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PRACTICE GUIDELINE FOR THE PERFORMANCE OF MAGNETIC RESONANCE IMAGING (MRI) OF THE ADULT SPINE

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 on 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 Society of Neuroradiology (ASNR) and the American College of Radiology (ACR).

Magnetic resonance imaging (MRI) of the spine is a proven and useful tool for the evaluation, assessment of severity, and follow-up of diseases of the spine. Spine MRI should be performed only for a valid medical reason. While spinal MRI is one of the most sensitive diagnostic tests for detecting anatomic abnormalities of the spine and adjacent structures, findings may be misleading if not closely correlated with the clinical history, clinical examination, or physiologic tests. Adherence to the following guideline will enhance the probability of detecting such abnormalities.

Spine MRI has important attributes that make it valuable in assessing spinal disease. Alternative diagnostic imaging tests for such assessment include radiography, computed tomography (CT), myelography, and CT myelography. Compared with these other modalities, MRI does not use ionizing radiation. That is particularly advantageous in the lumbar area where gonadal exposure

may occur. Myelography requires an invasive procedure to introduce intrathecal contrast agents. Both the puncture and the contrast agent can produce side effects and rarely significant adverse reactions. MRI allows direct visualization of the spinal cord, nerve roots, and discs, while their location and morphology can only be inferred on plain radiography and less completely evaluated on myelography. Compared to CT, MRI provides better soft tissue contrast and the ability to directly image in the sagittal and coronal planes. MRI is also the only modality for evaluating the internal structure of the cord. However, CT in particular provides better visualization of cortical bone than MRI, and some patients who have contraindications to MRI will require other modalities for primary evaluation. While not a contraindication to spine MR, metallic hardware in the area of scanning may in some cases limit the usefulness of MR. In selected cases, more than one of these modalities will be needed for a complete evaluation.

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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

III. INDICATIONS

Indications for spine MRI include, but are not limited to, the evaluation of:

1. Degenerative disk disease and its sequelae in the lumbar, thoracic, and cervical spine.
2. Extradural soft tissue and bony neoplasms.
3. Intradural extramedullary masses.
4. Intradural leptomeningeal disease.
5. Intramedullary tumors.
6. Treatment fields for radiation therapy.
7. Intrinsic spinal cord pathology, including demyelinating and inflammatory conditions.
8. Spinal vascular malformations and/or the cause of occult subarachnoid hemorrhage.
9. Syringohydromyelia.
10. Congenital spinal abnormalities.
11. Spinal abnormalities associated with scoliosis.
12. Postoperative intraspinal fluid collections.
13. Postoperative intraspinal soft tissue changes.
14. Meningeal abnormalities.
15. Spinal infection, including disk space infection, vertebral osteomyelitis, and epidural abscess.
16. Nature and extent of injury to spinal cord, vertebral column, ligaments, and intraspinal and paraspinal soft tissues following trauma.
17. Nature and extent of bony malalignment.
18. Preprocedure assessment for vertebroplasty and kyphoplasty.

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](#)¹.

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis.

V. APPLICATIONS OF MR IMAGING

A. Neoplasms

The most critical piece of information used in forming a differential diagnosis of an intraspinal mass involves determination of the precise anatomic location of disease (i.e., intramedullary, extramedullary, intradural, or extradural). This information is essential for planning the treatment of the patient. MRI is particularly well suited to this task. Delineation of an abnormal intraspinal mass lesion and of its extent within or outside of the thecal sac, its extension into the surrounding vertebral structures and paravertebral tissues, and its impact on or involvement of the spinal cord and intraspinal nerve roots all can be accurately accomplished with MRI, possibly supplemented with intravenous administration of gadolinium-based paramagnetic contrast medium [11,22].

The diagnosis, localization, and characterization of suspected primary neoplasms of the vertebral bodies, posterior elements and intervertebral and paravertebral soft tissues is significantly enhanced with MR imaging. The multiplanar capabilities as well as the superior contrast resolution of this modality enable an evaluation of the nature and extent of the lesion with a high level of accuracy and confidence [21].

MRI is a powerful method of investigating and defining spinal metastatic disease. It not only demonstrates the presence and extent of bony involvement but also (most importantly) delineates the presence and location of paravertebral and epidural extension and the degree of neural compromise. Overall, MRI appears to be more sensitive than SPECT bone scintigraphy for the detection of metastatic disease [1,4,5] but may not be as sensitive for detecting small metastases in the posterior elements [19].

B. Infection

MR imaging is one of the most useful imaging techniques to characterize spine infection. In a well-designed study, the sensitivity was 96%, and the specificity was 92%,

¹In 2007 the following updated version was published: [ACR Guidance Document for Safe MR Practices. AJR 2007;188:1-27.](#)

making it more accurate than both radiographs and bone scans [24]. Moreover, MRI is better than CT in delineating the extent and stage of development of the infection, factors that are critical in determining the need for surgery [10]. Because of its greater soft tissue contrast, MRI can accurately demonstrate the extent of epidural extension and permit determination of the presence of a frank abscess [7].

Intravenous administration of a gadolinium-based paramagnetic contrast agent in conjunction with MRI is often necessary for full elucidation of the extent of spread of inflammation. Gadolinium contrast enhancement has proven a very useful adjunct for identifying the extent of a lesion when the plain MRI study is equivocal, for demonstrating activity of an infection, and for directing needle biopsy and follow-up treatment [26].

C. Degenerative Disc Disease

MR imaging has proven to be the technique of choice for imaging of intervertebral disc degeneration. Accuracy of diagnosis of intervertebral disc herniation (often associated with nerve root compression) on MR or CT imaging has been limited by lack of agreement on terminology [2,9]. In this guideline, diffuse posterior disc bulging into the spinal canal (not often associated with nerve root compression) is defined as a broad and relatively symmetrical extension of the disc material beyond the interspace, while herniation is a focal or asymmetrical posterocentral, posterolateral, or lateral extension of disc material into the spinal canal and/or the neural foramen [9]. Herniations can also be extraforaminal (also called far lateral) in location. Protrusion and extrusion are subcategories of herniations; protrusions are more broadly based against the parent disc, while in extrusions the base is often narrower than the extruded disc fragment [17,23].

Because of its greater contrast resolution and ability to image in the sagittal as well as axial planes, MR imaging is regarded as the diagnostic modality of choice for evaluating possible disc herniation with a high sensitivity for demonstrating the presence of nerve root compression [16]. As compared with CT (with or without myelography), the greater contrast resolution and multiplanar imaging capabilities of MR enable more accurate demonstration of nerve root impingement beyond the root sleeve and neural foramen [12]. However, CT myelography remains useful in the assessment of cervical neural foraminal narrowing.

D. Spinal Stenosis

On both axial and sagittal MR images, the sizes of both the spinal canal and the thecal sac are well demonstrated. The contents of the thecal sac (spinal cord, nerve roots)

can also be assessed. These capabilities enable the use of MRI for evaluating possible spinal stenosis with high sensitivity and specificity [13,18].

E. Intramedullary Disease

MR imaging, without and/or with intravenous contrast, is almost unique in its capability to demonstrate the presence and extent of spinal cord disease processes of many different etiologies: demyelinating, neoplastic, degenerative, inflammatory, congenital, etc. No other spinal imaging modality, invasive or noninvasive, allows the detection and, in many cases, the differentiation of an intramedullary lesion that does not expand the spinal cord [21].

F. Trauma

MR imaging is a valuable tool for assessing the integrity of the ligaments, bones, and spinal cord following trauma. It can be helpful in determining the stability of the vertebral column and can influence patient management. Epidural hematomas and intrinsic cord damage/blood are particularly well depicted by MRI.

Application of this guideline should be in accordance with the [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) and the [ACR Practice Guideline for Adult Sedation/Analgesia](#).

VI. 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 (potential hazards might include spinal hardware if recently implanted, especially in the case of neoplasia or significant trauma). 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 adult spine 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 scope of practice requirements. (2006 - ACR Resolution 35)

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.

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 or "conscious" 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.

C. Examination Technique

1. General principles

Physicians who determine the pulse sequences to be employed and interpret spine MR examinations shall understand the artifacts

associated with and the limitations of the various imaging pulse sequences. MRI of the spine involves the application of various MR pulse sequences that are designed to provide a range of imaging characteristics and capabilities. These include the following:

- a. Variable soft tissue contrast, e.g., T1-weighted, T2-weighted, and T2*(T2 star)-weighted images.
- b. Direct multiplanar display, e.g., sagittal, axial, and coronal images.
- c. Darkening of certain tissues (e.g., fat) or defined regions (e.g., anterior abdomen) of an image by suppression of their MR signal.
- d. Flow (cerebral spinal fluid [CSF] or blood) sensitization or desensitization (compensation).

The MR signal that is produced from a region of the spine (cervical, thoracic, and lumbosacral) in response to a particular pulse sequence is often, but not always, detected using dedicated surface coil receivers, commonly in a phased array configuration. Two-dimensional (2D) or three-dimensional (3D) data sets are generated from the received MR signal intensities by fast Fourier transformation.

In addition to images with contrast based on intrinsic MR properties of the spinal and paraspinal tissues, some images may be acquired after the intravenous administration of a paramagnetic MR contrast agent (e.g., a chelate of gadolinium). This agent is used to detect regions where the normal vascular circulation has been altered by injury or disease. For example, the use of intravenous paramagnetic contrast is recommended for distinguishing recurrent or residual disc material from scar tissue in patients who have undergone prior spinal surgery.

2. Pulse sequences

The choice of MR pulse sequences is guided by the clinical history and physical examination and is based on the indications for the study (see Section III, Indications). Certain sequences are commonly employed in MR imaging of the spine. These include:

- a. Two-dimensional spin-echo T1-weighted sagittal imaging.
- b. Two-dimensional fast-spin-echo T2-weighted or T2*-weighted sagittal imaging.
- c. Two-dimensional spin-echo T1-weighted axial imaging.

- d. Two-dimensional fast-spin-echo T2-weighted or gradient-echo, T2*-weighted axial imaging.

The pulse sequences described above may be modified to suppress the MR signal from lipid-containing regions, producing images in which fat is dark. T1-weighted images with fat saturation are primarily acquired as part of studies that include the intravenous administration of a paramagnetic contrast agent. For the purpose of comparison, images with fat suppression are sometimes acquired before and after administration of the contrast agent.

Low-flip-angle sequences with intermediate to long TE values produce T2*-weighted tissue contrast. This has similarities to T2-weighted contrast but is usually more sensitive to local magnetic field inhomogeneities (e.g., greater signal loss at interfaces between bone and CSF or between bone and soft tissue) and less sensitive to CSF flow-induced artifacts (e.g., signal voids due to brisk or pulsatile CSF flow).

Another commonly used modification is the set of MR pulses that produce spatial saturation zones anterior, inferior, and/or superior to the spinal region of interest. MR signal intensity within each zone is markedly reduced, so that motion-induced (e.g., breathing, blood flow) phase encoding artifacts originating in the zone are suppressed and do not degrade the spinal image.

Because of anatomical and physiological differences in three major spinal regions, certain types of images are more likely to be acquired in one region than in another. In the cervical and thoracic spine, CSF flow is normally more brisk than in the lumbosacral spine, and T2*-weighted axial and sagittal images are often acquired because these are less apt to have CSF flow-related artifacts than are T2-weighted fast-spin-echo images. In the cervical spine, where the neural foramina are generally smaller and more obliquely oriented than those in the thoracolumbar region, gradient-echo or fast-spin-echo pulse sequence data may be acquired in three dimensions in order to provide higher spatial resolution and postprocessed multiplanar display of the foramina. In the lumbosacral spine, T1-weighted axial images benefit from the tissue contrast between abundant high-signal-intensity epidural fat juxtaposed to low-signal-intensity CSF and intermediate signal intensity epidural lesions (e.g., disc herniation).

Minimum recommended pulse sequences for evaluating the spine for pain, radiculopathy, or suspected stenosis:

- a. Cervical/thoracic spine
 - Sagittal T1-weighted
 - Sagittal T2-weighted or T2*-weighted
 - Axial T2-weighted or T2*-weighted
- b. Lumbar spine
 - Sagittal T1-weighted
 - Sagittal T2-weighted or T2*-weighted
 - Axial T1-weighted and/or T2-weighted

In postoperative cases for differentiating scar from disk, postcontrast sagittal and axial T1-weighted series with or without fat suppression are useful. When evaluating spinal bone marrow for tumor, sagittal T1-weighted sequences, as well as short TI inversion recovery (STIR) or fat-suppressed T2-weighted fast-spin-echo sequences, are recommended. In addition, a contrast enhanced or a fat suppressed contrast enhanced study can evaluate extrasosseous extension of a neoplastic process. When evaluating soft tissues after trauma or surgery, STIR or T2-weighted fat-suppressed fast-spin-echo sequences are recommended.

3. Slice thickness

The following are recommended maximum slice thicknesses for performing the typical spine examinations:²

Sequence	Slice Thickness	Gap
Cervical spine - sagittal	≤ 3 mm	≤ 1 mm
Cervical spine - axial	≤ 3 mm	≤ 1 mm
Thoracic spine – sagittal	≤ 4 mm	≤ 1 mm
Thoracic spine – axial	≤ 4 mm	≤ 1 mm
Lumbar spine – sagittal	≤ 5 mm	≤ 1.5 mm
Lumbar spine – axial	≤ 4 mm	≤ 1 mm

4. Area of coverage

The imaging protocol should be designed to cover the area of clinical interest. Because

²Thicker slices may be acceptable when the goal of the examination is primarily to survey most or the entire spine.

treatment is frequently determined by the clinical situation, the following should be viewed only as general recommendations and not strict criteria. For pain, radiculopathy, suspected stenosis, or other degenerative conditions:

Cervical spine: Sagittal and axial images should include from the atlanto-occipital joints through at least the C7-T1 intervertebral disc.

Thoracic spine: Sagittal and axial images should include the area of clinical interest. If the entire thoracic spine is to be studied, C7-L1 should be imaged in the sagittal plane, and the axial images should be obtained at each vertebral level.

Lumbar spine: Sagittal and axial images should include the area of clinical interest. The entire lumbar spine should be studied on the sagittal images (T12-S1), and axial images should be obtained through at least the lowest three lumbar discs (L3/4, L4/5, and L5/S1). Axial images through other discs can be obtained as needed. Sagittal imaging should include the entire lumbar spine, including parasagittal imaging of all of the neural foramina on both sides.

For trauma, tumor, and infection: Sagittal and axial images should include the area of clinical interest. If another imaging modality or the clinical examination has demonstrated an abnormality, then MRI can be limited to the area of interest. If MRI is to be used as the only diagnostic imaging modality for clinically occult disease, screening of the entire spine is recommended.

VII. DOCUMENTATION

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

VIII. 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 magnetic field strength (dB/dt), maximum radiofrequency power deposition (specific absorption rate), and maximum acoustic noise levels.

IX. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION CONCERNS

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 concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

Specific policies and procedures related to safety should be in place along with documentation that these policies and procedures are updated annually and that they are formulated under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with MRI examinations to the patients as well as to others in the immediate area. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [29,31,32].

Equipment performance 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 Reviewer: Brian C. Bowen, MD, PhD

Committee on Musculoskeletal Imaging

Mark W. Anderson, MD
Murray K. Dalinka, MD
Arthur A. DeSmet, MD
David G. Disler, MD
Jon A. Jacobson, MD
Jeremy J. Kaye, MD
Mark D. Murphey, MD
Leanne L. Seeger, MD
Lynne S. Steinbach, MD
N. Reed Dunnick, MD, Chair, Commission

Comments Reconciliation Committee

Paul A. Larson, MD, Co-Chair
Michael M. Raskin, MD, MPH, JD, Co-Chair
Mark W. Anderson, MD
Brian C. Bowen, MD, PhD

N. Reed Dunnick, MD
Emanuel Kanal, MD
Lawrence A. Liebscher, MD
David M. Yousem, MD, MBA

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