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Revised 2011 (Resolution 24)\*

## **ACR–SPR–SSR PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF MAGNETIC RESONANCE IMAGING (MRI) OF THE ELBOW**

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### **PREAMBLE**

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiation oncology care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

### **I. INTRODUCTION**

This guideline was revised collaboratively by the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Skeletal Radiology (SSR).

Magnetic resonance imaging (MRI) is a proven imaging modality for the detection, evaluation, staging, and follow-up of disorders of the elbow. Properly performed and interpreted, MRI not only contributes to diagnosis but also can guide treatment planning and help predict outcomes. Nevertheless, elbow MRI should be performed only for a valid medical reason, and only after careful consideration of alternative imaging modalities.

Radiographs should be the first imaging test performed to evaluate the elbow [1-4]. Radiographs are an effective screening test for many bone and joint conditions around the elbow and for mineralized soft tissue lesions, but radiographs are less sensitive and specific for many entities [5-9]. Radiographs taken during valgus stress can aid in the diagnosis and management of ulnar collateral ligament injuries [10-12]. While conventional arthrography can help diagnose internal derangements in

the elbow joint, computed tomography (CT) arthrography and MR arthrography have largely replaced it [13-14]. Radionuclide imaging is sensitive for detecting early bone pathology, which may be radiographically occult, but scintigraphy lacks specificity, often necessitating additional imaging studies for complete evaluation [3]. Bone scintigraphy may be used to evaluate athletes with suspected stress injuries [15], although MRI is a more comprehensive examination in this population [16].

Sonography can be used to assess many of the soft tissue structures of the elbow [17-18]. Ultrasound can show elbow effusions [19], bursitis [20-21], nerve abnormalities [22-24], and tendon pathology in adults [2,4,25-26], although the sensitivity of ultrasound for elbow effusions and lateral epicondylitis may be lower than the sensitivity of MRI [27]. Ultrasound can demonstrate cartilage and soft tissue abnormalities in the infant elbow [28-30]. Dynamic ultrasound examination may be useful for elbows with torn collateral ligaments [31-33] or snapping of the distal triceps tendon [22]. In the absence of an effusion, arthrosonography performed following intra-articular saline injection can be used to search for loose bodies [34]. Furthermore, sonography can also guide diagnostic and therapeutic injections [21].

Elbow CT, especially with 2D multiplanar reconstructions and 3D surface rendering, is most frequently used for surgical planning, to evaluate complex fractures [35-37], and to assess the articular surfaces [35-39]. When combined with arthrography, CT is an effective test for locating intra-articular bodies and symptomatic synovial folds [6,40-42]. It is also useful for staging chondral and osteochondral lesions [3,40].

Lastly, arthroscopy, an invasive procedure, provides direct visualization of the internal structures of the elbow joint [43-44], and can be used for both diagnosis and treatment [45].

While MRI is a sensitive, noninvasive diagnostic test for detecting anatomic abnormalities of the elbow, its findings may be misleading if not closely correlated with the clinical history, physical examination, physiologic tests (such as nerve conduction studies and electromyography), and other imaging studies. Adherence to the following guidelines will enhance the probability of detecting clinically important abnormalities.

## II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#).

## III. INDICATIONS

A. Primary indications for MRI of the elbow include, but are not limited to, diagnosis, exclusion, and grading of suspected:

1. Ligament disorders (ulnar collateral, lateral ulnar collateral, radial collateral, and annular ligaments): sprains, partial and complete tears [14,39,46-55]. †
2. Disorders of the flexor and extensor tendon origins (epicondylitis): tendinopathy, partial and complete tears [27,39,56-60].\*
3. Distal biceps tendon disease: tendinopathy, partial and complete tears [50,55,61-65].
4. Distal triceps tendon disease: tendinopathy, partial and complete tears, snapping, subluxation [50,55,66-68].
5. Muscle and myotendinous injuries [55].
6. Occult fractures [69-71].
7. Osteochondral lesions: osteochondral fractures and osteochondritis dissecans [6-7,14,54-55,72-78].\*†
8. Cartilage lesions: chondral fractures and flaps, chondromalacia, degenerative arthritis [14,55,73,79]. †
9. Joint effusions and inflammatory or proliferative synovitis [19,80-83].\*
10. Intra-articular bodies: chondral, osteochondral, osseous [6,14,41,54-55,72-73,77].†
11. Symptomatic plicae, synovial folds, and elbow menisci [14,84-85]. †
12. Olecranon and bicipitoradial bursitis: septic, traumatic, crystal-induced, inflammatory [20,55,81,83,86-87].\*
13. Marrow abnormalities: bone contusions, osteonecrosis, marrow edema syndromes, stress fractures [15-16,75,77,88].\*
14. Peripheral nerve disorders: entrapment, compression, cubital tunnel syndrome, muscle denervation [23,39,50,63,69,89-94].\*
15. Congenital and developmental abnormalities [95].
16. Neoplasms of bone, joint, or soft tissue [96].\*
17. Infections of bone, joint, or soft tissue [83].\*
18. Abnormalities of the proximal forearm interosseous membrane and neuromuscular structures [91,97-98].

B. MRI of the elbow may be indicated to further clarify and stage conditions diagnosed clinically and/or suggested by other imaging modalities, including but not limited to:

1. Arthritides: primary inflammatory and erosive, infectious, neuropathic, degenerative, crystal-induced, post-traumatic [82-83].\*

2. Primary and secondary bone and soft tissue tumors [96].\* See also the [ACR–SSR Practice Guideline for the Performance and Interpretation of Magnetic Resonance Imaging \(MRI\) of Bone and Soft Tissue Tumors](#).
3. Fractures and stress fractures [4,16,39,49,70-71,73,75,99-100].
4. Soft tissue injuries associated with a known fracture [101-102].

C. MRI of the elbow may be useful to evaluate specific clinical scenarios, including but not limited to:

1. Prolonged, refractory, or unexplained elbow pain. †
2. Sports injuries, especially in throwing athletes [15,53,55,75,88,103]. †
3. Elbow instability: acute, recurrent, chronic [49,52,104]. †
4. Painful elbow snapping or mechanical symptoms [17,48,66,68,84-85]. †
5. Refractory tennis elbow [50,56,60].
6. Limited or painful range of motion, or contracture [105].
7. Unexplained elbow swelling, mass, or atrophy [96].\*
8. Neuropathy whose cause is localized to the elbow [23,39,50,63,69,89-94].\*
9. Patients for whom diagnostic or therapeutic arthroscopy or elbow surgery is planned [60]. †
10. Patients with recurrent, residual, or new symptoms following elbow surgery. †

\* Conditions in which intravenous (IV) contrast may be useful.

† Conditions in which intra-articular contrast (performed by direct intra-articular injection or indirect joint opacification following IV administration) may be useful.

#### IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#), the ACR Guidance Document for Safe MR Practices [106], and the [ACR Manual on Contrast Media](#) [107].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [108-109].

#### V. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards

associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

The written or electronic request for MRI of the elbow should provide sufficient information to demonstrate the medical necessity of the examination and allow for its proper performance and interpretation.

Documentation that satisfies medical necessity includes 1) signs and symptoms and/or 2) relevant history (including known diagnoses). Additional information regarding the specific reason for the examination or a provisional diagnosis would be helpful and may at times be needed to allow for the proper performance and interpretation of the examination.

The request for the examination must be originated by a physician or other appropriately licensed health care provider. The accompanying clinical information should be provided by a physician or other appropriately licensed health care provider familiar with the patient’s clinical problem or question and consistent with the state’s scope of practice requirements. (ACR Resolution 35, adopted in 2006)

The supervising physician must also understand the pulse sequences to be used and their effect on the appearance of the images, including the potential generation of image artifacts. Standard imaging protocols may be established and varied on a case-by-case basis when necessary. These protocols should be reviewed and updated periodically.

#### A. Patient Selection

The physician responsible for the examination should supervise patient selection and preparation and be available in person or by phone for consultation. Patients must be screened and interviewed prior to the examination to exclude individuals who may be at risk by exposure to the MR environment.

For certain indications the administration of intravenous (IV) contrast media is beneficial. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution’s policy on IV contrast use. (See the [ACR Practice Guideline for the Use of Intravascular Contrast Media](#).)

Pediatric patients or patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation or

general anesthesia may be needed to achieve a successful examination particularly in young children. If moderate sedation is necessary, refer to the [ACR–SIR Practice Guideline for Sedation/Analgesia](#).

## B. Facility Requirements

Appropriate emergency equipment and medications must be immediately available to treat adverse reactions associated with administered medications. The equipment and medications should be monitored for inventory and drug expiration dates on a regular basis. The equipment, medications, and other emergency support must also be appropriate for the range of ages and sizes in the patient population.

## C. Examination Technique

Elbow MRI can be performed using a variety of magnet designs (closed or open) and field strengths (low, medium, or high), including dedicated, extremity-only scanners [59,110]. On lower field systems, however, the lower signal-to-noise ratio (SNR) may necessitate modifications in the imaging parameters to prevent image degradation [111-112]. For example, the number of signals averaged can be increased, at the expense of longer imaging times and increased risk of involuntary patient motion [112-113]. Alternatively, the voxel size can be increased (by a combination of larger field of view (FOV), thicker slices, and/or decreased matrix) at the expense of spatial resolution. Fat suppression techniques that rely on the difference between fat and water frequencies (chemical shift) are unreliable at low field strength, and substituting short-tau inversion recovery (STIR) images may be necessary.

Regardless of system design, a local receiver coil is mandatory to maximize the SNR [114]. In general, the coil size should closely approximate the size of the elbow [115]. Thus, a wrist coil may be appropriate for a small child's elbow, while an adult who cannot completely straighten the elbow may require a knee coil [61]. Circumferential, cylindrical coils — constructed in saddle, birdcage, or phased array configurations — provide the most homogenous receptive field [49,116]. Newer multichannel coils containing eight or more coil elements will further increase SNRs, and are necessary when using techniques like parallel imaging [117]. Other choices include an anterior neck, shoulder, or flexible coil, or a pair of surface coils joined in a Helmholtz configuration [14,49,75,116]. Because it must be oriented perpendicular to the  $B_0$  magnetic field, elbow MRI can only utilize a solenoid coil on a low field system with a vertically oriented  $B_0$  field [112].

Patient positioning for elbow MRI can be more difficult than for other joints [118]. Local equipment together with the patient's size and physical limitations will affect both

patient and arm positioning, which in turn will influence the choice of imaging coil. Lying prone with the affected arm overhead allows the elbow to be placed near the magnet isocenter, where the field is most homogeneous. Additionally, the prone position may be easier to tolerate for some patients with severe claustrophobia [119]. Nevertheless, this position is uncomfortable for many patients, resulting in involuntary motion and associated imaging artifacts [75,112,118]. Having the patient pronate the forearm may alleviate some discomfort, but this position may distort the anatomy of the collateral ligaments and tendons in the coronal plane [49,75,112]. Conversely, lying supine with the affected elbow at the side is more comfortable for most patients, but this position places the elbow towards the side of the magnet where the field is less homogeneous, often degrading image quality and hampering the ability to achieve effective chemical fat suppression. Furthermore, many cylindrical coils are too large to be placed alongside a supine patient [116]. A third position for elbow MRI is laying the patient on his or her side with the elbow extended overhead [120]. The patient should extend the elbow as much as possible for routine MRI [112], but for some indications, performing part of the examination with the elbow flexed assists in diagnosis. Full elbow flexion is often necessary to demonstrate snapping of the distal triceps or dislocation of the ulnar nerve [68,120]. The contents and size of the cubital tunnel may be easier to visualize with elbow flexion [104]. Lastly, elbow flexion with forearm supination (achievable with the patient prone and the arm overhead) allows imaging of the entire distal biceps tendon in one long-axis plane [121].

Elbow MRI should usually include images in three imaging planes [49,75,104]. Short-axis (transverse) images, perpendicular to the humerus and forearm bones, should extend distally to include the radial tuberosity [75]. Coronal and sagittal images need to be prescribed from the transverse images, parallel and perpendicular respectively to the epicondylar axis of the distal humerus [14,49,112]. Some practices will also angle the coronal images posteriorly by 2 to 30 degrees (either by using the sagittal images as a second localizer or by flexing the elbow slightly) to better show the collateral ligaments [47,75,104]. When a severe flexion contracture is present, acquiring separate transverse and coronal images for the humerus and forearm bones may be necessary; alternatively, curved coronal reformatted images can be created from sagittal images 3D gradient-recalled images [105].

Accurate diagnosis of elbow disorders requires high spatial resolution. The FOV should be 10 to 16 cm [49,75,116,118]; a FOV at the low end of this range is desirable if the coil provides a high enough SNR to support it [116]. Thin slices (1.5 to 4 mm thickness) are also necessary; on most systems, obtaining a slice thickness less than 2 to 3 mm requires a 3D gradient-echo

sequence. For 2D images, an interslice gap no more than 33% of the slice width can increase coverage and decrease signal loss due to cross talk [122] but should not impair complete visualization of the intra-articular structures. A need to balance the desired in-plane resolution with adequate intravoxel SNR will affect the size of the imaging matrix selection. For imaging the elbow, the matrix should include at least 256 steps in the phase and frequency encoding directions. Smaller pixels are preferred, but the available SNR often limits the attainable resolution [112]. High-resolution images are especially important for evaluating the collateral ligaments when routine MRI is performed without arthrography [46,123]. Depending on the size of the elbow, a rectangular FOV can save imaging time without sacrificing in-plane resolution [118].

Numerous pulse sequences — conventional spin-echo, fast (turbo) spin-echo, and gradient-recalled — are available for elbow MRI. The choice of sequences, like other aspects of the imaging protocol, can be tailored to answer the specific clinical questions [112,118], and may vary according to local preferences. A typical imaging protocol will be composed of several pulse sequences. The exact repetition time (TR), echo time (TE), and flip angle chosen will depend on the field strength of the magnet and the desired relative contrast weighting. T1-weighted sequences are useful for characterizing marrow abnormalities [96], various stages of hemorrhage [124], and muscle disorders [125]. T2-weighted images can identify tendon degeneration [56,118] as well as muscle and soft tissue edema [118]. Including at least one T2-weighted sequence with fat suppression (or a STIR sequence) will increase the sensitivity of the examination for soft tissue as well as marrow edema [75]. Some practices use high-resolution long TR, short effective TE (proton-density-weighted) fast spin-echo images to examine the collateral ligaments [49,123]. Most elbow imaging protocols will combine short-TE (proton-density-weighted or T1-weighted) images and fluid-sensitive (T2-weighted or STIR) images [104]. An additional option is the use of gradient-recalled pulse sequences. Two-dimensional T2\*-weighted images can be used for diagnosing intra-articular loose bodies [14,120] and ligament tears [118], or to identify hemosiderin in disorders such as pigmented villonodular synovitis [80]. Gradient-echo imaging performed in 3D mode, with volume acquisition of data, can create thin, contiguous sections. Images with thin slices (2 mm or less) are useful for analyzing the elbow tendons [58], physical injuries in children, and the collateral ligaments in patients with throwing injuries and/or elbow instability [49,52,104,118,126]. Susceptibility artifacts, however, severely affect gradient-recalled images, limiting their use in postoperative elbows [49,75], where fixation hardware and/or microscopic metal shavings are often present.

T1-weighted images are also used when gadolinium-based contrast is administered intravenously, or injected directly into the joint for MR arthrography [77,120]. Intravenous contrast may be helpful in diagnosing bursitis [81], tendinopathy [59], osteochondral lesions [77], and tumors and inflammation [120]. Elbow MR arthrography can be performed by direct injection of saline or dilute gadolinium into the joint [14,120] or by indirect diffusion of contrast into the joint following IV administration [127]. Exercising the elbow and a delay of 10 to 15 minutes after IV injection will enhance joint opacification for indirect MR arthrography [127]. Direct or indirect MR arthrography can be used to evaluate the elbow ligaments [39,46,49,51,54,75,123,128] and articular cartilage [79], to stage osteochondral lesions and to identify intra-articular bodies [54,75,120]. While performing MR arthrography, fat-suppressed T1-weighted images are typically used with at least one additional fluid-sensitive sequence to detect pathology that does not communicate with the joint [14,75,127]. Including at least one T1-weighted sequence without fat suppression is useful for evaluating the bone marrow, detecting fatty atrophy of muscle, and characterizing soft tissue lesions.

Suppressing the signal from fat may enhance the diagnostic yield of some pulse sequences [115]. Fat suppression can be performed using spectrally selective RF pulses, a phase-dependent method (e.g., the Dixon technique), or a STIR sequence [129-131]. The latter technique may be necessary on low-field systems. Adding fat suppression to T2-weighted images (or using a STIR sequence) increases the conspicuity of subtle marrow and soft tissue edema [75]. Fat suppression is a useful adjunct to T1-weighted images when IV contrast is used, or when MR arthrography is performed [132], especially indirect MR arthrography, because of the inherently low gadolinium concentration in the elbow joint achieved after IV injection [127]. STIR imaging should be avoided in these cases since the signal intensity from gadolinium is usually suppressed along with fat with this technique.

It may be possible to shorten the time required for an elbow MRI examination without compromising diagnostic yield. Multichannel local coils allow the use of parallel imaging techniques, which decrease acquisition times for individual pulse sequences [117]. Additionally, fast 3D near isotropic imaging is now possible with newer gradient-recalled and fast spin-echo sequences [133-135]. Using these methods, a single volumetric acquisition can be obtained in less than ten minutes, and reconstructed images can be made in other imaging planes, decreasing the total number of pulse sequences needed to fully evaluate the joint.

Various techniques can minimize artifacts that reduce imaging quality. Aliasing is usually not a problem when the elbow is imaged over the head. However, with the

elbow at the patient's side, phase-encoding in the left-to-right direction should be avoided; if that is not possible, phase oversampling should be used to prevent wraparound artifact [136]. Presaturation pulses or gradient moment nulling will reduce ghosting artifacts from flowing blood and other periodic motion [136-137]. Chemical shift artifact is most severe at high field strengths and may necessitate an increase in the receiver bandwidth [113,136]. Susceptibility artifacts, which originate from heterogeneity of the local field, are also more severe at higher field strengths, in the presence of metallic implants, and when using gradient-recalled pulse sequences. Reducing the voxel size by increasing the imaging matrix and/or decreasing the slice thickness and FOV will help reduce the magnitude of susceptibility artifacts [136].

It is the responsibility of the supervising physician to determine whether additional or unconventional pulse sequences and imaging techniques confer added benefit for the diagnosis and management of the patient. Examinations that use techniques not approved by the Food and Drug Administration, such as the intra-articular injection of gadolinium chelates (direct MR arthrography) [138], can be considered when they are judged to be medically appropriate.

## VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Guideline for Communication of Diagnostic Imaging Findings](#).

At a minimum, the report should address the condition of the major elbow ligaments and tendons and the articular surfaces, as well as any abnormalities in the surrounding structures. In selected cases, a description of findings in the bone marrow, synovium, muscles, neurovascular structures, and subcutaneous tissue would be appropriate. The report should use standard anatomic nomenclature and precise terms for describing identified abnormalities, whenever possible.

## VII. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance must meet all state and federal requirements. The requirements include, but are not limited to, specifications of maximum static magnetic strength, maximum rate of change of the magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

## VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR web site (<http://www.acr.org/guidelines>).

Specific policies and procedures related to MRI safety should be in place along with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with the MRI examination of the patient as well as to others in the immediate area [108-109,139]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [140].

Equipment monitoring should be in accordance with the [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging \(MRI\) Equipment](#).

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