its lower sensitivity to soft-tissue abnormalities compared with MRI.

High-resolution (typically multidetector) CT of the wrist following contrast injection into one or more wrist compartments (CT arthrography) is a powerful tool for diagnosing intra-articular abnormalities [14,15]. The intraobserver agreement on CT arthrogram images is extremely high and better than that reported for MRI [14,16].

US

US of the wrist is useful for examining extra-articular soft tissues, such as suspected ganglion cysts [17], because its accuracy is similar to that of MRI. US can also be used to diagnose abnormalities of the flexor and extensor tendons and tendon sheaths. For de Quervain disease (stenosing tenosynovitis of the abductor pollicis longus and extensor pollicis brevis tendon compartment), preoperative identification of a septum or subcompartmentalization within the first dorsal compartment with US may affect surgical management [18,19].

In patients with suspected or established rheumatoid arthritis (RA), US examination of the wrist and selected finger joints can identify erosions and active synovitis (with the use of power Doppler), findings that influence early diagnosis and treatment decisions [20]. Using US to measure the size of the median nerve is a validated technique in patients with clinical symptoms of carpal tunnel syndrome [21-24].

In addition, wrist US is a useful technique to guide therapeutic intra-articular and other soft-tissue injections [25].

Discussion of Procedures by Variant

Variant 1: Chronic wrist pain. With or without prior injury. Best initial study.

Radiographs

While there is no recent literature that directly addresses the role of first-line examinations for chronic wrist pain, radiographs are usually appropriate as an initial study. Radiographs are widely available, and for many bone, joint, and alignment abnormalities, radiographs alone are diagnostic. In other patients, nonspecific radiologic findings (including those in the soft tissues) combined with the history and physical examination may be sufficient for clinical diagnosis, or may suggest preferred secondary imaging studies.

MRI

MRI is not routinely used in the initial evaluation of chronic wrist pain.

MR Arthrography
MR arthrography is not routinely used in the initial evaluation of chronic wrist pain.

CT
CT is not routinely used in the initial evaluation of chronic wrist pain.

CT Arthrography
CT arthrography is not routinely used in the initial evaluation of chronic wrist pain.

US
US is not routinely used in the initial evaluation of chronic wrist pain.

Bone Scan
Bone scan is not routinely used in the initial evaluation of chronic wrist pain.

Arthrography
X-ray arthrography is not routinely used in the initial evaluation of chronic wrist pain.

Variant 2: Chronic wrist pain. Routine radiographs normal or nonspecific. Persistent symptoms. Next study.

MRI
In most cases, further imaging would not be required in patients with chronic wrist pain in whom initial radiographs did not show a specific diagnosis. Rather, the treating physician would be able to manage the patient based on history, physical examination findings, laboratory analysis, and electrodiagnostic studies. When further imaging is needed and none of the specific scenarios described in Variants 3 through 7, 10, or 12 apply, MRI is the preferred examination and MR arthrography may be appropriate in some circumstances [3,12,26].

MR Arthrography
MR arthrography may have an advantage over other studies when there is a strong suspicion of an internal wrist derangement such as a peripheral TFCC tear or intrinsic ligament abnormality [3,12,26].

CT
CT is not routinely used to further evaluate chronic wrist pain in cases without a specific, clinically suspected condition.

CT Arthrography
CT arthrography is not routinely used to further evaluate chronic wrist pain in cases without a specific, clinically suspected condition.

US
US is not routinely used to further evaluate chronic wrist pain in cases without a specific, clinically suspected condition.

Bone Scan
Bone scan is not routinely used to further evaluate chronic wrist pain in cases without a specific, clinically suspected condition.

Arthrography
X-ray arthrography is not routinely used to further evaluate chronic wrist pain in cases without a specific, clinically suspected condition.

Variant 3: Chronic wrist pain. Routine radiographs normal or nonspecific. Suspect inflammatory arthritis. Next study.

MRI
The diagnosis of a specific inflammatory arthritis is typically established based on clinical and laboratory analysis. Advanced imaging is usually performed to determine disease activity, guide management decisions, and prognosticate outcomes. In patients with early RA and other inflammatory arthritides, active synovitis may be better quantified following MRI with IV contrast administration, possibly if performed dynamically, allowing confident early diagnosis, prognostication, and treatment guidance in these patients [27,28]. Additionally, inflammatory tenosynovitis may be more conspicuous after IV contrast administration [29]. As is the case for any tomographic study, MRI is much more sensitive than radiographs for identifying erosions in RA [30,31]. More importantly, though, the finding of enhancing bone marrow “edema” (osteitis) on MRI studies in patients with

early RA is proving to be the best single predictor of future disease progression and functional deterioration, even compared to serologies and clinical measures [27,28,32-34].

US

The diagnosis of a specific inflammatory arthritis is typically established based on clinical and laboratory analysis. Advanced imaging is usually performed to determine disease activity, guide management decisions, and prognosticate outcomes. In patients with RA, US of the wrist and metacarpophalangeal joints can show inflammation as active synovitis. Identifying active synovitis with power Doppler assessment is a useful adjunct in making an early diagnosis of RA when a patient with early arthritis does not meet the 2010 criteria established by the American College of Rheumatology and the European League Against Rheumatism [20]. The presence of synovitis predicts progression of erosions [31] and erosions themselves [35]. US can also depict small bone erosions with high spatial resolution; however, US is less sensitive to erosions that occur on the radial or ulnar sides of the inner carpal bones because direct scanning of these regions is blocked, unlike the dorsal and volar bone surfaces. Furthermore, unlike MRI, US cannot show changes within the bone marrow, which are the strongest prognosticators for disease progression in RA [27,28,32-34]. In patients with established inflammatory arthritis who are undergoing therapy, judging progression or reduction of synovitis may be more difficult with sequential US compared to sequential MRI.

MR Arthrography

MR arthrography does not contribute to the diagnosis or management of patients with suspected inflammatory arthritides.

CT

While CT is more sensitive than radiographs for erosions, CT is not routinely used for the diagnosis and management of patients with suspected inflammatory arthritides.

CT Arthrography

CT arthrography does not contribute to the diagnosis or management of patients with suspected inflammatory arthritides.

Bone Scan

Bone scan does not contribute to the diagnosis or management of patients with suspected inflammatory arthritides.

Arthrography

X-ray arthrography does not contribute to the diagnosis or management of patients with suspected inflammatory arthritides.

Variant 4: Chronic wrist pain. Radiographs normal or show nonspecific arthritis. Exclude infection. Next study.

Aspiration

No literature directly addresses the appropriateness of imaging studies beyond radiographs in patients with suspected infection in the wrist. However, generalizing from experience with septic arthritis in other joints, joint aspiration should not be delayed in order to obtain advanced imaging studies. In cases of suspected septic arthritis, percutaneous aspiration of the wrist is indicated, even when radiographs appear normal. Aspirates should be analyzed by cell count, gram stain, and appropriate cultures. Microscopic crystal analysis should also be obtained if there is a possibility of gout, acute pseudogout, or hydroxyapatite deposition disease. Aspiration can be performed without imaging guidance if the joint is distended, but either fluoroscopy or US may be useful if a specific compartment is to be targeted.

MRI

There may be a role for MRI with IV contrast enhancement in the staging of infections (for example, to delineate the location and extent of soft-tissue abscesses) after aspiration has been performed. Especially in chronic cases, MRI with IV contrast may be useful to identify a fluid collection or joint effusion to target for aspiration. However, MRI is usually not appropriate as the next study after radiographs for suspected wrist infections.

MR Arthrography

MR arthrography is not routinely used to evaluate suspected wrist infection.

CT
While CT with IV contrast enhancement can depict abscesses, it is usually not appropriate for evaluation of suspected wrist infections.

CT Arthrography
CT arthrography is not routinely used to evaluate suspected wrist infection.

US
There may be a role for US in the staging of infections (for example, to delineate the location and extent of soft-tissue abscesses) after aspiration has been performed. Alternatively, US may be used in conjunction with aspiration as a method to first identify collections and then as the imaging method to guide aspiration.

Bone Scan
Bone scan is not routinely used to evaluate suspected chronic wrist infection.

Arthrography
X-ray arthrography is not routinely used to evaluate suspected wrist infection.

Variant 5: Ulnar-sided chronic wrist pain. Radiographs normal or nonspecific. Next study.

MRI
Both traumatic and degenerative lesions of the TFCC can produce chronic, ulnar-sided wrist pain. MRI is highly accurate for lesions involving the radial (central) zone of the disc, especially with the use of high-resolution fast spin-echo or 3-D gradient-recalled pulse sequences [36]. There is some evidence suggesting that MRI performed with a 3.0 T system is even more accurate than MRI performed with a 1.5 T system for TFCC lesions [37], but there are no studies comparing the accuracy of the two field strengths in the same patients. The sensitivity for tears of the ulnar attachment of the disc and the peripheral attachments (the ulnocarpal ligaments) are only fair with noncontrast-enhanced wrist MRI [12,36]. IV contrast seldom provides added benefit in patients with ulnar-sided wrist pain but may increase sensitivity for TFCC lesions if MR arthrography is desired but direct joint injection is not feasible.

MR Arthrography
Direct MR arthrography (performed with contrast injection of the radiocarpal or distal radioulnar compartments, alone or in combination) does result in better diagnostic accuracy for the TFCC compared with conventional MRI, especially for ulnar-sided lesions [26,38], even when compared to conventional MRI performed with a 3.0 T magnet [7,8,39]. The same is true for intrinsic ligament injuries, such as those of the lunotriquetral ligament, which can produce ulnar-sided pain [7,8,39]. Performing either MR arthrography or noncontrast-enhanced MRI is usually appropriate in this scenario.

CT Arthrography
The accuracy of CT arthrography is superior to MRI and similar to that of MR arthrography for TFCC and intrinsic ligament lesions [8,40]. In addition, CT arthrography appears to be more accurate than either MRI or MR arthrography for identifying articular cartilage defects in the wrist [38]. In contrast to MRI and MR arthrography, CT arthrography is less sensitive to lesions occurring outside of the joint (like abnormalities of the extensor carpi ulnaris tendon) that can result in ulnar-sided pain. For these reasons, CT arthrography may be appropriate in this setting, especially if there is a contraindication to MRI or if artifact from metallic implants produce too much artifact on MRI.

Arthrography
Conventional (x-ray) arthrography—performed with contrast injection into one or more wrist compartments—has moderate accuracy for the diagnosis of TFCC perforations [7]. However, x-ray arthrography alone is usually not appropriate and has largely been supplanted by CT arthrography, MRI, and MR arthrography, which provide more anatomic detail that is needed for treatment planning and often demonstrate extra-articular abnormalities responsible for pain when there is no ligament or TFCC abnormality.

US
While some investigators have tried high-resolution US with or without arthrography for diagnosing intrinsic ligament or TFCC abnormalities [41,42], its sensitivity in comparison to MRI, MR arthrography, and CT arthrography is unknown. Additionally, imaging with US is largely limited to the dorsal fibers of the ligaments and TFCC [42]. US is usually not appropriate in patients with ulnar-sided wrist pain.

CT
CT, with or without IV contrast, is not routinely used to further evaluate ulnar-sided chronic wrist pain when radiographs are normal or nonspecific.

Bone Scan
Bone scan is not routinely used to further evaluate ulnar-sided chronic wrist pain when radiographs are normal or nonspecific.

Variant 6: Radial-sided chronic wrist pain. Radiographs normal or nonspecific. Next study.

MRI
MRI is accurate for diagnosing scapholunate ligament tears [8,10,38,39], and noncontrast-enhanced MRI is usually appropriate in this scenario. IV contrast seldom provides added benefit in patients with radial-sided wrist pain but may increase sensitivity for ligament lesions if MR arthrography is desired but direct joint injection is not feasible.

MR Arthrography
Direct MR arthrography (with contrast injection either into the radiocarpal joint or into all three compartments of the wrist) may be appropriate in this scenario; the examination has higher sensitivity than noncontrast-enhanced MRI—even when performed at 3.0 T—for diagnosis of complete and incomplete scapholunate and lunotriquetral ligament tears [3,8,38]. For the scapholunate ligament, direct MR arthrography also allows more accurate determination of which specific segments of the ligament are torn compared to conventional MRI [43], which has important biomechanical implications for wrist stability. Direct MR arthrography also has an advantage over noncontrast-enhanced MRI for diagnosing extrinsic ligament abnormalities [44].

CT Arthrography
The accuracy of CT arthrography and MR arthrography are similar for lesions of the scapholunate ligament [8]. Compared to conventional MRI, CT arthrography may be more sensitive for tears of the biomechanically important dorsal ligament fibers [16]. In contrast to MRI and MR arthrography, CT arthrography is less sensitive for diagnosis of extra-articular findings (like ganglion cysts and tendon disorders) that can cause radial-sided pain. CT arthrography may be appropriate in this scenario.

CT
CT, with or without IV contrast, is not routinely used to further evaluate chronic radial-sided wrist pain when radiographs are normal or nonspecific.

US
While some investigators have tried high-resolution US with or without arthrography for diagnosing intrinsic ligament [41,42], its sensitivity in comparison to MRI, MR arthrography, and CT arthrography is unknown. Additionally, imaging with US is largely limited to the dorsal fibers of the ligaments [42]. US may be appropriate in cases of suspected de Quervain disease (stenosing tenosynovitis of the abductor pollicis longus and extensor pollicis brevis tendon compartment), where preoperative identification of a septum or subcompartmentalization within the first dorsal compartment with US may affect surgical management [18,19]. US may be appropriate in patients with radial-sided pain in cases where extra-articular pathology is the primary consideration.

Arthrography
Conventional (x-ray) arthrography has largely been supplanted by CT arthrography and MR arthrography because these cross-sectional studies are better able to predict which fibers of the scapholunate ligament are torn and whether any repairable fibers remain, both of which are important features that affect operative management. Additionally, while fibrocartilage and ligament perforations are moderately associated with ulnar-sided wrist pain, there is a poor correlation between ligament lesions and radial-sided pain [45]. Furthermore, conventional arthrography is unable to show extra-articular findings (like ganglion cysts and tendon disorders) that can cause radial-sided pain, further limiting its usefulness in this patient population.

Bone Scan
Bone scan is not routinely used to further evaluate radial-sided chronic wrist pain when radiographs are normal or nonspecific.

Variant 7: Chronic wrist pain. Radiographs normal or nonspecific. Suspect Kienböck's disease. Next study.

MRI

While no recent literature addresses the role of MRI in suspected Kienböck's disease, generalizing from experience with osteonecrosis elsewhere in the body, noncontrast-enhanced MRI is usually an appropriate examination for diagnosis. IV contrast seldom provides added benefit in patients with suspected lunate osteonecrosis.

CT

While no recent literature addresses the role of CT in suspected Kienböck's disease, generalizing from experience with osteonecrosis elsewhere in the body, CT may be appropriate in some patients. IV contrast seldom provides added benefit in patients with suspected lunate osteonecrosis.

MR Arthrography

MR arthrography is not routinely used in the diagnosis of Kienböck's disease.

CT Arthrography

CT arthrography is not routinely used in the diagnosis of Kienböck's disease.

US

US is not routinely used in the diagnosis of Kienböck's disease.

Bone Scan

Bone scan is not routinely used in the diagnosis of Kienböck's disease.

Arthrography

X-ray arthrography is not routinely used in the diagnosis of Kienböck's disease.

Variant 8: Chronic wrist pain. Kienböck's disease on radiographs. Next study.

CT

No recent literature addresses the role of CT in suspected staging of Kienböck's disease. In most cases, the radiographic findings are diagnostic and provide the necessary information (degree of carpal collapse, ulnar variance, and associated osteoarthritis) to adequately plan management. In cases in which the amount of collapse or the presence and size of bone fragments is uncertain from the radiographs and is deemed clinically important, noncontrast-enhanced CT may be appropriate. CT with IV contrast is usually not appropriate.

MRI

No recent literature addresses the role of MRI in suspected staging of Kienböck's disease. In many cases, the radiographic findings are diagnostic and provide the necessary information (degree of carpal collapse, ulnar variance, and associated osteoarthritis) to adequately plan management. In cases in which the amount of collapse or the presence and size of bone fragments is uncertain from the radiographs and is deemed clinically important, noncontrast-enhanced MRI may be appropriate. MRI with IV contrast is usually not appropriate.

MR Arthrography

MR arthrography is not routinely used in the diagnosis of Kienböck's disease.

CT Arthrography

CT arthrography is not routinely used in the diagnosis of Kienböck's disease.

US

US is not routinely used in the diagnosis of Kienböck's disease.

Bone Scan

Bone scan is not routinely used in the diagnosis of Kienböck's disease.

Arthrography

X-ray arthrography is not routinely used in the diagnosis of Kienböck's disease.

Variant 9: Chronic wrist pain. Palpable mass or suspected occult ganglion cyst. Radiographs normal or nonspecific. Next study.

MRI

MRI (without or without and with IV contrast) or US are alternative initial examinations that are usually appropriate in this setting. Fluid-filled and synovial-lined structures (including ganglia, cysts, bursa, and tendon sheaths) are well depicted with MRI. MRI is useful for diagnosing infectious and noninfectious tenosynovitis in both the flexor and extensor wrist compartments [46]. Occult ganglion cysts are also easily identified with MRI, but some authors recommend use of IV contrast to distinguish ganglia from synovitis [47]. For noncystic soft-tissue masses, MRI may demonstrate findings that are diagnostic for certain benign conditions (eg, lipomas, hemangiomas, benign nerve sheath tumors), and can stage the extent of involvement for nonspecific masses (see the ACR Appropriateness Criteria® topic on "Soft Tissue Masses" [48]).

US

Wrist US or MRI (without or without and with IV contrast) are alternative initial examinations that are usually appropriate in this setting. US is useful for examining extra-articular soft tissues, such as suspected ganglion cysts [17], with an accuracy similar to that of MRI.

CT

There is no support in the literature for CT in the initial diagnosis of a palpable mass or suspected ganglion cyst with normal or nonspecific radiologic findings. CT may have a role in cases in which calcification or ossification is demonstrated radiologically, or in the staging of a lesion that is first evaluated by MRI or US, but CT with or without IV contrast are usually not appropriate initial examinations for a suspected soft-tissue mass.

MR Arthrography

MR arthrography is not routinely used to evaluate a palpable mass or ganglion cyst.

CT Arthrography

CT arthrography is not routinely used to evaluate a palpable mass or ganglion cyst.

Bone Scan

Bone scan is not routinely used to evaluate a palpable mass or ganglion cyst.

Arthrography

X-ray arthrography is not routinely used to evaluate a palpable mass or ganglion cyst.

Variant 10: Chronic wrist pain. Suspect occult fracture or stress fracture. Radiographs nondiagnostic. Next study.

MRI

Either MRI without IV contrast or CT without IV contrast is usually appropriate in this scenario. MRI is highly sensitive to changes in bone marrow composition, and thus is frequently used to identify radiographically occult acute fractures throughout the skeleton, including in the wrist (see the ACR Appropriateness Criteria® topic on "Acute Hand and Wrist Trauma" [49]). In patients with persistent symptoms thought to be due to an occult wrist fracture, MRI can be used as an alternative to presumptive casting and repeat radiographs [12]. MRI is also sensitive to stress fractures and stress injuries of the physes, for example, in gymnasts [50]. IV contrast does not add to the examination and is usually not appropriate.

CT

Either CT without IV contrast or MRI without IV contrast is usually appropriate in this scenario. CT can provide high-detail imaging of bone cortex and trabeculae and thus can be used to identify radiographically occult fractures and stress fractures. Acquisition times are shorter for CT compared to MRI, and CT may be easier to perform in patients who are casted. However, MRI's sensitivity for bone bruises and soft-tissue injuries is greater than CT. In specific circumstances—like suspected fractures of the hook of the hamate—CT may be preferable to MRI. IV contrast does not add to the examination and is usually not appropriate.

Radiography

If not obtained as part of the initial radiographic series, additional views such as a carpal tunnel or semipronated oblique projection (a "scaphoid view") may show an otherwise radiographically occult fracture, and may be appropriate.

Bone Scan

Bone scans are frequently positive for occult fractures by the time of clinical presentation, typically 1 to 2 weeks before radiographs. A normal bone scan can reliably exclude an occult scaphoid fracture [51] because, like CT and MRI, bone scans have a high sensitivity; however, the specificity for bone scan is lower than CT and MRI [52,53] because entities such as bone contusions, osteoarthritis, and other osteoblastic processes will show increased uptake. Scintigraphy may be a reasonable alternative to MRI in claustrophobic patients with suspected occult scaphoid fractures [54]. Single-photon emission computed tomography (SPECT)/CT appears to be more sensitive than CT for occult fractures, with the CT component increasing examination specificity by co-registering scintigraphic activity with anatomic detail; a negative SPECT/CT has a high negative predictive value for occult and stress fractures, and may be appropriate in this scenario [55,56].

US
While there are circumstances in which an US may identify a specific occult fracture or healing stress fracture, there is no literature systematically analyzing US. It is usually not appropriate as the next study in this setting.

CT Arthrography
CT arthrography is not routinely used to evaluate a suspected occult or stress fracture.

MR Arthrography
MR arthrography is not routinely used to evaluate a suspected occult or stress fracture.

Arthrography
X-ray arthrography is not routinely used to evaluate a suspected occult or stress fracture.

Variant 11: Chronic wrist pain. Radiographs show old scaphoid fracture. Evaluate for nonunion, malunion, osteonecrosis, or post-traumatic osteoarthritis. Next study.

MRI
Either MRI without IV contrast or CT without IV contrast is usually appropriate in this scenario. MRI shows only moderate sensitivity and specificity for predicting osteonecrosis of the proximal pole of scaphoid fractures, and even some scaphoid fractures with MRI evidence of osteonecrosis may still heal with treatment [57]. While the addition of IV contrast, especially given dynamically, can improve the accuracy for osteonecrosis and predicting graft healing, the routine use of IV contrast for this indication is controversial: while nonenhancement of the proximal scaphoid pole is a reliable sign of osteonecrosis, enhancement can be seen in both viable and nonviable fracture fragments [58]. MRI with IV contrast may be appropriate for these patients. Additionally, unlike the case for the knee and other larger joints, MRI shows only fair sensitivity for depicting articular cartilage defects in the distal radius and carpal bones, even with the use of indirect MR arthrography or 3.0 T scanners [59,60]. The presence of focal bone marrow edema may be a clue to underlying chondral defects [59]. Despite these limitations, noncontrast MRI and noncontrast CT are both usually appropriate examinations to evaluate potential sequelae of chronic scaphoid fractures, but only one of the tests needs to be performed for a given patient. The use of IV contrast for MRI may be appropriate in some cases.

MR Arthrography
A single study found that direct MR arthrography was more sensitive for articular cartilage defects compared to conventional MRI, but the same study showed that CT arthrography was even more sensitive [38]. MR arthrography is not routinely used in this setting.

CT
Either CT without IV contrast or MRI without IV contrast is usually appropriate in this scenario. CT historically has been the most commonly used examination to detect scaphoid nonunion, malunion, osteonecrosis and wrist osteoarthritis in patients with chronic scaphoid fractures, despite a lack of evidence-based literature. IV contrast does not have added benefit in these patients and is usually not appropriate. Either CT or MRI is usually appropriate in this setting, but only one of the tests is necessary.

CT Arthrography
While CT arthrography may increase the sensitivity for articular cartilage defects [38], it is not routinely used in this setting.

US
Once a scaphoid fracture is identified, US does not contribute to the evaluation for complications of the fracture.

Bone Scan
Once a scaphoid fracture is identified, bone scan does not contribute to the evaluation for complications of the fracture.

Arthrography
Once a scaphoid fracture is identified, x-ray arthrography does not contribute to the evaluation for complications of the fracture.

Variant 12: Chronic wrist pain. Radiographs normal or nonspecific. Suspect carpal tunnel syndrome. Next study.

US

Several meta-analyses have confirmed that the cross-sectional area of the median nerve (typically measured at the carpal tunnel inlet) is highly accurate for identifying carpal tunnel syndrome diagnosed clinically or with the combination of clinical and electrophysiologic studies [21,22,24]. The expected sensitivity and specificity of US varies depending on what cut-off values are chosen for the size of the nerve and where in the carpal tunnel the measurements are made [24,61-64]. There is strong evidence that US can be a replacement or complementary examination to nerve conduction studies and electromyography in patients with clinically suspected carpal tunnel syndrome [21-23]. There is also some evidence that the presence of vessels or hypervascularity within the carpal tunnel, demonstrated with power Doppler US, is another feature of carpal tunnel syndrome [65,66]. Nevertheless, clinical examination combined with electrophysiologic testing remains the gold standard for the diagnosis of carpal tunnel syndrome. US may be appropriate in cases where this initial evaluation is equivocal.

MRI

Historically, carpal tunnel syndrome has been diagnosed based on clinical signs and symptoms and confirmed by the results of electrodiagnostic studies [67]. MRI without IV contrast may be appropriate in cases in which this initial evaluation is equivocal. The MRI findings that have been reported in wrists with carpal tunnel syndrome—including nerve enlargement, nerve flattening, and retinacular bowing—may be associated with clinical severity but have limited usefulness in patients with clinically recognized carpal tunnel syndrome and low predictive value in patients with nonspecific wrist pain [68]. In rare cases of secondary carpal tunnel syndrome, MRI may identify a mass lesion compressing the median nerve. There is some evidence that the length of T2 hyperintensity in the median nerve can help prognosticate the success of surgery [69] and that the shape and signal of the nerve predict clinical response to a steroid injection in patients with idiopathic carpal tunnel syndrome [70]. MR neurography may be an option in patients with suspected carpal tunnel syndrome. The use of IV contrast does not contribute to diagnosis and is usually not appropriate.

MR Arthrography

MR arthrography is not routinely used to diagnose carpal tunnel syndrome.

CT

CT, with or without IV contrast, is not routinely used to diagnose carpal tunnel syndrome.

CT Arthrography

CT arthrography is not routinely used to diagnose carpal tunnel syndrome.

Bone Scan

Bone scan is not routinely used to diagnose carpal tunnel syndrome.

Arthrography

X-ray arthrography is not routinely used to diagnose carpal tunnel syndrome.

Summary of Recommendations

- Wrist radiographs are indicated as the best initial imaging examination in patients with chronic wrist pain.
- When radiographs are normal or equivocal and a patient has persistent symptoms with an unclear diagnosis, MRI without IV contrast is usually appropriate.
- In patients with suspected inflammatory arthritis, MRI either with or without IV contrast is usually appropriate if guidance for management or prognostication is needed.
- Patients with suspected wrist infection should undergo aspiration.
- When radiographs are normal or equivocal in a patient with ulnar-sided pain, either MRI without IV contrast or an MR arthrogram of the wrist is usually appropriate.
- When radiographs are normal or equivocal in a patient with radial-sided pain, MRI without IV contrast is usually appropriate.
- For patients with suspected Kienböck’s disease without radiographic confirmation, MRI without IV contrast is usually appropriate.

- For patients with radiographic evidence of Kienböck's disease, further imaging is usually not necessary. In selected circumstances, either CT or MR without IV contrast may be appropriate for staging of the disease.
- In patients with a palpable mass or suspected ganglion cyst, one of the examinations, MRI without IV contrast, MRI with IV contrast, or wrist US, is usually appropriate.
- Either MRI or CT without contrast is usually appropriate in patients with suspected radiographically occult fractures or stress fractures.
- Patients with prior scaphoid fractures and chronic pain should undergo either CT or MR without IV contrast to evaluate for fracture complications.
- Suspected carpal tunnel syndrome is diagnosed by clinical evaluation combined with electrophysiologic studies. Further imaging is usually not needed, but in selected circumstances, either wrist US or MRI without contrast may be appropriate.

Summary of Evidence

Of the 71 references cited in the ACR Appropriateness Criteria® *Chronic Wrist Pain* document, all of them are categorized as diagnostic references including 3 well-designed studies, 16 good-quality studies, and 23 quality studies that may have design limitations. There are 23 references that may not be useful as primary evidence. There are 6 references that are meta-analysis studies.

The 71 references cited in the ACR Appropriateness Criteria® *Chronic Wrist Pain* document were published from 1989 to 2014.

Although there are references that report on studies with design limitations, 19 well-designed or good-quality studies provide good evidence.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [71].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

1. Coggins CA. Imaging of ulnar-sided wrist pain. *Clin Sports Med.* 2006;25(3):505-526, vii.
2. Forman TA, Forman SK, Rose NE. A clinical approach to diagnosing wrist pain. *Am Fam Physician.* 2005;72(9):1753-1758.
3. Theumann NH, Etechami G, Duvoisin B, et al. Association between extrinsic and intrinsic carpal ligament injuries at MR arthrography and carpal instability at radiography: initial observations. *Radiology.* 2006;238(3):950-957.
4. Ozcelik A, Gunal I, Kose N. Stress views in the radiography of scapholunate instability. *Eur J Radiol.* 2005;56(3):358-361.
5. Cerezal L, del Pinal F, Abascal F, Garcia-Valtuille R, Pereda T, Canga A. Imaging findings in ulnar-sided wrist impaction syndromes. *Radiographics.* 2002;22(1):105-121.
6. Al-Janabi M. Imaging modalities of the painful wrist: the role of bone scintigraphy. *Rheumatology (Oxford).* 2002;41(10):1085-1087.
7. Smith TO, Drew BT, Toms AP, Chojnowski AJ. The diagnostic accuracy of X-ray arthrography for triangular fibrocartilaginous complex injury: a systematic review and meta-analysis. *J Hand Surg Eur Vol.* 2012;37(9):879-887.
8. Lee RK, Ng AW, Tong CS, et al. Intrinsic ligament and triangular fibrocartilage complex tears of the wrist: comparison of MDCT arthrography, conventional 3-T MRI, and MR arthrography. *Skeletal Radiol.* 2013;42(9):1277-1285.
9. Kocharian A, Adkins MC, Amrami KK, et al. Wrist: improved MR imaging with optimized transmit-receive coil design. *Radiology.* 2002;223(3):870-876.
10. Lenk S, Ludescher B, Martirosan P, Schick F, Claussen CD, Schlemmer HP. 3.0 T high-resolution MR imaging of carpal ligaments and TFCC. *Rofo.* 2004;176(5):664-667.
11. Saupe N, Prussmann KP, Luechinger R, Bosiger P, Marincek B, Weishaupt D. MR imaging of the wrist: comparison between 1.5- and 3-T MR imaging--preliminary experience. *Radiology.* 2005;234(1):256-264.
12. Zanetti M, Saupe N, Nagy L. Role of MR imaging in chronic wrist pain. *Eur Radiol.* 2007;17(4):927-938.
13. Szabo RM. Distal radioulnar joint instability. *J Bone Joint Surg Am.* 2006;88(4):884-894.
14. De Filippo M, Pogliacomi F, Bertellini A, et al. MDCT arthrography of the wrist: diagnostic accuracy and indications. *Eur J Radiol.* 2010;74(1):221-225.
15. Moser T, Dosch JC, Moussaoui A, Buy X, Gangi A, Dietemann JL. Multidetector CT arthrography of the wrist joint: how to do it. *Radiographics.* 2008;28(3):787-800; quiz 911.

16. Schmid MR, Schertler T, Pfirrmann CW, et al. Interosseous ligament tears of the wrist: comparison of multi-detector row CT arthrography and MR imaging. *Radiology.* 2005;237(3):1008-1013.
17. Teefey SA, Dahiya N, Middleton WD, Gelberman RH, Boyer MI. Ganglia of the hand and wrist: a sonographic analysis. *AJR Am J Roentgenol.* 2008;191(3):716-720.
18. Choi SJ, Ahn JH, Lee YJ, et al. de Quervain disease: US identification of anatomic variations in the first extensor compartment with an emphasis on subcompartmentalization. *Radiology.* 2011;260(2):480-486.
19. Kwon BC, Choi SJ, Koh SH, Shin DJ, Baek GH. Sonographic Identification of the intracompartmental septum in de Quervain's disease. *Clin Orthop Relat Res.* 2010;468(8):2129-2134.
20. Kawashiri SY, Suzuki T, Okada A, et al. Musculoskeletal ultrasonography assists the diagnostic performance of the 2010 classification criteria for rheumatoid arthritis. *Mod Rheumatol.* 2013;23(1):36-43.
21. Descatha A, Huard L, Aubert F, Barbato B, Gorand O, Chastang JF. Meta-analysis on the performance of sonography for the diagnosis of carpal tunnel syndrome. *Semin Arthritis Rheum.* 2012;41(6):914-922.
22. Fowler JR, Gaughan JP, Ilyas AM. The sensitivity and specificity of ultrasound for the diagnosis of carpal tunnel syndrome: a meta-analysis. *Clin Orthop Relat Res.* 2011;469(4):1089-1094.
23. Fowler JR, Munsch M, Tosti R, Hagberg WC, Imbriglia JE. Comparison of ultrasound and electrodiagnostic testing for diagnosis of carpal tunnel syndrome: study using a validated clinical tool as the reference standard. *J Bone Joint Surg Am.* 2014;96(17):e148.
24. Tai TW, Wu CY, Su FC, Chern TC, Jou IM. Ultrasonography for diagnosing carpal tunnel syndrome: a meta-analysis of diagnostic test accuracy. *Ultrasound Med Biol.* 2012;38(7):1121-1128.
25. Teh J, Vlychou M. Ultrasound-guided interventional procedures of the wrist and hand. *Eur Radiol.* 2009;19(4):1002-1010.
26. Ruegger C, Schmid MR, Pfirrmann CW, Nagy L, Gilula LA, Zanetti M. Peripheral tear of the triangular fibrocartilage: depiction with MR arthrography of the distal radioulnar joint. *AJR Am J Roentgenol.* 2007;188(1):187-192.
27. Boyesen P, Haavardsholm EA, Ostergaard M, van der Heijde D, Sesseng S, Kvien TK. MRI in early rheumatoid arthritis: synovitis and bone marrow oedema are independent predictors of subsequent radiographic progression. *Ann Rheum Dis.* 2011;70(3):428-433.
28. Navalho M, Resende C, Rodrigues AM, et al. Dynamic contrast-enhanced 3-T magnetic resonance imaging: a method for quantifying disease activity in early polyarthritis. *Skeletal Radiol.* 2012;41(1):51-59.
29. Tehranzadeh J, Ashikyan O, Anavim A, Tramma S. Enhanced MR imaging of tenosynovitis of hand and wrist in inflammatory arthritis. *Skeletal Radiol.* 2006;35(11):814-822.
30. Dohn UM, Ejbjerg BJ, Hasselquist M, et al. Detection of bone erosions in rheumatoid arthritis wrist joints with magnetic resonance imaging, computed tomography and radiography. *Arthritis Res Ther.* 2008;10(1):R25.
31. Duer-Jensen A, Ejbjerg B, Albrecht-Beste E, et al. Does low-field dedicated extremity MRI (E-MRI) reliably detect bone erosions in rheumatoid arthritis? A comparison of two different E-MRI units and conventional radiography with high-resolution CT scanning. *Ann Rheum Dis.* 2009;68(8):1296-1302.
32. Boyesen P, Haavardsholm EA, van der Heijde D, et al. Prediction of MRI erosive progression: a comparison of modern imaging modalities in early rheumatoid arthritis patients. *Ann Rheum Dis.* 2011;70(1):176-179.
33. Hetland ML, Ejbjerg B, Horslev-Petersen K, et al. MRI bone oedema is the strongest predictor of subsequent radiographic progression in early rheumatoid arthritis. Results from a 2-year randomised controlled trial (CIMESTRA). *Ann Rheum Dis.* 2009;68(3):384-390.
34. Zheng S, Robinson E, Yeoman S, et al. MRI bone oedema predicts eight year tendon function at the wrist but not the requirement for orthopaedic surgery in rheumatoid arthritis. *Ann Rheum Dis.* 2006;65(5):607-611.
35. McAlindon T, Kissin E, Nazarian L, et al. American College of Rheumatology report on reasonable use of musculoskeletal ultrasonography in rheumatology clinical practice. *Arthritis Care Res (Hoboken).* 2012;64(11):1625-1640.
36. Oneson SR, Timins ME, Scales LM, Erickson SJ, Chamoy L. MR imaging diagnosis of triangular fibrocartilage pathology with arthroscopic correlation. *AJR Am J Roentgenol.* 1997;168(6):1513-1518.
37. Anderson ML, Skinner JA, Felmlee JP, Berger RA, Amrami KK. Diagnostic comparison of 1.5 Tesla and 3.0 Tesla preoperative MRI of the wrist in patients with ulnar-sided wrist pain. *J Hand Surg Am.* 2008;33(7):1153-1159.
38. Moser T, Dosch JC, Moussaoui A, Dietemann JL. Wrist ligament tears: evaluation of MRI and combined MDCT and MR arthrography. *AJR Am J Roentgenol.* 2007;188(5):1278-1286.

39. Magee T. Comparison of 3-T MRI and arthroscopy of intrinsic wrist ligament and TFCC tears. *AJR Am J Roentgenol.* 2009;192(1):80-85.
40. Omlor G, Jung M, Grieser T, Ludwig K. Depiction of the triangular fibro-cartilage in patients with ulnar-sided wrist pain: comparison of direct multi-slice CT arthrography and direct MR arthrography. *Eur Radiol.* 2009;19(1):147-151.
41. Taljanovic MS, Goldberg MR, Sheppard JE, Rogers LF. US of the intrinsic and extrinsic wrist ligaments and triangular fibrocartilage complex--normal anatomy and imaging technique. *Radiographics.* 2011;31(1):e44.
42. Taljanovic MS, Sheppard JE, Jones MD, Switlick DN, Hunter TB, Rogers LF. Sonography and sonoarthrography of the scapholunate and lunotriquetral ligaments and triangular fibrocartilage disk: initial experience and correlation with arthrography and magnetic resonance arthrography. *J Ultrasound Med.* 2008;27(2):179-191.
43. Scheck RJ, Kubitzek C, Hierner R, et al. The scapholunate interosseous ligament in MR arthrography of the wrist: correlation with non-enhanced MRI and wrist arthroscopy. *Skeletal Radiol.* 1997;26(5):263-271.
44. Scheck RJ, Romagnolo A, Hierner R, Pfluger T, Wilhelm K, Hahn K. The carpal ligaments in MR arthrography of the wrist: correlation with standard MRI and wrist arthroscopy. *J Magn Reson Imaging.* 1999;9(3):468-474.
45. Manaster BJ, Mann RJ, Rubenstein S. Wrist pain: correlation of clinical and plain film findings with arthrographic results. *J Hand Surg Am.* 1989;14(3):466-473.
46. Parellada AJ, Gopez AG, Morrison WB, et al. Distal intersection tenosynovitis of the wrist: a lesser-known extensor tendinopathy with characteristic MR imaging features. *Skeletal Radiol.* 2007;36(3):203-208.
47. Anderson SE, Steinbach LS, Stauffer E, Voegelin E. MRI for differentiating ganglion and synovitis in the chronic painful wrist. *AJR Am J Roentgenol.* 2006;186(3):812-818.
48. American College of Radiology. ACR Appropriateness Criteria®: Soft-Tissue Masses. Available at: https://acsearch.acr.org/docs/69434/Narrative/. Accessed September 1, 2017.
49. American College of Radiology. ACR Appropriateness Criteria®: Acute Hand and Wrist Trauma. Available at: https://acsearch.acr.org/docs/69418/Narrative/. Accessed September 1, 2017.
50. Dwek JR, Cardoso F, Chung CB. MR imaging of overuse injuries in the skeletally immature gymnast: spectrum of soft-tissue and osseous lesions in the hand and wrist. *Pediatr Radiol.* 2009;39(12):1310-1316.
51. Rhemrev SJ, Ootes D, Beeres FJ, Meylaerts SA, Schipper IB. Current methods of diagnosis and treatment of scaphoid fractures. *Int J Emerg Med.* 2011;4:4.
52. Mujoomdar M, Russell E, Dionne F, et al. *Optimizing Health System Use of Medical Isotopes and Other Imaging Modalities*. Ottawa: Canadian Agency for Drugs and Technologies in Health; 2012.
53. Yin ZG, Zhang JB, Kan SL, Wang XG. Diagnosing suspected scaphoid fractures: a systematic review and meta-analysis. *Clin Orthop Relat Res.* 2010;468(3):723-734.
54. Foex B, Speake P, Body R. Best evidence topic report. Magnetic resonance imaging or bone scintigraphy in the diagnosis of plain x ray occult scaphoid fractures. *Emerg Med J.* 2005;22(6):434-435.
55. Allainmat L, Aubault M, Noel V, Baulieu F, Laulan J, Eder V. Use of hybrid SPECT/CT for diagnosis of radiographic occult fractures of the wrist. *Clin Nucl Med.* 2013;38(6):e246-251.
56. Querellou S, Arnaud L, Williams T, et al. Role of SPECT/CT compared with MRI in the diagnosis and management of patients with wrist trauma occult fractures. *Clin Nucl Med.* 2014;39(1):8-13.
57. Fox MG, Gaskin CM, Chhabra AB, Anderson MW. Assessment of scaphoid viability with MRI: a reassessment of findings on unenhanced MR images. *AJR Am J Roentgenol.* 2010;195(4):W281-286.
58. Cerezal L, Abascal F, Canga A, Garcia-Valtuille R, Bustamante M, del Pinal F. Usefulness of gadolinium-enhanced MR imaging in the evaluation of the vascularity of scaphoid nonunions. *AJR Am J Roentgenol.* 2000;174(1):141-149.
59. Bordalo-Rodrigues M, Schweitzer M, Bergin D, Culp R, Barakat MS. Lunate chondromalacia: evaluation of routine MRI sequences. *AJR Am J Roentgenol.* 2005;184(5):1464-1469.
60. Saupe N, Pfirrmann CW, Schmid MR, Schertler T, Manestar M, Weishaupt D. MR imaging of cartilage in cadaveric wrists: comparison between imaging at 1.5 and 3.0 T and gross pathologic inspection. *Radiology.* 2007;243(1):180-187.
61. Tajika T, Kobayashi T, Yamamoto A, Kaneko T, Takagishi K. Diagnostic utility of sonography and correlation between sonographic and clinical findings in patients with carpal tunnel syndrome. *J Ultrasound Med.* 2013;32(11):1987-1993.
62. Ashraf AR, Jali R, Moghtaderi AR, Yazdani AH. The diagnostic value of ultrasonography in patients with electrophysiologicaly confirmed carpal tunnel syndrome. *Electromyogr Clin Neurophysiol.* 2009;49(1):3-8.

63. Klauser AS, Halpern EJ, De Zordo T, et al. Carpal tunnel syndrome assessment with US: value of additional cross-sectional area measurements of the median nerve in patients versus healthy volunteers. *Radiology.* 2009;250(1):171-177.
64. Sernik RA, Abicalaf CA, Pimentel BF, Braga-Baiak A, Braga L, Cerri GG. Ultrasound features of carpal tunnel syndrome: a prospective case-control study. *Skeletal Radiol.* 2008;37(1):49-53.
65. Akcar N, Ozkan S, Mehmetoglu O, Calisir C, Adapinar B. Value of power Doppler and gray-scale US in the diagnosis of carpal tunnel syndrome: contribution of cross-sectional area just before the tunnel inlet as compared with the cross-sectional area at the tunnel. *Korean J Radiol.* 2010;11(6):632-639.
66. Mallouhi A, Pulzl P, Trieb T, Piza H, Bodner G. Predictors of carpal tunnel syndrome: accuracy of gray-scale and color Doppler sonography. *AJR Am J Roentgenol.* 2006;186(5):1240-1245.
67. Rempel D, Evanoff B, Amadio PC, et al. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. *Am J Public Health.* 1998;88(10):1447-1451.
68. Martins RS, Siqueira MG, Simplicio H, Agapito D, Medeiros M. Magnetic resonance imaging of idiopathic carpal tunnel syndrome: correlation with clinical findings and electrophysiological investigation. *Clin Neurol Neurosurg.* 2008;110(1):38-45.
69. Jarvik JG, Comstock BA, Heagerty PJ, et al. Magnetic resonance imaging compared with electrodiagnostic studies in patients with suspected carpal tunnel syndrome: predicting symptoms, function, and surgical benefit at 1 year. *J Neurosurg.* 2008;108(3):541-550.
70. Aoki T, Oshige T, Matsuyama A, et al. High-resolution MRI predicts steroid injection response in carpal tunnel syndrome patients. *Eur Radiol.* 2014;24(3):559-565.
71. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: http://www.acr.org/~/media/ACR/Documents/AppCriteria/RadiationDoseAssessmentIntro.pdf. Accessed September 1, 2017.