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The American College of Radiology will periodically define new practice guidelines 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 guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

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## **PRACTICE GUIDELINE FOR THE PERFORMANCE AND INTERPRETATION OF MAGNETIC RESONANCE IMAGING (MRI) OF BONE AND SOFT TISSUE TUMORS**

### **PREAMBLE**

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic 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 developed and written collaboratively by the American College of Radiology and the Society of Skeletal Radiology (SSR).

Magnetic resonance imaging (MRI) is a proven and well-established imaging modality in the detection, evaluation, assessment, staging, and follow-up of tumors of the musculoskeletal system. Properly performed and interpreted, MRI not only contributes to diagnosis but also serves as an important guide to treatment planning, prognosis, and follow-up of tumors. However, MRI of a tumor or suspected mass should be performed only for a valid medical reason and after careful consideration of alternative imaging modalities. An analysis of the strengths of MRI and other modalities should be weighed against their suitability for particular patients and particular clinical conditions. Radiographs should be used as the initial diagnosis for primary bone tumors. In addition, radiographs are usually the first imaging test to be performed for suspected soft tissue masses, in particular for the value of showing calcification. Radionuclide bone scanning is often used when occult osseous disease is suspected, or to screen the entire skeleton, for conditions such as metastases. Other nuclear

medicine examinations have a role for specific clinical scenarios (e.g., a labeled white blood cell study for suspected osteomyelitis). Computed tomography can show the detailed osseous anatomy and better identify osteoid and chondroid matrix. Sonography may be appropriate to examine relatively superficial soft tissue masses [1,2]. Angiography still remains useful for the evaluation of tumor vascularity, for the presence and location of major arteries, and for planning surgical resection and reconstruction [3]. MR angiography may be used as well.

While MRI is one of the most sensitive, noninvasive diagnostic tests for detecting anatomic abnormalities of the musculoskeletal system, findings may be misleading if not closely correlated with the clinical history, clinical examination, and physiologic tests. Adherence to the following guidelines will enhance the probability of detecting such abnormalities.

## II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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

## III. INDICATIONS

Indications for MRI of soft tissue and bone tumors include, but are not limited to:

1. Initial characterization, detection or exclusion of bone tumors and soft tissue tumors or suspected masses [4-19].
2. Staging of known bone and soft tissue tumors [20-24].
3. Preoperative evaluation and surgical planning of bone and soft tissue tumors [11,20,25-27].
4. Evaluation of the response of tumors to treatment, including neoadjuvant chemotherapy, postresection chemotherapy, and radiation therapy [28-38].
5. Detection and evaluation of complications related to bone and soft tissue tumors, or to their treatment, including hemorrhage, infection, and neurologic and vascular conditions [36-48].
6. Post-treatment and long-term surveillance and characterization of local, regional, and distant tumor recurrences.

## IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) and the [ACR White Paper on Magnetic Resonance Safety](#)<sup>1</sup>.

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [69,71].

## 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 bone and soft tissue tumors 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 employed 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.

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<sup>1</sup>In 2007 the following updated version was published: ACR Guidance Document for Safe MR Practices. AJR 2007; 188:1-27.

## A. Patient Selection

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

Certain indications require administration of intravenous (IV) contrast media. IV contrast enhancement should be performed using appropriate injection protocols and in accordance with the institution's policy on IV contrast utilization. (See the [ACR Practice Guideline for the Use of Intravascular Contrast Media](#).)

Patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation may be needed to achieve a successful examination. If moderate sedation is necessary, refer to the [ACR Practice Guideline for Adult Sedation/Analgesia](#) or the [ACR Practice Guideline for Pediatric 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

Diagnostic quality MRI of suspected bone and soft tissue masses can be performed using a variety of magnetic designs (closed-bore whole body, open whole body) and a variety of field strengths [5,8,10,13]. Regardless of system design, efforts should be made to maximize signal-to-noise ratios. Field of view (FOV) should be tailored to the size of the patient and the size of the suspected mass [8,49,50,51]. For example, a 48 cm FOV would be appropriate for an extremely large tumor of the pelvis or thigh, whereas a 12 cm FOV may be appropriate for a small mass in the foot. At times, additional sequences with a larger FOV will be necessary to evaluate proximal or distal spread of disease. It is important to obtain as many axial, sagittal, or coronal images through the lesion as is reasonable. Slice thicknesses will also vary depending on the size of the lesion [8]. For example, a 1 cm mass might require 3 mm thick slices, whereas a tumor greater than 30 cm in size may be appropriately imaged with 1 cm slice thickness [8]. An interslice gap may be chosen to decrease signal loss due to cross-talk

[50], but in general should be no more than one-half of the slice width and should not impair complete visualization of the mass. The imaging matrix should balance intravoxel signal-to-noise with desired in-plane spatial resolution.

The size of the lesion would also dictate whether it is more appropriate to use a local surface or cylindrical coil, in particular for a small lesion, whereas the body coil may be more appropriate for extremely large lesions [8,24,27]. Every attempt should be made to include the entire soft tissue or bone tumor in the imaged volume. Additionally, for high-grade sarcomas of bone, the entire bone should be imaged to evaluate for more proximal skip lesions and regional metastases.

For patients with more than one suspected bone or soft tissue mass it may be necessary to perform separate MR examinations. For example, a patient with a pelvic and leg mass may require a separate examination of the leg and pelvis.

When using a low-field system to perform MRI of bone and soft tissue tumors, other imaging parameters – such as the receiver bandwidth and number of acquisitions – will require modification to ensure adequate spatial and contrast resolution for confident diagnosis, often at the expense of longer examination times [49,52]. It may also be more difficult to achieve uniform fat suppression on low-field systems, using spectrally selective RF pulses, necessitating the use of Dixon or short TI inversion recovery (STIR) techniques [53,54,55,56]. Other systems may be more prone to imaging artifacts (e.g., chemical shift artifact on high-field magnets), again necessitating modification of imaging parameters such as receiver bandwidth to ensure that these artifacts do not detract from the diagnostic quality of the resultant images. Some MR imaging systems may not be appropriate for specific indications. For example, high-resolution evaluation of a sub centimeter mass may not be feasible with a low-field, open magnet, regardless of the chosen imaging parameters [57].

MRI imaging of bone and soft tissue tumors usually includes images in at least two, and in some cases three orthogonal planes (transverse, sagittal, and coronal) [5,7,8,18,49]. The sagittal and coronal images may be oriented orthogonal to the magnetic bore, or may be angled to better identify specific anatomic structures. The coverage of the tumor ideally should include all of the anterior, posterior, medial, lateral, superior, and inferior margins of the mass [5,8,25].

MRI of suspected bone and soft tissue tumors can be performed with a variety of pulse sequences. The choice of sequences can be tailored to optimize the examination for specific clinical questions and according to local

preferences. In general, however, conventional spin-echo and fast (turbo) spin-echo images are preferred [5,8,49]. Gradient-recalled sequences may also be valuable, in particular in evaluating for internal areas of hemorrhage, ossification, or calcification. An imaging protocol would usually be composed of one or more of these pulse sequence types, but typically would include at least T1-weighted images and T2-weighted images with and/or without fat suppression [8,49]. The exact TR, TE, and flip angle chosen will depend on the field-strength of the magnet and the relative contrast weighting desired [5,49,52].

Short-TE images with a relatively short TR (T1-weighted) are commonly used to evaluate tumors [5,8,51,52]. Because of the image blurring inherent in a fast spin-echo image made with a short effective TE, conventional spin-echo imaging may be preferred [5,8,51,52]. Properly optimized, however, some investigators have used fast spin-echo imaging for T1-weighted images. To demonstrate pathologic tissues, T2-weighted imaging using conventional spin-echo or fast spin-echo sequences are most commonly used [8,53,54,55,56].

T1-weighted sequences are routinely done without fat suppression to depict anatomic relationships; however, the addition of fat suppression may be helpful to detect hemorrhage or fat within a mass, and when intravenous contrast is given [58]. Water sensitive images, obtained with long TR using conventional or fast spin-echo sequences, can be used to characterize bone and soft tissue tumors, providing complementary information to the T1-weighted images. Therefore, a combination of both T1-weighted and T2-weighted images is typically performed in each imaging plane [5,8,53,54,55]. Lesion conspicuity may be increased with the addition of fat suppression to the water-sensitive images, but for enhancement and optimal characterization of hemorrhage, calcification, and osteoid tissue, T2-weighted sequences can be performed with and/or without fat suppression, or STIR sequences can be used [8,53,54]. For example, the transverse images may be obtained without fat suppression and the long axis planes (sagittal and/or coronal images) performed with fat suppression or STIR sequences.

Various techniques may be used to reduce the MR artifacts that can reduce imaging quality. Wraparound artifact, including that originating from signal received from other parts of the body, can be reduced by phase oversampling, by switching the phase and frequency readout directions, or by using radiofrequency shielding. Truncation (Gibbs) artifacts may obscure or mimic intralesional detail and can be reduced by changing the phase-encoding direction. Involuntary patient motion is best controlled by ensuring patient comfort combined with gentle immobilization when necessary [49,59]. Flowing blood can produce ghosting artifacts, which can

be reduced with presaturation pulses or the use of gradient moment nulling [49,59].

In many cases it may be advantageous to administer a gadolinium-based intravenous contrast agent [60-66]. Intravenous contrast may be helpful to differentiate cysts from solid masses and may provide additional details of the imaging features of bone and soft tissue masses [8,61,62]. Follow-up MR examinations of patients with previously treated soft tissue tumors often benefit by the addition of intravenous gadolinium chelates [34,36]. Subtracting the precontrast images from the postcontrast ones may be beneficial to show subtle areas of enhancement. The decision to use intravenous contrast should be based on medical appropriateness.

For interpretation, the images can be printed on film or viewed on a workstation. If hardcopy viewing is used, some practices may film the images with magnified or narrowed window settings, but this can be left to local preferences. MR examinations in patients with suspected tumors should be read cautiously and preferably in conjunction with available radiographs. There are many pitfalls and artifacts which can suggest that a non-neoplastic mass is an aggressive tumor, or that a malignant tumor appears to be a benign lesion based on the MR appearance alone [8,67,68]. Furthermore, imaging artifacts can also contribute to incorrect staging of tumors [8,67,68].

## VI. DOCUMENTATION

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

The report should address the presence or absence of a mass, the size of the lesion and its composition, signal intensity, and enhancement characteristics. A description of the anatomic location of a tumor, including its relationships to adjacent major muscles, vessels, and nerves, will contribute to the tumor's grading and staging.

## VII. EQUIPMENT SPECIFICATIONS

The MRI equipment specifications and performance shall 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 elsewhere in the ACR Practice Guidelines and Technical Standards book.

Specific policies and procedures related to MRI safety should be in place 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 MRI examination to the patient as well as to others in the immediate area [69,70,71]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [69,70,71,72].

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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Principal Drafter: James S. Jelinek, MD

#### Society of Skeletal Radiology, Standards Committee

David A. Rubin, MD, Chair  
James S. Jelinek, MD  
Thomas L. Pope Jr., MD  
Jeffrey D. Towers, MD

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David A. Rubin, MD

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