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

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### **PREAMBLE**

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

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

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

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

### **I. INTRODUCTION**

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

Magnetic resonance imaging (MRI) is a proven imaging modality for the detection, evaluation, staging, and follow-up of disorders of the ankle and hindfoot. Properly performed and interpreted, MRI not only contributes to diagnosis but also can guide treatment planning, help predict outcome, and increase diagnostic confidence [1-7]. However, ankle MRI should be performed only for a valid medical reason [8], and only after careful consideration of alternative imaging modalities. The strengths of MRI and other modalities should be weighed as to their suitability in particular patients and in particular clinical conditions.

Radiographs should be the first imaging test performed for suspected bone and soft tissue abnormalities in the ankle, and will often permit diagnosis or exclusion of an abnormality or will direct further imaging workup. Bone scintigraphy is most often used to screen the entire

skeleton for multifocal diseases such as metastases, local conditions like complex regional pain syndrome and other potentially radiographically occult bone disorders. While MRI is typically the preferred imaging modality for suspected stress fractures and osteomyelitis of the foot and ankle, radionuclide imaging can also be useful to confirm or exclude these diagnoses [9]. Conventional arthrography and tenography in the past have been used for the diagnosis and staging of ankle ligament disruptions [10], and they currently have a diagnostic and therapeutic role (when combined with anesthetic and/or corticosteroid injection) in localizing the source of pain [11-12]. Similarly, contrast tenography aids the evaluation and treatment of tenosynovitis in the hindfoot [13]. The hindfoot tendons and other superficial soft tissues are accessible to ultrasound examination [14-18]. Sonography of the Achilles tendon can also be used to screen probands and relatives with familial hyperlipidemia and hypercholesterolemia for xanthomas [19-20]. Sonography and stress radiography have been used with variable success in ankles with ligament injuries [21].

Computed tomography (CT), especially with multichannel row scanners and the use of multiplanar reformations, has an important role in the evaluation of complex fractures and dislocations of the ankle and hindfoot, osteochondral lesions, and tarsal coalition, and also for surgical planning [22-27]. Additionally, CT can be used for diagnosis of bone and soft tissue injuries when there is a contraindication to MR imaging [28-29]. Three-dimensional volume rendering can show the anatomic relationships of bones and tendons, which may be useful for preoperative planning [30-31]. When combined with arthrography, CT can also be used for evaluating the articular cartilage and joint bodies [32]. Lastly, arthroscopy provides a detailed examination of the internal structures of the ankle and subtalar joints, allowing the surgeon to diagnose as well as treat many internal derangements.

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

## II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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

## III. INDICATIONS

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

1. Achilles tendon disorders: partial and complete tears, tendinitis, tendinopathy, treated tears, and xanthomas [5,33-37].\*
2. Posterior tibial tendon disorders: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, subluxation, and dislocation [3,17-18,38-41].
3. Peroneal tendon disorders: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, subluxation, dislocation, and abnormalities of the peroneal retinaculum [42-45].
4. Abnormalities of other hindfoot tendons: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, and entrapment [11,46-50].
5. Anterior talofibular, calcaneofibular, deltoid, spring, and syndesmotic ligament tears [6,21,51-59]. †
6. Impingement syndromes: anterolateral, anteromedial, posterior, and posteromedial [40,52,60-67].\*†
7. Osteochondral and articular cartilage abnormalities: osteochondral fractures and lesions, degenerative chondrosis, and chondral fractures [32,52,68-71]. †
8. Neurologic conditions: nerve entrapment and compression, denervation peripheral neuritis, including tarsal tunnel syndrome [72-76].\*
9. Chondral, osteochondral, and osseous loose bodies [52]†.
10. Plantar fasciitis, fascial rupture, and plantar fibromatosis [77-80].
11. Sinus tarsi syndrome [81].\*
12. Synovial-based disorders: inflammatory and nodular synovitis, tenosynovitis, bursitis, and ganglion cysts [47,82-85]. \*
13. Marrow abnormalities: bone contusions, osteonecrosis, marrow edema syndromes, and stress fractures [86-90].\*
14. Neoplasms of bone, joint, or soft tissue [91-94].\*
15. Infections of bone, joint, or soft tissue [95-96].\*
16. Congenital and developmental conditions: dysplasia, tarsal coalition, symptomatic and asymptomatic normal variants [73,97-102].

B. MRI of the ankle and hindfoot 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: inflammatory, infectious, neuropathic, degenerative, crystal-induced, and post-traumatic [4,16,39,47,83,103-106].\*

2. Primary and secondary bone and soft tissue tumors [91-94,107].\* See also the [ACR–SSR Practice Guideline for the Performance and Interpretation of Magnetic Resonance Imaging \(MRI\) of Bone and Soft Tissue Tumors](#).
3. Fractures and stress fractures [108-110].

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

1. Prolonged, refractory, or unexplained ankle or heel pain. †\*
2. Acute ankle trauma [7,57,111-112].
3. Ankle and hindfoot injuries in athletes and dancers [86,113-116]. †
4. Ankle or subtalar instability [6,53,57,117]. †
5. Ankle and/or hindfoot malalignments [40,101].
6. Limited or painful range of motion.
7. Unexplained ankle or hindfoot swelling, mass, or atrophy.\*
8. Patients for whom diagnostic or therapeutic arthroscopy is planned. †
9. Patients with recurrent, residual, or new symptoms following ankle surgery [37,117-120]. †
10. Patients or relatives with familial hypercholesterolemia or hyperlipidemia [19,34,121].

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

#### IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

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

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [122-123].

#### V. SPECIFICATIONS OF THE EXAMINATION

The supervising physician must have complete understanding of the indications, risks, and benefits of the examination, as well as alternative imaging procedures. The physician must be familiar with potential hazards associated with MRI, including potential adverse reactions to contrast media. The physician should be familiar with relevant ancillary studies that the patient may have undergone. The physician performing MRI

interpretation must have a clear understanding and knowledge of the anatomy and pathophysiology relevant to the MRI examination.

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

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

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

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

#### A. Patient Selection

The physician responsible for the examination should supervise patient selection and preparation and be available in person or by phone for consultation. Patients must be screened and interviewed prior to the examination to exclude those 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](#).)

Pediatric patients or patients suffering from anxiety or claustrophobia may require sedation or additional assistance. Administration of moderate sedation or general anesthesia may be needed to achieve a successful examination particularly in young children. If moderate sedation is necessary, refer to the [ACR–SIR Practice Guideline for Sedation/Analgesia](#).

## B. Facility Requirements

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

## C. Examination Technique

Diagnostic quality ankle and hindfoot MRI is possible using a variety of magnet designs (closed or open) and field strengths [104]. At least in cadaveric ankles studies, images obtained with a 3T scanner may have higher accuracy for articular cartilage abnormalities in the ankle, compared to those obtained with 1T or 1.5T scanners [124-125]. While not widely available, a local gradient coil can be used to generate images with extremely high resolution to depict the fine detail of anatomic structures like the ankle collateral ligaments [126]. When imaging the ankle and hindfoot on low-field scanners, the reduced signal-to-noise ratio (SNR) necessitates modifications in the imaging parameters [127]. For example, the number of signals averaged can be increased, at the expense of longer imaging times and increased risk of involuntary patient motion [128]. Alternatively, the voxel size can be increased (by a combination of larger field of view (FOV), thicker slices, and/or decreased matrix) at the expense of spatial resolution. In addition, fat suppression techniques that rely on the difference between fat and water precessional frequencies (chemical shift) are unreliable at low-field strength, and substituting short-tau inversion recovery (STIR) images may be necessary.

MR scanners that are built for only extremity imaging can also be used for the hindfoot and ankle [111,129]. Low-field dedicated extremity machines are more susceptible to artifacts and degraded image quality than their high-field counterparts [129-130]. Conversely, newer high-field dedicated scanners impose a limitation on the useable FOV, which may make imaging a long structure like the entire Achilles' tendon problematic.

Regardless of system design, a local receiver coil is mandatory to maximize the SNR [131]. Several choices are available for the ankle and hindfoot [132]. A whole-volume extremity coil allows examination of the ankle in neutral position or plantar flexion, with the patient lying supine or prone. A single surface coil can image relatively superficial structures, while a pair of surface coils joined in an array or in a Helmholtz configuration can substitute for a whole volume coil, if one is not available. If both ankles are to be imaged, examining each side separately with a smaller coil (e.g., an extremity coil) will provide better SNR and higher resolution imaging [133] than can

be achieved by imaging both ankles together in a larger coil (e.g., a head coil). For very small relatively superficial structures, a microscopy coil provides the SNR for very high spatial resolution, at the expense of anatomic coverage [92]. Newer multichannel coils containing multiple coil elements will further increase SNR, and are required to use techniques like parallel imaging, which decrease the time of the scan. The coil selected for a given study will also influence limb positioning.

Patient and hindfoot positioning may be individually tailored to the specific indication(s). Allowing the patient to plantar flex the ankle avoids aliasing of the toes onto the heel when the phase direction is oriented along the long axis of the foot [132]. Plantar flexion, which is possible with the patient either supine or prone, also reorients the medial and lateral ankle tendons, so that a single imaging plane will show a larger length of each in cross-section, and so that a smaller segment of each tendon will pass through the magic angle [134-135]. However, this nonstandard position may make visualization of the ankle ligaments more difficult [56,136] and may make it harder to include the entire Achilles tendon in the FOV. The prone position is more comfortable for some patients, reduces involuntary motion, and may reduce claustrophobic feelings in susceptible individuals [137].

Ankle and hindfoot MRI usually includes images acquired in both the short axis and long axis of the foot. These may be sagittal, coronal, transverse, or oblique to the bore of the magnet and to the limb, depending on the position of the ankle. It is beneficial to orient the imaging planes orthogonal to a specific anatomic structure: for the ankle, the talar dome is commonly used; for the hindfoot, the posterior subtalar joint [41]. Multiplanar images can be acquired directly, or reconstructed electronically from volumetric data acquired in one imaging plane. Standard MR software also allows the prescription of oblique images in virtually any plane, if images oriented along the course of a given structure are needed [138]. Confident identification of anatomy and pathology requires the use of at least two different imaging planes for a given study.

The size of the anatomic structures under consideration and the suspected pathology determine the necessary FOV. For example, visualization of the entire extent of a large Achilles tendon tear may require a 22 cm FOV in the sagittal plane, while a FOV of 12 cm or smaller in the coronal plane may be needed to demonstrate small chondral defects in the talar dome, the syndesmotic ligaments, and the contents of the sinus tarsi [57,124-125]. For routine ankle and hindfoot studies, a FOV of 16 cm or less is desirable for detecting most clinically relevant disorders. A rectangular FOV for coronal and transaxial images of the hindfoot can save imaging time without sacrificing in-plane resolution [132]. Slice

thickness should be 4 mm or less to minimize partial-volume effects, but thinner sections may be advantageous for detailed analysis of the ligaments and articular cartilage. Typically an interslice gap no wider than 10% of the slice width will ensure complete visualization of the intra-articular structures. However, when relatively larger abnormalities like tumors or infections are being imaged, an interslice gap of up to 33% may be useful to increase anatomic coverage and/or decrease imaging time in studies where motion artifacts are unavoidable. Acquiring three-dimensional gradient recalled images as a volume and reconstructing them into 1 mm or thinner slices can assist the visualization of normal and abnormal ligaments and intratendinous disorders [139], although multiplanar reconstructions of the ankle ligaments can also be produced from conventional two-dimensional sequences [140]. The imaging matrix should balance SNR with desired in-plane spatial resolution and reduction of truncation artifacts, but should be at least 192 steps in the phase encoding direction and 256 steps in the frequency direction for 2D imaging. Even higher matrices combined with smaller FOVs can show fine intratendinous detail [33,141].

A wide variety of pulse sequences — conventional spin-echo, fast (turbo) spin-echo, and gradient-recalled echo — is available for ankle and hindfoot MRI [132]. The choice of sequences may be optimized to address specific clinical questions, and many practices tailor protocols based on the suspected pathology. A typical imaging protocol will be composed of one or more pulse sequence types. 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.

Fluid-sensitive (T2-weighted or STIR) sequences are typically used for evaluating the ankle and hindfoot ligaments [56]. These sequences complement short-TE (T1-weighted or proton-density-weighted) ones for plantar fascia and tendon imaging [41-42,77,134], and are especially important to compensate for magic angle artifact seen in tendons [139]. Fat-suppressed T2-weighted, or STIR images are most sensitive for bone marrow abnormalities [88,90,99], although T1-weighted images are still important for marrow lesion characterization. T1-weighted sequences also have a role in detection of various stages of hemorrhage and muscle disorders [142], as well as tendon infiltration [19,121]. Evaluation of articular cartilage and osteochondral infractions can be performed with fast-spin-echo, long-TR (water-sensitive or intermediate-weighted) images, or with gradient-echo sequences [124,143-144]. Gradient-echo sequences can also demonstrate tendon infiltration by xanthomas and fractures involving the open growth plates [108]. Effusions, cysts, and intra-articular impingement lesions are most conspicuous on T2-weighted sequences [85,145], while T1-weighted images,

especially using fat suppression, following gadolinium-based IV contrast administration may be useful to characterize synovial processes [83,146].

Intravenous contrast enhancement may be useful for evaluating ankle and hindfoot tumors and infections [94-96] and may have an adjunct role for tendon imaging [35] and for intrasynovial disorders [61]. Additionally, gadolinium-enhanced MR arthrography, by either direct intra-articular injection or indirect diffusion into the joint following IV injection, may improve diagnostic performance for detecting chronic ligament abnormalities, osteochondral and articular cartilage defects, and impingement lesions [32,52-53,71,91]. Spin-echo, fast spin-echo, or gradient-recalled T1-weighted images with fat suppression are used for contrast-enhanced MR sequences [54,61]. At least one fluid sensitive sequence is still necessary when performing MR arthrography to detect extra-articular pathology as well as at least one T1-weighted sequence without fat suppression for evaluating bone marrow and characterizing soft tissue lesions.

Suppressing the signal from fat may enhance the diagnostic yield of some pulse sequences [133]. Fat suppression is most frequently performed using spectrally selective RF pulses; however, this technique is limited by field heterogeneity. Bags of distilled water or “sat pads” may be necessary to achieve homogeneous spectral fat suppression because of the field heterogeneity accentuated by the off-center position and irregular air soft tissue interfaces often encountered when imaging the ankle and hindfoot [147]. Other methods that are less reliant on field heterogeneity include pulse sequences that decompose fat and water iteratively, exploit phase differences between fat and water (Dixon), or null signal from fat using an inversion pulse (STIR) [148-152]. The STIR technique may be necessary on low-field systems. Techniques that rely on separate acquisitions to obtain separate fat and water images are prone to misregistration artifacts because of motion, but combining these sequences with a motion correction algorithm can result in robust fat suppression in reasonable scan times [153]. Fat-suppression is a useful adjunct to T1-weighted images when intravenous contrast is used, or when MR arthrography is performed with a dilute gadolinium mixture [66,154].

It may be possible to shorten the time required for an ankle or hindfoot MR examination without compromising diagnostic yield. Parallel imaging techniques decrease acquisition times for individual pulse sequences, but at the expense of decreased SNR and the required use of a multichannel receiver coil [155-156]. Alternatively, newer fast 3D gradient-recalled and fast spin-echo sequences can produce near isotropic images that can be reconstructed into multiple imaging planes; using these methods, a single volumetric acquisition can substitute for

several acquisitions in separate imaging planes, thereby decreasing the total time required for a complete examination [61,154].

Various techniques are useful to minimize artifacts that can degrade image quality. Aliasing is reduced or eliminated by repositioning the extremity (e.g., plantar flexing the hindfoot to prevent images of the toes from superimposing on the heel), by orienting the phase-encoding direction anterior-to-posterior when possible, by shielding body parts outside of the area of interest, or by the use of phase oversampling [132,157-158]. Gentle immobilization combined with patient comfort measures best controls involuntary motion [133], while newer pulse sequences can partly correct for some limb motion [153]. Presaturation pulses or gradient moment nulling will reduce ghosting artifacts from flowing blood and other periodic motion [157,159]. Chemical shift artifact is most severe at high field strengths and may necessitate an increase in the receiver bandwidth on high-field scanners [128,157]. Susceptibility artifacts, which originate from heterogeneity of the local field, are also more severe at higher field strengths, in the presence of metallic implants, and when using gradient-recalled pulse sequences. Avoiding gradient-echo imaging and 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 [157]. Lastly, magic angle artifact can produce apparently increased signal intensity on short TE images within tendons that curve around the ankle, mimicking intratendinous pathology [160-162]. Plantar flexing the hindfoot to reorient the tendons can reduce this phenomenon [135]. Confirming abnormal signal intensity in the tendons on images with a longer TE and correlating apparent signal intensity abnormalities with changes in tendon thickness will also help avoid this pitfall [132,134].

It is the responsibility of the supervising physician to determine whether additional or unconventional pulse sequences and imaging techniques confer added benefit for the diagnosis and management of the patient. Examinations that use techniques not approved by the Food and Drug Administration, such as the intra-articular injection of gadolinium chelates (direct MR arthrography) [163] can be considered when they are judged to be medically appropriate.

## VI. DOCUMENTATION

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

At a minimum, the report should address the condition of the major ankle tendons, ligaments, and articular surfaces. In selected cases, a description of findings in the bone and bone marrow, synovium, joints, retinacula, muscles, sinus

tarsi, plantar fascia, neurovascular structures, and subcutaneous tissue would be appropriate. The report should use standard anatomic nomenclature and precise terms for describing identified abnormalities whenever possible.

## VII. EQUIPMENT SPECIFICATIONS

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

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

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

Specific policies and procedures related to MRI safety should be in place along with documentation that is updated annually and compiled under the supervision and direction of the supervising MRI physician. Guidelines should be provided that deal with potential hazards associated with the MRI examination of the patient as well as to others in the immediate area [122-123,164]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [165].

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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\*Guidelines and 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 guidelines and standards published before 1999, the effective date was January 1 following the year in which the guideline or standard was amended, revised, or approved by the ACR Council.

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