

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

The American College of Radiology, with more than 40,000 members, is the principal organization of radiologists, radiation oncologists, and clinical medical physicists in the United States. The College is a nonprofit professional society whose primary purposes are to advance the science of radiology, improve radiologic services to the patient, study the socioeconomic aspects of the practice of radiology, and encourage continuing education for radiologists, radiation oncologists, medical physicists, and persons practicing in allied professional fields.

The American College of Radiology will periodically define new practice parameters and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

## PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care<sup>1</sup>. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and 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 the guidance in this document 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 purpose of this document is to assist practitioners in achieving this objective.

---

<sup>1</sup> *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, 831 N.W.2d 826 (Iowa 2013) Iowa Supreme Court refuses to find that the "ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures (Revised 2008)" sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

## I. INTRODUCTION

This practice parameter 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 and useful tool for the detection, evaluation, staging, and follow-up of disorders of the elbow. When properly utilized and performed, MRI not only contributes to diagnosis but can also guide treatment planning and help predict outcomes in many situations. Nevertheless, elbow MRI should be performed for a valid medical reason and should address a specific medical concern. When indicated, it should be utilized in conjunction with other imaging modalities, such as radiographs.

Radiography should be the first imaging test performed to evaluate the elbow [1-4]. Radiography is an effective screening tool for many bone and joint conditions in and around the elbow. Radiography provides valuable information, such as general mineralization status and alignment of the elbow [5-9]. Because of its superior spatial resolution, radiography is imperative when characterizing bone lesions, and can be used to assess for mineralization in soft-tissue masses. Radiography can also be used in dynamic situations, such as stress views, when evaluating the integrity of the ulnar collateral ligament [10-12].

Conventional arthrography has mostly been replaced or augmented by CT or MR arthrography [13,14].

Scintigraphy is a sensitive tool for assessing early bony pathology that may be radiographically occult [3], but lacks specificity and has been replaced by MRI in most circumstances, being used in more specific situations on a case-by-case basis. It can be utilized to assess stress injuries, infections, and tumors [3,15,16].

Ultrasonography is a very valuable tool for assessing the soft tissues of the elbow [17,18]. Ultrasound can evaluate for joint effusions and synovitis, bursitis, tendon and ligament pathology, erosions, and enthesitis, as well as nerve abnormalities [2,19-27]. Dynamic ultrasound can assess the integrity of the ulnar collateral ligament, dislocating ulnar nerve, or snapping of the distal triceps tendon [22,31-33]. Ultrasound can be used in infants to assess immature bone cartilage and soft tissues [28-30]. Finally, ultrasound can be used for diagnostic and therapeutic injections [21,34].

Computed tomography (CT) is frequently used for preoperative planning and evaluation of complex fractures and articular surfaces [35-39]. CT arthrography is an effective test for locating intra-articular osteochondral fragments, identifying symptomatic synovial folds, and staging chondral and osteochondral lesions [3,6,40-42].

Arthroscopy, as an invasive procedure, provides direct visualization of the internal structures of the elbow joint, and is used for diagnosis and treatment.

MRI is a sensitive, noninvasive diagnostic test used to detect anatomic abnormalities of the elbow, and, when correlated with clinical history, physical examination, and physiologic testing, can be a valuable tool for identifying clinically important abnormalities and formulating a treatment plan.

## II. INDICATIONS

A. Primary indications for MRI of the elbow include, but are not limited to, diagnosis, exclusion, and grading of suspected [46]:

1. Ligament disorders (ulnar collateral, lateral ulnar collateral, radial collateral, and annular ligaments): posterior lateral elbow instability, sprains, partial and complete tears[1] [14,39,47-59]
2. Disorders of the flexor and extensor tendon origins (epicondylitis): tendinopathy, partial and complete tears[2] [27,39,60-64]
3. Distal biceps tendon disease: tendinopathy, partial and complete tears [51,56,65-69]
4. Distal triceps tendon disease: tendinopathy, partial and complete tears, snapping, subluxation [51,56,70-72]
5. Muscle and myotendinous injuries [56]
6. Occult fractures [73-76]
7. Osteochondral lesions: osteochondral fractures and osteochondritis dissecans<sup>2,3</sup> [6,7,14,55,56,77-83]

8. Cartilage lesions: chondral fractures and flaps, chondromalacia, degenerative arthritis<sup>†</sup> [4,56,78,84]
9. Joint effusions and inflammatory or proliferative synovitis<sup>3</sup> [19,85-88]
10. Intra-articular bodies: chondral, osteochondral, osseous<sup>2</sup> [6,14,41,55,56,77,78,82]
11. Symptomatic plicae and synovial folds [14,89,90]
12. Olecranon and bicipitoradial bursitis: septic, traumatic, crystal-induced, inflammatory<sup>2</sup> [20,56,86,88,91,92]
13. Marrow abnormalities: bone contusions, osteonecrosis, apophysitis, marrow edema syndromes, stress fractures<sup>2</sup> [15,16,80,82,93,94]
14. Peripheral nerve disorders: entrapment, compression, cubital tunnel syndrome, muscle denervation<sup>2</sup> [23,39,51,67,73,95-103]
15. Congenital and developmental abnormalities [104]
16. Neoplasms of bone, joint, or soft tissue<sup>2</sup> [105]
17. Infections of bone, joint, or soft tissue<sup>2</sup> [88,106]
18. Abnormalities of the proximal forearm interosseous membrane and neuromuscular structures [97,107,108]

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, posttraumatic<sup>2</sup> [87,88]
2. Primary and secondary bone and soft-tissue tumors<sup>2</sup> [105] (see also the [ACR–SPR–SSR Practice Parameter for the Performance and Interpretation of Magnetic Resonance Imaging \(MRI\) of Bone and Soft-Tissue Tumors](#) [109])
3. Fractures and stress fractures [4,16,39,50,74,75,78,80,110,111]
4. Soft-tissue injuries associated with a known fracture [112,113]

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<sup>3</sup>
2. Sports injuries, especially in throwing athletes<sup>3</sup> [15,54,56,80,93,114,115]
3. Elbow instability: acute, recurrent, chronic (eg, posterolateral rotatory instability)<sup>3</sup> [50,53,57,116]
4. Painful elbow snapping or mechanical symptoms<sup>3</sup> [17,49,70,72,89,90]
5. Refractory tennis elbow [51,60,64]
6. Limited or painful range of motion, or contracture [117]
7. Unexplained elbow swelling, mass, or atrophy<sup>2</sup> [105,106]
8. Neuropathy whose cause is localized to the elbow<sup>2</sup> [23,39,51,67,73,95-100]
9. Patients for whom diagnostic or therapeutic arthroscopy or elbow surgery is planned<sup>3</sup> [64]
10. Patients with recurrent, residual, or new symptoms following elbow surgery<sup>3</sup>

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

[2] Conditions in which intravenous (IV) contrast may be useful

### III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [118].

### IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [118], the [ACR Guidance Document on MR Safe Practices 2020](#) [119], and the [ACR Manual on Contrast Media](#) [120].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [121,122].

## V. SPECIFICATIONS OF THE 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 – revised in 2016, Resolution 12-b)

The supervising physician must have adequate understanding of the indications, risks, and benefits of the imaging 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 and gadolinium deposition. 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 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 telephone for consultation. Patients must be screened and interviewed prior to the examination to exclude individuals who may be at potential 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–SPR Practice Parameter for the Use of Intravascular Contrast Media](#) [123]).

Pediatric patients or patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation or general anesthesia may be infrequently needed to achieve a successful examination, particularly in young children, although patient education, mock scanner simulation, distraction with audiovisual media, and child life services are often successful in averting sedation use in children [124]. If moderate sedation is necessary, refer to the [ACR–SIR Practice Parameter for Minimal and/or Moderate Sedation/Analgesia](#) [125].

### 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

#### 1. Equipment

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 [63,126]. Although arbitrary, 0.3T is designated as low field, 1T as medium field, and 1.5T to 3T as high field [127,128]. On lower field strength

systems, poorer signal-to-noise ratio (SNR) may necessitate modifications in the imaging parameters to prevent image degradation [129,130]. For example, the number of signals averaged can be increased at the expense of longer acquisition times and increased risk of involuntary patient motion [130,131]. Alternatively, voxel size can be increased (through a combination of larger field of view (FOV), thicker slices, and/or decreased matrix) at the cost of lower 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 [132]. In general, the coil size should closely approximate the size of the elbow [133]. Thus, a wrist coil may be appropriate for a small child's elbow, whereas an adult who cannot completely straighten the elbow may require a knee coil [65]. Circumferential, cylindrical coils—constructed in saddle, birdcage, or phased-array configurations—provide the most homogenous receptive field [50,134]. Multichannel coils containing 8 or more coil elements increase SNRs and are necessary when using techniques like parallel imaging [135]. Other choices include an anterior neck, shoulder, or flexible coil or a pair of surface coils joined in a Helmholtz configuration [14,50,80,134]. 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 [130].

## 2. Patient Positioning

Patient positioning for elbow MRI can be more difficult than for other joints [136]. 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 [137]. Nevertheless, this position is uncomfortable for many patients, resulting in involuntary motion and associated imaging artifacts [80,130,136]. 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 [50,80,130]. Conversely, lying supine with the affected elbow at the side is more comfortable for most patients, but this position places the elbow toward the side of the magnet where the magnetic field is less homogeneous, degrading image quality and hampering the ability to achieve effective chemical fat suppression [138]. Furthermore, many cylindrical coils are too large to be placed alongside a supine patient [134]. A third position for elbow MRI is the patient lying on the side with the elbow extended overhead [139]. The patient should extend the elbow as much as possible for routine MRI [130], but for some indications, performing part of the examination with the elbow flexed may assist in the diagnosis. Full elbow flexion may be necessary to demonstrate subluxation of the distal triceps or dislocation of the ulnar nerve in snapping elbow syndrome [72,139]. The contents and size of the cubital tunnel are also easier to visualize with elbow flexion [116]. 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 [140].

## 3. Imaging Planes and Technical Considerations

Elbow MRI should usually include images in three imaging planes [50,80,116]. Short-axis (transverse) images, perpendicular to the humerus and forearm bones, should extend distally to include the radial tuberosity for the biceps brachii tendon attachment [80]. Coronal and sagittal images need to be prescribed from the transverse images, parallel and perpendicular, respectively, to the epicondylar axis of the distal humerus [14,50,130]. 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 delineate the collateral ligaments [48,80,116]. When severe flexion contractures are present, acquiring separate transverse and coronal images for the humerus and forearm bones may be necessary. Accurate diagnosis of elbow disorders requires high spatial resolution. The FOV should be 10 to 16 cm [50,80,134,136]; a FOV at the low end of this range is desirable if the coil provides a high enough SNR to support it [134]. Thin slices (1.5–4 mm thick) are also necessary; on most systems, obtaining a slice thickness <2 to 3 mm requires a 3-D sequence. 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 available SNR limits the attainable resolution [130]. High-resolution images are especially important for

evaluating the collateral ligaments when routine MRI is performed without arthrography [47,142]. Depending on the size of the elbow, a rectangular FOV can save imaging time without sacrificing in-plane resolution [136].

#### 4. Conventional Pulse Sequences

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 [130,136] 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 [105], various stages of hemorrhage [143], and muscle disorders [144]. T2-weighted images can identify tendon degeneration [60,136] as well as muscle and soft-tissue edema [136]. 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 [80]. Some practices use high-resolution long-TR, short-effective-TE (proton-density-weighted) fast spin-echo images to examine the collateral ligaments [50,142]. Most elbow imaging protocols will combine short-TE (proton-density-weighted or T1-weighted) images and fluid-sensitive (T2-weighted or STIR) images [116]. An additional option is the use of gradient-recalled pulse sequences. Chemical shift (phase-dependent)-based sequences (eg, T2-weighted Dixon) can also be used to achieve homogeneous fat suppression and can provide in-phase, out-of-phase, water-, and fat-suppressed images in a single acquisition, yielding fat-suppressed fluid-sensitive images as well as providing marrow-specific information [145]. Two-dimensional T2\*-weighted images can be used for diagnosing intra-articular loose bodies [14,139] and ligament tears [136] or to identify hemosiderin in disorders such as tenosynovial giant-cell tumor [85]. Gradient-echo imaging performed in 3-D 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 [62], physical injuries in children, and the collateral ligaments in patients with throwing injuries and/or elbow instability [50,53,116,136,146]. Susceptibility artifacts, however, severely affect gradient-recalled images, limiting their use in postoperative elbows [50,80], in which fixation hardware and/or microscopic metal shavings are often present.

##### 1. IV and Intra-Articular Contrast

T1-weighted images are also used when gadolinium-based contrast is administered intravenously or injected directly into the joint for MR arthrography [82,139]. IV contrast may be helpful in diagnosing bursitis [86], tendinopathy [63], osteochondral lesions [82], and tumors and inflammation [139]. Elbow MR arthrography can be performed by direct injection of saline or dilute gadolinium into the joint [14,139] or by indirect diffusion of contrast into the joint following IV administration [147]. Exercising the elbow and a delay of 10 to 15 minutes after IV injection will enhance joint opacification for indirect MR arthrography [147]. Direct or indirect MR arthrography can be used to evaluate the elbow ligaments [39,47,50,52,55,80,142,148] and articular cartilage [84], to stage osteochondral lesions, and to identify intra-articular bodies [55,80,139]. 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 [14,80,147]. Including at least one T1-weighted sequence without fat suppression is useful for evaluating the bone marrow, detecting fatty replacement and atrophy of muscle, and characterizing soft-tissue lesions.

#### 6. Advanced Pulse Sequences

Although diffusion tensor imaging (DTI) of the peripheral nerves at the elbow can be a highly sensitive technique to detect neuropathy [149], the technical requirements to apply DTI in the extremities currently limit its widespread use. Other promising techniques for sensitive evaluation for peripheral neuropathy include radiomics analysis of structural changes of nerves [150].

#### 7. Fat Suppression

Suppressing the signal from fat may enhance the diagnostic yield of some MRI acquisitions [133]. Fat

suppression can be performed using spectrally selective radiofrequency (RF) pulses, a phase-dependent method (eg, Dixon technique), or a STIR sequence [151-153]. 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 [80]. Fat suppression is a useful adjunct to T1-weighted images when IV contrast is used or when MR arthrography is performed [154], especially indirect MR arthrography, because of the inherently low gadolinium concentration in the joint that is achieved after IV injection [147]. STIR imaging should be avoided in these cases because the signal intensity from gadolinium is usually suppressed along with fat with this technique.

## 8. Time Constraints

It is 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 [135]. Additionally, fast 3-D isotropic imaging is possible with gradient-recalled and fast spin-echo sequences [155-157]. Using these methods, a single volumetric acquisition can be obtained in <10 minutes, and reconstructed images can be made in other imaging planes, decreasing the total number of pulse sequences needed to fully evaluate the joint. In the future, techniques such as compressed sensing may potentially further reduce scan times [158].

## 9. Artifact Reduction

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 [159]. Presaturation pulses or gradient moment nulling will reduce ghosting artifacts from flowing blood and other periodic motion [159,160]. Chemical shift artifact is most severe at high field strengths and may necessitate an increase in the receiver bandwidth [131,159]. 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 gradient-recalled pulse sequences are used. 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 [159].

It is the responsibility of the supervising physician to determine whether additional or advanced 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 (FDA), such as the intra-articular injection of gadolinium chelates (direct MR arthrography) [161], can be considered when they are judged to be medically appropriate.

## VI. DOCUMENTATION

Reporting should be in accordance with the [ACR Practice Parameter for Communication of Diagnostic Imaging Findings](#) [162].

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.

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 [121,122,163]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [164].

## VII. EQUIPMENT SPECIFICATIONS



Equipment monitoring should be in accordance with the [ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance \(MR\) Imaging Equipment](#) [165].

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 *ACR Position Statement on Quality Control & Improvement, Safety, Infection Control, and Patient Education* on the ACR website

(<https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement>).

## **ACKNOWLEDGEMENTS**

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (<https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards>) by the Committee on Practice Parameters – Body Imaging (Musculoskeletal) of the ACR Commission on Body Imaging and the Committee on Practice Parameters – Pediatric Radiology of the ACR Commission on Pediatric Radiology, in collaboration with the SPR, and the SSR.

Writing Committee – members represent their societies in the initial and final revision of this practice parameter

<u>ACR</u>	<u>SPR</u>	<u>SSR</u>
Varand Ghazikhanian, MD, Co-Chair	Andrew Degnan, MD, MPhil, MRMD	Padmaja Jonnalagadda, MD
Kambiz Motamedi, MD, Co-Chair	Victor Ho-Fung, MD	
Jason Higgins MD		
Kenneth S. Lee, MD		

## Committee on Body Imaging (Musculoskeletal)

(ACR Committee responsible for sponsoring the draft through the process)

Catherine C. Roberts, MD, Chair	Suzanne S. Long, MD
---------------------------------	---------------------



Jeffrey M. Brody, MD, FACR

Kambiz Motamedi, MD

Bethany U. Casagrande, DO

Carlos A. Rivera, BSc

Elaine S Gould, MD, FACR

Aleksandr Rozenberg, MD

Mary K. Jesse, MD

Naveen Subhas, MD

Kenneth S. Lee, MD

#### Committee on Practice Parameters – Pediatric Radiology

(ACR Committee responsible for sponsoring the draft through the process)

Terry L. Levin, MD, FACR, Chair

Jane Sun Kim, MD

John B. Amodio, MD, FACR

Jennifer A Knight, MD

Jesse Berman, MD

Jessica Kurian, MD

Tara M. Catanzano, MB, BCh

Matthew P. Lungren, MD, MPH

Harris L. Cohen, MD, FACR

Helen R. Nadel, MD

Kassa Darge, MD, PhD

Erica Poletto, MD

Dorothy L. Gilbertson-Dahdal, MD

Richard B. Towbin, MD, FACR

Lauren P. Golding, MD

Andrew T. Trout, MD

Safwan S. Halabi, MD

Esben S. Vogelius, MD

Jason Higgins, DO

Andrew B. Rosenkrantz, MD, Chair, Commission on Body Imaging

Richard A. Barth, MD, FACR, Chair, Commission on Pediatric Radiology

David B. Larson, MD, MBA, Chair, Commission on Quality and Safety

Mary S. Newell, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

#### Comment Reconciliation Committee

Taj Kattapuram, MD, Chair

Amy Kotsenas, MD, FACR

Eric Friedberg, MD, FACR, Co-Chair

David B. Larson, MD, MBA

Mahmoud M. Al-Hawary, MD

Paul A. Larson, MD, FACR

Richard A. Barth, MD, FACR

Kenneth S. Lee, MD

Andrew Degnan, MD, MPhil, MRMD

Terry L. Levin, MD, FACR

Richard Duszak Jr., MD, FACR

Douglas N. Mintz, MD

Varand Ghazikhanian, MD

Kambiz Motamedi, MD

Jason Higgins MD

Mary S. Newell, MD, FACR

Victor Ho-Fung, MD

Catherine C. Roberts, MD

Padmaja Jonnalagadda, MD

Andrew B. Rosenkrantz, MD

#### **REFERENCES**

1. Miller TT. Imaging of elbow disorders. *Orthop Clin North Am* 1999;30:21-36.
2. Potter HG. Imaging of posttraumatic and soft tissue dysfunction of the elbow. *Clin Orthop Relat Res* 2000;9-18.
3. Sauser DD, Thordarson SH, Fahr LM. Imaging of the elbow. *Radiol Clin North Am* 1990;28:923-40.
4. Sofka CM, Potter HG. Imaging of elbow injuries in the child and adult athlete. *Radiol Clin North Am* 2002;40:251-65.
5. Baker CL, 3rd, Romeo AA, Baker CL, Jr. Osteochondritis dissecans of the capitellum. *Am J Sports Med* 2010;38:1917-28.
6. Dubberley JH, Faber KJ, Patterson SD, et al. The detection of loose bodies in the elbow: the value of MRI and CT arthrography. *J Bone Joint Surg Br* 2005;87:684-6.
7. Janarv PM, Hesser U, Hirsch G. Osteochondral lesions in the radiocapitellar joint in the skeletally immature: radiographic, MRI, and arthroscopic findings in 13 consecutive cases. *J Pediatr Orthop* 1997;17:311-4.
8. Kijowski R, De Smet AA. Radiography of the elbow for evaluation of patients with osteochondritis dissecans of the capitellum. *Skeletal Radiol* 2005;34:266-71.
9. Mulligan SA, Schwartz ML, Broussard MF, Andrews JR. Heterotopic calcification and tears of the ulnar collateral ligament: radiographic and MR imaging findings. *AJR Am J Roentgenol* 2000;175:1099-102.

10. Eygendaal D, Heijboer MP, Obermann WR, Rozing PM. Medial instability of the elbow: findings on valgus load radiography and MRI in 16 athletes. *Acta Orthop Scand* 2000;71:480-3.
11. Lynch JR, Waitayawinyu T, Hanel DP, Trumble TE. Medial collateral ligament injury in the overhand-throwing athlete. *J Hand Surg Am* 2008;33:430-7.
12. Rijke AM, Goitz HT, McCue FC, Andrews JR, Berr SS. Stress radiography of the medial elbow ligaments. *Radiology* 1994;191:213-6.
13. Buckwalter KA. CT Arthrography. *Clin Sports Med* 2006;25:899-915.
14. Steinbach LS, Schwartz M. Elbow arthrography. *Radiol Clin North Am* 1998;36:635-49.
15. Ahmad CS, ElAttrache NS. Valgus extension overload syndrome and stress injury of the olecranon. *Clin Sports Med* 2004;23:665-76, x.
16. Anderson MW. Imaging of upper extremity stress fractures in the athlete. *Clin Sports Med* 2006;25:489-504, vii.
17. Finlay K, Ferri M, Friedman L. Ultrasound of the elbow. *Skeletal Radiol* 2004;33:63-79.
18. Martinoli C, Bianchi S, Giovagnorio F, Pugliese F. Ultrasound of the elbow. *Skeletal Radiol* 2001;30:605-14.
19. De Maeseneer M, Jacobson JA, Jaovisidha S, et al. Elbow effusions: distribution of joint fluid with flexion and extension and imaging implications. *Invest Radiol* 1998;33:117-25.
20. Liessi G, Cesari S, Spaliviero B, Dell'Antonio C, Avventi P. The US, CT and MR findings of cubital bursitis: a report of five cases. *Skeletal Radiol* 1996;25:471-5.
21. Sofka CM, Adler RS. Sonography of cubital bursitis. *AJR Am J Roentgenol* 2004;183:51-3.
22. Jacobson JA, Jebson PJ, Jeffers AW, Fessell DP, Hayes CW. Ulnar nerve dislocation and snapping triceps syndrome: diagnosis with dynamic sonography--report of three cases. *Radiology* 2001;220:601-5.
23. Kinni V, Craig J, van Holsbeeck M, Ditmars D. Entrapment of the posterior interosseous nerve at the arcade of Frohse with sonographic, magnetic resonance imaging, and intraoperative confirmation. *J Ultrasound Med* 2009;28:807-12.
24. Park GY, Kim JM, Lee SM. The ultrasonographic and electrodiagnostic findings of ulnar neuropathy at the elbow. *Arch Phys Med Rehabil* 2004;85:1000-5.
25. Connell D, Burke F, Coombes P, et al. Sonographic examination of lateral epicondylitis. *AJR Am J Roentgenol* 2001;176:777-82.
26. Miller TT, Adler RS. Sonography of tears of the distal biceps tendon. *AJR Am J Roentgenol* 2000;175:1081-6.
27. Miller TT, Shapiro MA, Schultz E, Kalish PE. Comparison of sonography and MRI for diagnosing epicondylitis. *J Clin Ultrasound* 2002;30:193-202.
28. Markowitz RI, Davidson RS, Harty MP, Bellah RD, Hubbard AM, Rosenberg HK. Sonography of the elbow in infants and children. *AJR Am J Roentgenol* 1992;159:829-33.
29. Zhang JD, Chen H. Ultrasonography for non-displaced and mini-displaced humeral lateral condyle fractures in children. *Chin J Traumatol* 2008;11:297-300.
30. Zuazo I, Bonnefoy O, Tauzin C, et al. Acute elbow trauma in children: role of ultrasonography. *Pediatr Radiol* 2008;38:982-8.
31. De Smet AA, Winter TC, Best TM, Bernhardt DT. Dynamic sonography with valgus stress to assess elbow ulnar collateral ligament injury in baseball pitchers. *Skeletal Radiol* 2002;31:671-6.
32. Nazarian LN, McShane JM, Ciccotti MG, O'Kane PL, Harwood MI. Dynamic US of the anterior band of the ulnar collateral ligament of the elbow in asymptomatic major league baseball pitchers. *Radiology* 2003;227:149-54.
33. Sasaki J, Takahara M, Ogino T, Kashiwa H, Ishigaki D, Kanauchi Y. Ultrasonographic assessment of the ulnar collateral ligament and medial elbow laxity in college baseball players. *J Bone Joint Surg Am* 2002;84-A:525-31.
34. Miller JH, Beggs I. Detection of intraarticular bodies of the elbow with saline arthrosonography. *Clin Radiol* 2001;56:231-4.
35. Blickman JG, Dunlop RW, Sanzone CF, Franklin PD. Is CT useful in the traumatized pediatric elbow? *Pediatr Radiol* 1990;20:184-5.
36. Franklin PD, Dunlop RW, Whitelaw G, Jacques E, Jr., Blickman JG, Shapiro JH. Computed tomography of the normal and traumatized elbow. *J Comput Assist Tomogr* 1988;12:817-23.
37. Hindman BW, Schreiber RR, Wiss DA, Ghilarducci MJ, Avolio RE. Supracondylar fractures of the humerus: prediction of the cubitus varus deformity with CT. *Radiology* 1988;168:513-5.
38. Garniek A, Morag B, Yaffe B, Luboshitz S, Rubinstein Z. True sagittal CT scanning of the elbow. *J Comput*

Assist Tomogr 1995;19:1012-3.

39. Shahabpour M, Kichouh M, Laridon E, Gielen JL, De Mey J. The effectiveness of diagnostic imaging methods for the assessment of soft tissue and articular disorders of the shoulder and elbow. *Eur J Radiol* 2008;65:194-200.
40. Holland P, Davies AM, Cassar-Pullicino VN. Computed tomographic arthrography in the assessment of osteochondritis dissecans of the elbow. *Clin Radiol* 1994;49:231-5.
41. Quinn SF, Haberman JJ, Fitzgerald SW, Traugher PD, Belkin RI, Murray WT. Evaluation of loose bodies in the elbow with MR imaging. *J Magn Reson Imaging* 1994;4:169-72.
42. Singson RD, Feldman F, Rosenberg ZS. Elbow joint: assessment with double-contrast CT arthrography. *Radiology* 1986;160:167-73.
43. Dodson CC, Nho SJ, Williams RJ, 3rd, Altchek DW. Elbow arthroscopy. *J Am Acad Orthop Surg* 2008;16:574-85.
44. Steinmann SP. Elbow arthroscopy: where are we now? *Arthroscopy* 2007;23:1231-6.
45. Reddy AS, Kvitne RS, Yocum LA, Elattrache NS, Glousman RE, Jobe FW. Arthroscopy of the elbow: a long-term clinical review. *Arthroscopy* 2000;16:588-94.
46. Sheehan SE, Dyer GS, Sodickson AD, Patel KI, Khurana B. Traumatic elbow injuries: what the orthopedic surgeon wants to know. *Radiographics* 2013;33:869-88.
47. Carrino JA, Morrison WB, Zou KH, Steffen RT, Snearly WN, Murray PM. Lateral ulnar collateral ligament of the elbow: optimization of evaluation with two-dimensional MR imaging. *Radiology* 2001;218:118-25.
48. Cotten A, Jacobson J, Brossmann J, et al. Collateral ligaments of the elbow: conventional MR imaging and MR arthrography with coronal oblique plane and elbow flexion. *Radiology* 1997;204:806-12.
49. Huang GS, Lee CH, Lee HS, Chen CY. MRI, arthroscopy, and histologic observations of an annular ligament causing painful snapping of the elbow joint. *AJR Am J Roentgenol* 2005;185:397-9.
50. Kaplan LJ, Potter HG. MR imaging of ligament injuries to the elbow. *Magn Reson Imaging Clin N Am* 2004;12:221-32, v-vi.
51. Kijowski R, Tuite M, Sanford M. Magnetic resonance imaging of the elbow. Part II: Abnormalities of the ligaments, tendons, and nerves. *Skeletal Radiol* 2005;34:1-18.
52. Nassab PF, Schickendantz MS. Evaluation and treatment of medial ulnar collateral ligament injuries in the throwing athlete. *Sports Med Arthrosc* 2006;14:221-31.
53. Potter HG, Weiland AJ, Schatz JA, Paletta GA, Hotchkiss RN. Posterolateral rotatory instability of the elbow: usefulness of MR imaging in diagnosis. *Radiology* 1997;204:185-9.
54. Salvo JP, Rizio L, 3rd, Zvijac JE, Uribe JW, Hechtman KS. Avulsion fracture of the ulnar sublime tubercle in overhead throwing athletes. *Am J Sports Med* 2002;30:426-31.
55. Steinbach LS, Palmer WE, Schweitzer ME. Special focus session. MR arthrography. *Radiographics* 2002;22:1223-46.
56. Thornton R, Riley GM, Steinbach LS. Magnetic resonance imaging of sports injuries of the elbow. *Top Magn Reson Imaging* 2003;14:69-86.
57. Mak S, Beltran LS, Bencardino J, et al. MRI of the annular ligament of the elbow: review of anatomic considerations and pathologic findings in patients with posterolateral elbow instability. *AJR Am J Roentgenol* 2014;203:1272-9.
58. Cha YK, Kim SJ, Park NH, Kim JY, Kim JH, Park JY. Magnetic resonance imaging of patients with lateral epicondylitis: Relationship between pain and severity of imaging features in elbow joints. *Acta Orthop Traumatol Turc* 2019;53:366-71.
59. Kwak SH, Lee SJ, Jeong HS, Do MU, Suh KT. Subtle elbow instability associated with lateral epicondylitis. *BMC Musculoskelet Disord* 2018;19:136.
60. Aoki M, Wada T, Isogai S, Kanaya K, Aiki H, Yamashita T. Magnetic resonance imaging findings of refractory tennis elbows and their relationship to surgical treatment. *J Shoulder Elbow Surg* 2005;14:172-7.
61. Kijowski R, De Smet AA. Magnetic resonance imaging findings in patients with medial epicondylitis. *Skeletal Radiol* 2005;34:196-202.
62. Potter HG, Hannafin JA, Morwessel RM, DiCarlo EF, O'Brien SJ, Altchek DW. Lateral epicondylitis: correlation of MR imaging, surgical, and histopathologic findings. *Radiology* 1995;196:43-6.
63. Steinborn M, Heuck A, Jessel C, Bonel H, Reiser M. Magnetic resonance imaging of lateral epicondylitis of the elbow with a 0.2-T dedicated system. *Eur Radiol* 1999;9:1376-80.
64. Walz DM, Newman JS, Konin GP, Ross G. Epicondylitis: pathogenesis, imaging, and treatment.

Radiographics 2010;30:167-84.

65. Falchhook FS, Zlatkin MB, Erbacher GE, Moulton JS, Bisset GS, Murphy BJ. Rupture of the distal biceps tendon: evaluation with MR imaging. *Radiology* 1994;190:659-63.
66. Festa A, Mulieri PJ, Newman JS, Spitz DJ, Leslie BM. Effectiveness of magnetic resonance imaging in detecting partial and complete distal biceps tendon rupture. *J Hand Surg Am* 2010;35:77-83.
67. Ho CP. MR imaging of tendon injuries in the elbow. *Magn Reson Imaging Clin N Am* 1997;5:529-43.
68. Koulouris G, Malone W, Omar IM, Gopez AG, Wright W, Kavanagh EC. Bifid insertion of the distal biceps brachii tendon with isolated rupture: magnetic resonance findings. *J Shoulder Elbow Surg* 2009;18:e22-5.
69. Williams BD, Schweitzer ME, Weishaupt D, et al. Partial tears of the distal biceps tendon: MR appearance and associated clinical findings. *Skeletal Radiol* 2001;30:560-4.
70. Spinner RJ, Hayden FR, Jr., Hipps CT, Goldner RD. Imaging the snapping triceps. *AJR Am J Roentgenol* 1996;167:1550-1.
71. Tiger E, Mayer DP, Glazer R. Complete avulsion of the triceps tendon: MRI diagnosis. *Comput Med Imaging Graph* 1993;17:51-4.
72. Yiannakopoulos CK. Imaging diagnosis of the snapping triceps syndrome. *Radiology* 2002;225:607-8; author reply 08.
73. Andreisek G, Crook DW, Burg D, Marincek B, Weishaupt D. Peripheral neuropathies of the median, radial, and ulnar nerves: MR imaging features. *Radiographics* 2006;26:1267-87.
74. Costa M, Owen-Johnstone S, Tucker JK, Marshall T. The value of MRI in the assessment of an elbow injury in a neonate. *J Bone Joint Surg Br* 2001;83:544-6.
75. Sawant MR, Narayanan S, O'Neill K, Hudson I. Distal humeral epiphysis fracture separation in neonates -- diagnosis using MRI scan. *Injury* 2002;33:179-81.
76. Tanabe K, Miyamoto N. Fracture of an unossified humeral medial epicondyle: use of magnetic resonance imaging for diagnosis. *Skeletal Radiol* 2016;45:1409-12.
77. Bowen RE, Otsuka NY, Yoon ST, Lang P. Osteochondral lesions of the capitellum in pediatric patients: role of magnetic resonance imaging. *J Pediatr Orthop* 2001;21:298-301.
78. Fritz RC. MR imaging of osteochondral and articular lesions. *Magn Reson Imaging Clin N Am* 1997;5:579-602.
79. Kijowski R, De Smet AA. MRI findings of osteochondritis dissecans of the capitellum with surgical correlation. *AJR Am J Roentgenol* 2005;185:1453-9.
80. Kijowski R, Tuite M, Sanford M. Magnetic resonance imaging of the elbow. Part I: normal anatomy, imaging technique, and osseous abnormalities. *Skeletal Radiol* 2004;33:685-97.
81. Marshall KW, Marshall DL, Busch MT, Williams JP. Osteochondral lesions of the humeral trochlea in the young athlete. *Skeletal Radiol* 2009;38:479-91.
82. Peiss J, Adam G, Casser R, Urhahn R, Gunther RW. Gadopentetate-dimeglumine-enhanced MR imaging of osteonecrosis and osteochondritis dissecans of the elbow: initial experience. *Skeletal Radiol* 1995;24:17-20.
83. Pruthi S, Parnell SE, Thapa MM. Pseudointercondylar notch sign: manifestation of osteochondritis dissecans of the trochlea. *Pediatr Radiol* 2009;39:180-3.
84. Waldt S, Bruegel M, Ganter K, et al. Comparison of multislice CT arthrography and MR arthrography for the detection of articular cartilage lesions of the elbow. *Eur Radiol* 2005;15:784-91.
85. Cheng XG, You YH, Liu W, Zhao T, Qu H. MRI features of pigmented villonodular synovitis (PVNS). *Clin Rheumatol* 2004;23:31-4.
86. Floemer F, Morrison WB, Bongartz G, Ledermann HP. MRI characteristics of olecranon bursitis. *AJR Am J Roentgenol* 2004;183:29-34.
87. Jbara M, Patnana M, Kazmi F, Beltran J. MR imaging: arthropathies and infectious conditions of the elbow, wrist, and hand. *Magn Reson Imaging Clin N Am* 2004;12:361-79, vii.
88. Schweitzer M, Morrison WB. Arthropathies and inflammatory conditions of the elbow. *Magn Reson Imaging Clin N Am* 1997;5:603-17.
89. Awaya H, Schweitzer ME, Feng SA, et al. Elbow synovial fold syndrome: MR imaging findings. *AJR Am J Roentgenol* 2001;177:1377-81.
90. Steinert AF, Goebel S, Rucker A, Barthel T. Snapping elbow caused by hypertrophic synovial plica in the radiohumeral joint: a report of three cases and review of literature. *Arch Orthop Trauma Surg* 2010;130:347-51.
91. Skaf AY, Boutin RD, Dantas RW, et al. Bicipitoradial bursitis: MR imaging findings in eight patients and

anatomic data from contrast material opacification of bursae followed by routine radiography and MR imaging in cadavers. *Radiology* 1999;212:111-6.

92. Yamamoto T, Mizuno K, Soejima T, Fujii M. Bicipital radial bursitis: CT and MR appearance. *Comput Med Imaging Graph* 2001;25:531-3.
93. Schickendantz MS, Ho CP, Koh J. Stress injury of the proximal ulna in professional baseball players. *Am J Sports Med* 2002;30:737-41.
94. Delgado J, Jaramillo D, Chauvin NA. Imaging the Injured Pediatric Athlete: Upper Extremity. *Radiographics* 2016;36:1672-87.
95. Akansel G, Dalbayrak S, Yilmaz M, Bekler H, Arslan A. MRI demonstration of intra-articular median nerve entrapment after elbow dislocation. *Skeletal Radiol* 2003;32:537-41.
96. Bordalo-Rodrigues M, Rosenberg ZS. MR imaging of entrapment neuropathies at the elbow. *Magn Reson Imaging Clin N Am* 2004;12:247-63, vi.
97. Chien AJ, Jamadar DA, Jacobson JA, Hayes CW, Louis DS. Sonography and MR imaging of posterior interosseous nerve syndrome with surgical correlation. *AJR Am J Roentgenol* 2003;181:219-21.
98. Mobbs RJ, Rogan C, Blum P. Entrapment neuropathy of the ulnar nerve by a constriction band: the role of MRI. *J Clin Neurosci* 2003;10:374-5.
99. Pecina M, Boric I, Anticevic D. Intraoperatively proven anomalous Struthers' ligament diagnosed by MRI. *Skeletal Radiol* 2002;31:532-5.
100. Vucic S, Cordato DJ, Yiannikas C, Schwartz RS, Shnier RC. Utility of magnetic resonance imaging in diagnosing ulnar neuropathy at the elbow. *Clin Neurophysiol* 2006;117:590-5.
101. Naam NH, Nemani S. Radial tunnel syndrome. *Orthop Clin North Am* 2012;43:529-36.
102. Moradi A, Ebrahimzadeh MH, Jupiter JB. Radial Tunnel Syndrome, Diagnostic and Treatment Dilemma. *Arch Bone Jt Surg* 2015;3:156-62.
103. Miller TT, Reinus WR. Nerve entrapment syndromes of the elbow, forearm, and wrist. *AJR Am J Roentgenol* 2010;195:585-94.
104. Jeon IH, Fairbairn KJ, Neumann L, Wallace WA. MR imaging of edematous anconeus epitrochlearis: another cause of medial elbow pain? *Skeletal Radiol* 2005;34:103-7.
105. Steinbach LS, Anderson S, Panicek D. MR imaging of musculoskeletal tumors in the elbow region. *Magn Reson Imaging Clin N Am* 1997;5:619-53.
106. Elzohairy MM. Primary pyomyositis in children. *Orthop Traumatol Surg Res* 2018;104:397-403.
107. Hausmann JT, Veksler G, Breitenseher M, Braunsteiner T, Vecsei V, Gabler C. Mason type-I radial head fractures and interosseous membrane lesions--a prospective study. *J Trauma* 2009;66:457-61.
108. Starch DW, Dabezies EJ. Magnetic resonance imaging of the interosseous membrane of the forearm. *J Bone Joint Surg Am* 2001;83-A:235-8.
109. American College of Radiology. ACR-SSR practice parameter for the performance and interpretation of magnetic resonance imaging (MRI) of bone and soft tissue tumors. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-SoftTissue-Tumors.pdf>. Accessed January 14, 2020.
110. Frick MA. Imaging of the elbow: a review of imaging findings in acute and chronic traumatic disorders of the elbow. *J Hand Ther* 2006;19:98-112.
111. Pudas T, Hurme T, Mattila K, Svedstrom E. Magnetic resonance imaging in pediatric elbow fractures. *Acta Radiol* 2005;46:636-44.
112. Itamura J, Roidis N, Mirzayan R, Vaishnav S, Leach T, Shean C. Radial head fractures: MRI evaluation of associated injuries. *J Shoulder Elbow Surg* 2005;14:421-4.
113. Kaas L, Turkenburg JL, van Riet RP, Vroemen JP, Eygendaal D. Magnetic resonance imaging findings in 46 elbows with a radial head fracture. *Acta Orthop* 2010;81:373-6.
114. Ouellette H, Bredella M, Labis J, Palmer WE, Torriani M. MR imaging of the elbow in baseball pitchers. *Skeletal Radiol* 2008;37:115-21.
115. Wenzke DR. MR imaging of the elbow in the injured athlete. *Radiol Clin North Am* 2013;51:195-213.
116. Chung CB, Stanley AJ, Gentili A. Magnetic resonance imaging of elbow instability. *Semin Musculoskelet Radiol* 2005;9:67-76.
117. Fortier MV, Forster BB, Pinney S, Regan W. MR assessment of posttraumatic flexion contracture of the elbow. *J Magn Reson Imaging* 1995;5:473-7.
118. American College of Radiology. ACR practice parameter for performing and interpreting magnetic

resonance imaging (MRI). Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Perf-Interpret.pdf>. Accessed January 14, 2020.

119. American College of Radiology. ACR guidance document on MR safe practices: 2020. Available at: <https://www.acr.org/-/media/ACR/Files/Radiology-Safety/MR-Safety/Manual-on-MR-Safety.pdf>. Accessed July 6, 2020.
120. American College of Radiology. ACR manual on contrast media. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/IVCM.pdf>. Accessed January 14, 2020.
121. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants and Devices*. 2005 ed. Los Angeles, Calif.: Biomedical Research Publishing; 2005.
122. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology* 2004;232:635-52.
123. American College of Radiology. ACR–SPR practice parameter for the use of intravascular contrast media. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/IVCM.pdf>. Accessed January 14, 2020.
124. Edwards AD, Arthurs OJ. Paediatric MRI under sedation: is it necessary? What is the evidence for the alternatives? *Pediatr Radiol* 2011;41:1353-64.
125. American College of Radiology. ACR–SIR practice parameter for sedation/analgesia. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Sed-Analgesia.pdf>. Accessed January 14, 2020.
126. Kersting-Sommerhoff B, Hof N, Lenz M, Gerhardt P. MRI of peripheral joints with a low-field dedicated system: a reliable and cost-effective alternative to high-field units? *Eur Radiol* 1996;6:561-5.
127. Trattnig S, Kontaxis G, Breitenseher M, et al. [MRI on low-field tomography systems (0.2 Tesla). A quantitative comparison with equipment of medium-field strength (1.0 Tesla)]. *Radiologe* 1997;37:773-7.
128. Okamoto Y, Maehara K, Kanahori T, Hiyama T, Kawamura T, Minami M. Incidence of elbow injuries in adolescent baseball players: screening by a low field magnetic resonance imaging system specialized for small joints. *Jpn J Radiol* 2016;34:300-6.
129. Crooks LE, Arakawa M, Hoenninger J, McCarten B, Watts J, Kaufman L. Magnetic resonance imaging: effects of magnetic field strength. *Radiology* 1984;151:127-33.
130. Holtz P, Erickson SJ, Holmquist K. MR Imaging of the Elbow: Technical Considerations. *Semin Musculoskelet Radiol* 1998;2:121-32.
131. Erickson SJ. High-resolution imaging of the musculoskeletal system. *Radiology* 1997;205:593-618.
132. Fisher MR, Barker B, Amparo EG, et al. MR imaging using specialized coils. *Radiology* 1985;157:443-7.
133. Rubin DA, Kneeland JB. MR imaging of the musculoskeletal system: technical considerations for enhancing image quality and diagnostic yield. *AJR Am J Roentgenol* 1994;163:1155-63.
134. Kneeland JB. MR imaging of the elbow. Technical considerations. *Magn Reson Imaging Clin N Am* 1997;5:439-42.
135. Glockner JF, Hu HH, Stanley DW, Angelos L, King K. Parallel MR imaging: a user's guide. *Radiographics* 2005;25:1279-97.
136. Sonin AH, Fitzgerald SW. MR imaging of sports injuries in the adult elbow: a tailored approach. *AJR Am J Roentgenol* 1996;167:325-31.
137. Hricak H, Amparo EG. Body MRI: alleviation of claustrophobia by prone positioning. *Radiology* 1984;152:819.
138. Sampath SC, Sampath SC, Bredella MA. Magnetic resonance imaging of the elbow: a structured approach. *Sports Health* 2013;5:34-49.
139. Fritz RC. MR imaging of sports injuries of the elbow. *Magn Reson Imaging Clin N Am* 1999;7:51-72, viii.
140. Giuffre BM, Moss MJ. Optimal positioning for MRI of the distal biceps brachii tendon: flexed abducted supinated view. *AJR Am J Roentgenol* 2004;182:944-6.
141. Kneeland JB, Shimakawa A, Wehrli FW. Effect of intersection spacing on MR image contrast and study time. *Radiology* 1986;158:819-22.
142. Carrino JA, Morrison WB, Zou KH, Steffen RT, Snearly WN, Murray PM. Noncontrast MR imaging and MR arthrography of the ulnar collateral ligament of the elbow: prospective evaluation of two-dimensional pulse sequences for detection of complete tears. *Skeletal Radiol* 2001;30:625-32.
143. Bush CH. The magnetic resonance imaging of musculoskeletal hemorrhage. *Skeletal Radiol* 2000;29:1-9.
144. De Smet AA. Magnetic resonance findings in skeletal muscle tears. *Skeletal Radiol* 1993;22:479-84.
145. Maeder Y, Dunet V, Richard R, Becce F, Omoumi P. Bone Marrow Metastases: T2-weighted Dixon Spin-Echo



- Fat Images Can Replace T1-weighted Spin-Echo Images. *Radiology* 2018;286:948-59.
146. Sugimoto H, Hyodoh K, Shinozaki T. Throwing injury of the elbow: assessment with gradient three-dimensional, fourier transform gradient-echo and short tau inversion recovery images. *J Magn Reson Imaging* 1998;8:487-92.
  147. Bergin D, Schweitzer ME. Indirect magnetic resonance arthrography. *Skeletal Radiol* 2003;32:551-8.
  148. Schwartz ML, al-Zahrani S, Morwessel RM, Andrews JR. Ulnar collateral ligament injury in the throwing athlete: evaluation with saline-enhanced MR arthrography. *Radiology* 1995;197:297-9.
  149. Baumer P, Pham M, Ruetters M, et al. Peripheral neuropathy: detection with diffusion-tensor imaging. *Radiology* 2014;273:185-93.
  150. Rossi F, Bignotti B, Bianchi L, Picasso R, Martinoli C, Tagliafico AS. Radiomics of peripheral nerves MRI in mild carpal and cubital tunnel syndrome. *Radiol Med* 2020;125:197-203.
  151. Bydder GM, Young IR. MR imaging: clinical use of the inversion recovery sequence. *J Comput Assist Tomogr* 1985;9:659-75.
  152. Fleckenstein JL, Archer BT, Barker BA, Vaughan JT, Parkey RW, Peshock RM. Fast short-tau inversion-recovery MR imaging. *Radiology* 1991;179:499-504.
  153. Mirowitz SA. Fast scanning and fat-suppression MR imaging of musculoskeletal disorders. *AJR Am J Roentgenol* 1993;161:1147-57.
  154. Simon JH, Szumowski J. Chemical shift imaging with paramagnetic contrast material enhancement for improved lesion depiction. *Radiology* 1989;171:539-43.
  155. Jung JY, Yoon YC, Kwon JW, Ahn JH, Choe BK. Diagnosis of internal derangement of the knee at 3.0-T MR imaging: 3D isotropic intermediate-weighted versus 2D sequences. *Radiology* 2009;253:780-7.
  156. Kijowski R, Blankenbaker DG, Woods MA, Shinki K, De Smet AA, Reeder SB. 3.0-T evaluation of knee cartilage by using three-dimensional IDEAL GRASS imaging: comparison with fast spin-echo imaging. *Radiology* 2010;255:117-27.
  157. Kijowski R, Davis KW, Woods MA, et al. Knee joint: comprehensive assessment with 3D isotropic resolution fast spin-echo MR imaging--diagnostic performance compared with that of conventional MR imaging at 3.0 T. *Radiology* 2009;252:486-95.
  158. Delattre BMA, Boudabbous S, Hansen C, Neroladaki A, Hachulla AL, Vargas MI. Compressed sensing MRI of different organs: ready for clinical daily practice? *Eur Radiol* 2020;30:308-19.
  159. Peh WC, Chan JH. Artifacts in musculoskeletal magnetic resonance imaging: identification and correction. *Skeletal Radiol* 2001;30:179-91.
  160. Haacke EM, Lenz GW. Improving MR image quality in the presence of motion by using rephasing gradients. *AJR Am J Roentgenol* 1987;148:1251-8.
  161. Schulte-Altdorneburg G, Gebhard M, Wohlgemuth WA, et al. MR arthrography: pharmacology, efficacy and safety in clinical trials. *Skeletal Radiol* 2003;32:1-12.
  162. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf>. Accessed January 14, 2020.
  163. Shellock FG. *Guide to MR Procedures and Metallic Objects*. 7th ed. Philadelphia, Pa.: Lippincott, Williams and Wilkins; 2001.
  164. Sawyer-Glover AM, Shellock FG. Pre-MRI procedure screening: recommendations and safety considerations for biomedical implants and devices. *J Magn Reson Imaging* 2000;12:92-106.
  165. American College of Radiology. ACR-AAPM technical standard for diagnostic medical physics performance monitoring of magnetic resonance imaging (MRI) equipment. Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Equip.pdf>. Accessed January 14, 2020.

\*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

#### Development Chronology for this Practice Parameter

2006 (Resolution 5, 35)

~~Revised 2011 (Resolution 41)~~

Amended 2014 (Resolution 39)

Revised 2016 (Resolution 6)

Revised 2021 (Resolution 41)

Amended 2023 (Resolution 2c, 2d)