

The American College of Radiology, with more than 30,000 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.

Revised 2016 (Resolution 3)*

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

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 care¹. 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 in light of 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 the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document 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 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 sole purpose of this document is to assist practitioners in achieving this objective.

¹ *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, ___ N.W.2d ___ (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 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. Although 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 in the past has been used for the diagnosis and staging of ankle ligament disruptions [10]. Currently, it has a diagnostic and therapeutic role (when combined with anesthetic and/or corticosteroid injection) in localizing the source of pain [11,12] prior to MR arthrography of the ankle [13]. In recent years, ultrasonography has come to play an increasingly important role in the diagnostic evaluation of the soft tissues of the ankle and foot, including tendons, ligaments, and soft-tissue masses [14-16].

Contrast tenography, which has been described in the evaluation and treatment of tenosynovitis in the hindfoot [17], has largely been replaced by sonography in centers where this modality is performed. Stress radiography has been used with variable success in ankles with ligament injuries [18].

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 [19-24]. Additionally, CT can be used for diagnosis of bone and soft-tissue injuries when there is a contraindication to MR imaging [25,26]. Three-dimensional volume rendering can show the anatomic relationships of bones and tendons, which may be useful for preoperative planning [27,28]. When combined with arthrography, CT can also be used for evaluating the articular cartilage and joint bodies [29]. Lastly, arthroscopy provides a detailed examination of the internal structures of the tibiotalar and subtalar joints, allowing the surgeon to diagnose as well as treat many internal derangements.

Although 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 when indicated. Adherence to the following parameters will increase the probability of detecting clinically important abnormalities.

II. INDICATIONS

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

1. Achilles tendon disorders: partial and complete tears, tendinitis, tendinopathy, treated tears, paratenonitis, and xanthomas* [5,30-34]
2. Posterior tibial tendon disorders: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, subluxation, and dislocation [3,35-40]
3. Peroneal tendon disorders: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, subluxation, dislocation, and abnormalities of the peroneal retinaculum [14,41-44]

4. Abnormalities of other hindfoot tendons: partial and complete tears, tendinitis, tendinopathy, tenosynovitis, and entrapment [11,45-49]
5. Anterior and posterior talofibular, anterior and posterior tibiofibular, calcaneofibular, deltoid, spring, and syndesmotric ligament tears† [6,13,18,50-58]
6. Impingement syndromes: anterolateral, anteromedial, posterior, and posteromedial*† [13,40,59-67]
7. Osteochondral abnormalities, articular cartilage abnormalities, and intra-articular bodies, degenerative or traumatic† [13,29,68-74]
8. Neurologic conditions: nerve entrapment and compression, denervation neuropathy, including tarsal tunnel syndrome* [75-80]
9. Plantar fasciitis, plantar fascia rupture, and plantar fibromatosis [81-84]
10. Sinus tarsi syndrome* [85]
11. Synovial-based disorders: inflammatory and nodular synovitis, tenosynovitis, bursitis, and ganglion cysts* [46,86-89]
12. Marrow abnormalities: fractures, bone contusions, osteonecrosis, marrow edema syndromes, and stress fractures* [90-94]
13. Neoplasms of bone, joint, or soft tissue* [95-99]
14. Infections of bone, joint, or soft tissue* [100-103]
15. Congenital and developmental conditions: dysplasia, tarsal coalition, and symptomatic and asymptomatic normal variants [76,104-109]

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* [4,36,46,87,110-114]
2. Primary and secondary bone and soft-tissue tumors* [95-98,115] (see also the [ACR–SSR Practice Parameter for the Performance and Interpretation of Magnetic Resonance Imaging \(MRI\) of Bone and Soft Tissue Tumors](#) [116])
3. Fractures and stress fractures [117-119]

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 [7,55,120,121]
3. Ankle and hindfoot injuries in athletes† [90,122-125].
4. Ankle or subtalar instability† [6,51,55,126,127]
5. Ankle and/or hindfoot malalignments [40,108]
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† [34,126,128-131]
10. Patients or relatives with familial hypercholesterolemia or hyperlipidemia [31,132,133]

* 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

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [134].

IV. SAFETY GUIDELINES AND POSSIBLE CONTRAINDICATIONS

See the [ACR Practice Parameter for Performing and Interpreting Magnetic Resonance Imaging \(MRI\)](#) [134] and the [ACR Guidance Document on MR Safe Practices: 2013](#) [135].

Peer-reviewed literature pertaining to MR safety should be reviewed on a regular basis [136,137].

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 telephone 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-SPR Practice Parameter for the Use of Intravascular Contrast Media](#) [138]).

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 Parameter for Sedation/Analgesia](#) [139].

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 [112]. At least in cadaveric ankle 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 [140,141]. Although 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 [142]. When imaging the ankle and hindfoot on low-field scanners, the reduced signal-to-noise ratio (SNR) necessitates modifications in the imaging parameters [143]. For example, the number of signals averaged can be increased at the expense of longer imaging times and increased risk of involuntary patient motion [144]. 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 extremity-only imaging can also be used for the hindfoot and ankle [120,145]. Low-field dedicated extremity machines are more susceptible to artifacts and degraded image quality than their high-field counterparts [145,146]. 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 [147]. Several choices are available for the ankle and hindfoot [148]. 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 (eg, an extremity coil) will provide better SNR and higher-resolution imaging [149] than can be achieved by imaging both ankles together in a larger coil (eg, 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 [96]. Newer multichannel coils containing multiple coil elements will further increase SNR and are required to use techniques like parallel imaging that 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 [148]. 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 [150,151]. However, this nonstandard position may make visualization of the ankle ligaments more difficult [54,152] 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 [153].

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 [37]. 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 [154]. Confident identification of anatomy and pathology requires the use of at least 2 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, although a FOV of 12 cm or smaller in the coronal plane may be needed to demonstrate small chondral defects around the ankle joint, the syndesmotic ligaments, and the contents of the sinus tarsi

[55,140,141]. 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 [148]. 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 3-D 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 [155], although multiplanar reconstructions of the ankle ligaments can also be produced from conventional 2-D sequences [156]. 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-encoding direction for 2-D imaging. Even higher matrices combined with smaller FOVs can show fine intratendinous detail [30,157].

A wide variety of pulse sequences—conventional spin-echo, fast (turbo) spin-echo, and gradient-recalled echo—are available for ankle and hindfoot MRI [148]. 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 1 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 [54]. These sequences complement short-TE (T1-weighted or proton-density-weighted) ones for plantar fascia and tendon imaging [37,41,81,150] and are especially important to compensate for magic angle artifact seen in tendons [155]. Fat-suppressed T2-weighted or STIR images are most sensitive for bone marrow abnormalities [92,94,106], 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 [158], as well as tendon infiltration [132,133]. 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 [140,159,160]. Gradient-echo sequences can also demonstrate tendon infiltration by xanthomas and fractures involving the open growth plates [117]. In addition, they can also be used when there is suspicion of pigmented villonodular synovitis (PVNS), where the presence of paramagnetic hemosiderin results in amplified signal dropout (“blooming” artifact), a characteristic feature of PVNS [161]. Effusions, cysts, and intra-articular impingement lesions are most conspicuous on T2-weighted sequences [89,162], although T1-weighted images, especially using fat suppression, following gadolinium-based IV contrast administration may be useful to characterize synovial processes [87,163].

Intravenous contrast enhancement may be useful for evaluating ankle and hindfoot tumors and infections [98,100,101] and may have an adjunct role for tendon imaging [32] and for intrasynovial disorders [60]. 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 [13,29,51,71,95]. Spin-echo, fast spin-echo, or gradient-recalled T1-weighted images with fat suppression are used for contrast-enhanced MR sequences [52,60]. At least 1 fluid-sensitive sequence is still necessary when performing MR arthrography to detect extra-articular pathology, as well as at least 1 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 [149]. 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 [164]. 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) [165-169]. 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 [170]. 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 [65,171].

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 [172,173]. Alternatively, newer fast 3-D 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 [60,171].

Various techniques are useful to minimize artifacts that can degrade image quality. Aliasing is reduced or eliminated by repositioning the extremity (eg, 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 [148,174,175]. Gentle immobilization combined with patient comfort measures best controls involuntary motion [149], although newer pulse sequences can partly correct for some limb motion [170]. Presaturation pulses or gradient moment nulling will reduce ghosting artifacts from flowing blood and other periodic motion [174,176]. Chemical shift artifact is most severe at high field strengths and may necessitate an increase in the receiver bandwidth on high-field scanners [144,174]. 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 [174]. Lastly, magic angle artifact can produce apparently increased signal intensity on short TE images within tendons that curve around the ankle, mimicking intratendinous pathology [177-179]. Plantar flexing the hindfoot to reorient the tendons can reduce this phenomenon [151]. 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 [148,150].

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) [180], 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](#) [181].

At a minimum, the report should address the condition of the major ankle tendons, ligaments, and joints. 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 website (<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 [136,137,182]. Screening forms must also be provided to detect those patients who may be at risk for adverse events associated with the MRI examination [183].

Equipment monitoring should be in accordance with the [ACR–AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging \(MRI\) Equipment](#) [184].

ACKNOWLEDGEMENTS

This practice parameter was developed according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (<http://www.acr.org/guidelines>) 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.

Principal Reviewer: Viviane Khoury, MD

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

ACR

David A. Rubin, MD, FACR, Chair
Jenny T. Bencardino, MD
Diego Jaramillo, MD, MPH

SPR

Jerry R. Dwek, MD
Jeffrey L. Koning, MD
Amisha J. Shah, MD

SSR

Dawn M. Hastreiter, MD, PhD
Mary G. Hochman, MD
Jonathan S. Luchs, MD, FACR
Adam C. Zoga, MD

Committee on Body Imaging (Musculoskeletal)

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

William B. Morrison, MD, Chair
Christine B. Chung, MD
Robert K. Gelczer, MD
Dawn M. Hastreiter, MD, PhD
Viviane Khoury, MD
Jonathan S. Luchs, MD, FACR
Jeffrey J. Peterson, MD
Catherine C. Roberts, MD
Trenton D. Roth, MD
David A. Rubin, MD, FACR

Committee on Practice Parameters – Pediatric Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Beverley Newman, MB, BCh, BSc, FACR, Chair
Lorna P. Browne, MB, BCh
Timothy J. Carmody, MD, FACR
Brian D. Coley, MD, FACR
Lee K. Collins, MD
Monica S. Epelman, MD
Lynn Ansley Fordham, MD, FACR
Kerri A. Highmore, MD
Sue C. Kaste, DO
Tal Laor, MD
Terry L. Levin, MD
Marguerite T. Parisi, MD, MS
Sumit Pruthi, MBBS
Nancy K. Rollins, MD
Pallavi Sagar, MD

Lincoln L Berland, MD, FACR, Chair, Commission on Body Imaging
Marta Hernanz-Schulman, MD, FACR, Chair, Commission on Pediatric Radiology
Jacqueline A. Bello, MD, FACR, Chair, Commission on Quality and Safety
Matthew S. Pollack, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee

Catherine J. Everett, MD, MBA, FACR, Chair
Joshua M. McDonald, MD, Co-Chair
Jacqueline A. Bello, MD, FACR
Lincoln L Berland, MD, FACR
Jerry R. Dwek, MD
Patrick Gonzales, MD
Dawn M. Hastreiter, MD, PhD
Marta Hernanz-Schulman, MD, FACR
William T. Herrington, MD, FACR
Mary G. Hochman, MD
Diego Jaramillo, MD, MPH
Jeffrey L. Koning, MD
Viviane Khoury, MD
Paul A. Larson, MD, FACR
Jonathan S. Luchs, MD, FACR
William B. Morrison, MD
Beverley Newman, MB, BCh, BSc, FACR
Matthew S. Pollack, MD, FACR
Trenton D. Roth, MD
David A. Rubin, MD, FACR
Amisha J. Shah, MD
Timothy L. Swan, MD, FACR, FSIR
Adam C. Zoga, MD

REFERENCES

1. Anzilotti K, Jr., Schweitzer ME, Hecht P, Wapner K, Kahn M, Ross M. Effect of foot and ankle MR imaging on clinical decision making. *Radiology*. 1996;201(2):515-517.
2. Bearcroft PW, Guy S, Bradley M, Robinson F. MRI of the ankle: effect on diagnostic confidence and patient management. *AJR Am J Roentgenol*. 2006;187(5):1327-1331.

3. Conti S, Michelson J, Jahss M. Clinical significance of magnetic resonance imaging in preoperative planning for reconstruction of posterior tibial tendon ruptures. *Foot Ankle*. 1992;13(4):208-214.
4. Greenstein AS, Marzo-Ortega H, Emery P, O'Connor P, McGonagle D. Magnetic resonance imaging as a predictor of progressive joint destruction in neuropathic joint disease. *Arthritis Rheum*. 2002;46(10):2814-2815.
5. Nicholson CW, Berlet GC, Lee TH. Prediction of the success of nonoperative treatment of insertional Achilles tendinosis based on MRI. *Foot Ankle Int*. 2007;28(4):472-477.
6. Takao M, Innami K, Matsushita T, Uchio Y, Ochi M. Arthroscopic and magnetic resonance image appearance and reconstruction of the anterior talofibular ligament in cases of apparent functional ankle instability. *Am J Sports Med*. 2008;36(8):1542-1547.
7. Zanetti M, De Simoni C, Wetz HH, Zollinger H, Hodler J. Magnetic resonance imaging of injuries to the ankle joint: can it predict clinical outcome? *Skeletal Radiol*. 1997;26(2):82-88.
8. Tocci SL, Madom IA, Bradley MP, Langer PR, DiGiovanni CW. The diagnostic value of MRI in foot and ankle surgery. *Foot Ankle Int*. 2007;28(2):166-168.
9. Groshar D, Gorenberg M, Ben-Haim S, Jerusalemi J, Liberson A. Lower extremity scintigraphy: the foot and ankle. *Semin Nucl Med*. 1998;28(1):62-77.
10. Sugimoto K, Takakura Y, Samoto N, Nakayama S, Tanaka Y. Subtalar arthrography in recurrent instability of the ankle. *Clin Orthop Relat Res*. 2002(394):169-176.
11. Cooper AJ, Mizel MS, Patel PD, Steinmetz ND, Clifford PD. Comparison of MRI and local anesthetic tendon sheath injection in the diagnosis of posterior tibial tendon tenosynovitis. *Foot Ankle Int*. 2007;28(11):1124-1127.
12. Newman JS. Diagnostic and therapeutic injections of the foot and ankle. *Semin Roentgenol*. 2004;39(1):85-94.
13. Cerezal L, Llopis E, Canga A, Rolon A. MR arthrography of the ankle: indications and technique. *Radiol Clin North Am*. 2008;46(6):973-994, v.
14. Taljanovic MS, Alcalá JN, Gimber LH, Rieke JD, Chilvers MM, Latt LD. High-resolution US and MR imaging of peroneal tendon injuries. *Radiographics*. 2015;35(1):179-199.
15. Sconfienza LM, Orlandi D, Lacelli F, Serafini G, Silvestri E. Dynamic high-resolution US of ankle and midfoot ligaments: normal anatomic structure and imaging technique. *Radiographics*. 2015;35(1):164-178.
16. Khoury V, Guillin R, Dhanju J, Cardinal E. Ultrasound of ankle and foot: overuse and sports injuries. *Semin Musculoskelet Radiol*. 2007;11(2):149-161.
17. Schreiberman KL. Ankle tenography: what, how, and why. *Semin Roentgenol*. 2004;39(1):95-113.
18. Oae K, Takao M, Uchio Y, Ochi M. Evaluation of anterior talofibular ligament injury with stress radiography, ultrasonography and MR imaging. *Skeletal Radiol*. 2010;39(1):41-47.
19. Cutler L, Molloy A, Dhukuram V, Bass A. Do CT scans aid assessment of distal tibial physeal fractures? *J Bone Joint Surg Br*. 2004;86(2):239-243.
20. Haapamaki VV, Kiuru MJ, Koskinen SK. Ankle and foot injuries: analysis of MDCT findings. *AJR Am J Roentgenol*. 2004;183(3):615-622.
21. Hochman M, Reed MH. Features of calcaneonavicular coalition on coronal computed tomography. *Skeletal Radiol*. 2000;29(7):409-412.
22. Linsenmaier U, Brunner U, Schoning A, et al. Classification of calcaneal fractures by spiral computed tomography: implications for surgical treatment. *Eur Radiol*. 2003;13(10):2315-2322.
23. Rubino R, Valderrabano V, Sutter PM, Regazzoni P. Prognostic value of four classifications of calcaneal fractures. *Foot Ankle Int*. 2009;30(3):229-238.
24. Verhagen RA, Maas M, Dijkgraaf MG, Tol JL, Krips R, van Dijk CN. Prospective study on diagnostic strategies in osteochondral lesions of the talus. Is MRI superior to helical CT? *J Bone Joint Surg Br*. 2005;87(1):41-46.
25. Kiss ZS, Khan KM, Fuller PJ. Stress fractures of the tarsal navicular bone: CT findings in 55 cases. *AJR Am J Roentgenol*. 1993;160(1):111-115.
26. Rosenberg ZS, Jahss MH, Noto AM, et al. Rupture of the posterior tibial tendon: CT and surgical findings. *Radiology*. 1988;167(2):489-493.
27. Choplin RH, Buckwalter KA, Rydberg J, Farber JM. CT with 3D rendering of the tendons of the foot and ankle: technique, normal anatomy, and disease. *Radiographics*. 2004;24(2):343-356.
28. Pelc JS, Beaulieu CF. Volume rendering of tendon-bone relationships using unenhanced CT. *AJR Am J Roentgenol*. 2001;176(4):973-977.

29. Schmid MR, Pfirrmann CW, Hodler J, Vienne P, Zanetti M. Cartilage lesions in the ankle joint: comparison of MR arthrography and CT arthrography. *Skeletal Radiol.* 2003;32(5):259-265.
30. Karjalainen PT, Soila K, Aronen HJ, et al. MR imaging of overuse injuries of the Achilles tendon. *AJR Am J Roentgenol.* 2000;175(1):251-260.
31. Koivunen-Niemela T, Komu M, Viikari J, Alanen A. Magnetic resonance imaging of Achilles tendon xanthomas using a fat-water discrimination technique at 0.1 T. *Acad Radiol.* 1995;2(4):319-323.
32. Marshall H, Howarth C, Larkman DJ, Herlihy AH, Oatridge A, Bydder GM. Contrast-enhanced magic-angle MR imaging of the Achilles tendon. *AJR Am J Roentgenol.* 2002;179(1):187-192.
33. Schweitzer ME, Karasick D. MR imaging of disorders of the Achilles tendon. *AJR Am J Roentgenol.* 2000;175(3):613-625.
34. Shalabi A, Kristoffersen-Wiberg M, Aspelin P, Movin T. MR evaluation of chronic Achilles tendinosis. A longitudinal study of 15 patients preoperatively and two years postoperatively. *Acta Radiol.* 2001;42(3):269-276.
35. Bencardino J, Rosenberg ZS, Beltran J, et al. MR imaging of dislocation of the posterior tibial tendon. *AJR Am J Roentgenol.* 1997;169(4):1109-1112.
36. Bouysset M, Tebib J, Tavernier T, et al. Posterior tibial tendon and subtalar joint complex in rheumatoid arthritis: magnetic resonance imaging study. *J Rheumatol.* 2003;30(9):1951-1954.
37. Khoury NJ, el-Khoury GY, Saltzman CL, Brandser EA. MR imaging of posterior tibial tendon dysfunction. *AJR Am J Roentgenol.* 1996;167(3):675-682.
38. Nallamshetty L, Nazarian LN, Schweitzer ME, et al. Evaluation of posterior tibial pathology: comparison of sonography and MR imaging. *Skeletal Radiol.* 2005;34(7):375-380.
39. Premkumar A, Perry MB, Dwyer AJ, et al. Sonography and MR imaging of posterior tibial tendinopathy. *AJR Am J Roentgenol.* 2002;178(1):223-232.
40. Donovan A, Rosenberg ZS. Extraarticular lateral hindfoot impingement with posterior tibial tendon tear: MRI correlation. *AJR Am J Roentgenol.* 2009;193(3):672-678.
41. Khoury NJ, el-Khoury GY, Saltzman CL, Kathol MH. Peroneus longus and brevis tendon tears: MR imaging evaluation. *Radiology.* 1996;200(3):833-841.
42. Rademaker J, Rosenberg ZS, Delfaut EM, Cheung YY, Schweitzer ME. Tear of the peroneus longus tendon: MR imaging features in nine patients. *Radiology.* 2000;214(3):700-704.
43. Rosenberg ZS, Beltran J, Cheung YY, Colon E, Herraiz F. MR features of longitudinal tears of the peroneus brevis tendon. *AJR Am J Roentgenol.* 1997;168(1):141-147.
44. Rosenberg ZS, Bencardino J, Astion D, Schweitzer ME, Rokito A, Sheskier S. MRI features of chronic injuries of the superior peroneal retinaculum. *AJR Am J Roentgenol.* 2003;181(6):1551-1557.
45. Beischer AD, Beamon BM, Jowett AJ, O'Sullivan R. Distal tendinosis of the tibialis anterior tendon. *Foot Ankle Int.* 2009;30(11):1053-1059.
46. Bouysset M, Tavernier T, Tebib J, et al. CT and MRI evaluation of tenosynovitis of the rheumatoid hindfoot. *Clin Rheumatol.* 1995;14(3):303-307.
47. Gallo RA, Kolman BH, Daffner RH, Sciulli RL, Roberts CC, DeMeo PJ. MRI of tibialis anterior tendon rupture. *Skeletal Radiol.* 2004;33(2):102-106.
48. Lo LD, Schweitzer ME, Fan JK, Wapner KL, Hecht PJ. MR imaging findings of entrapment of the flexor hallucis longus tendon. *AJR Am J Roentgenol.* 2001;176(5):1145-1148.
49. Mengiardi B, Pfirrmann CW, Vienne P, et al. Anterior tibial tendon abnormalities: MR imaging findings. *Radiology.* 2005;235(3):977-984.
50. Brown KW, Morrison WB, Schweitzer ME, Parellada JA, Nothnagel H. MRI findings associated with distal tibiofibular syndesmosis injury. *AJR Am J Roentgenol.* 2004;182(1):131-136.
51. Chandnani VP, Harper MT, Ficke JR, et al. Chronic ankle instability: evaluation with MR arthrography, MR imaging, and stress radiography. *Radiology.* 1994;192(1):189-194.
52. Kim S, Huh YM, Song HT, et al. Chronic tibiofibular syndesmosis injury of ankle: evaluation with contrast-enhanced fat-suppressed 3D fast spoiled gradient-recalled acquisition in the steady state MR imaging. *Radiology.* 2007;242(1):225-235.
53. Klein MA. MR imaging of the ankle: normal and abnormal findings in the medial collateral ligament. *AJR Am J Roentgenol.* 1994;162(2):377-383.
54. Mesgarzadeh M, Schneck CD, Tehranzadeh J, Chandnani VP, Bonakdarpour A. Magnetic resonance imaging of ankle ligaments. Emphasis on anatomy and injuries to lateral collateral ligaments. *Magn Reson Imaging Clin N Am.* 1994;2(1):39-58.

55. Oae K, Takao M, Naito K, et al. Injury of the tibiofibular syndesmosis: value of MR imaging for diagnosis. *Radiology*. 2003;227(1):155-161.
56. Toye LR, Helms CA, Hoffman BD, Easley M, Nunley JA. MRI of spring ligament tears. *AJR Am J Roentgenol*. 2005;184(5):1475-1480.
57. Uys HD, Rijke AM. Clinical association of acute lateral ankle sprain with syndesmotic involvement: a stress radiography and magnetic resonance imaging study. *Am J Sports Med*. 2002;30(6):816-822.
58. Crim J, Longenecker LG. MRI and surgical findings in deltoid ligament tears. *AJR Am J Roentgenol*. 2015;204(1):W63-69.
59. Bureau NJ, Cardinal E, Hobden R, Aubin B. Posterior ankle impingement syndrome: MR imaging findings in seven patients. *Radiology*. 2000;215(2):497-503.
60. Choo HJ, Suh JS, Kim SJ, Huh YM, Kim MI, Lee JW. Ankle MRI for anterolateral soft tissue impingement: increased accuracy with the use of contrast-enhanced fat-suppressed 3D-FSPGR MRI. *Korean J Radiol*. 2008;9(5):409-415.
61. Duncan D, Mologne T, Hildebrand H, Stanley M, Schreckengaust R, Sitler D. The usefulness of magnetic resonance imaging in the diagnosis of anterolateral impingement of the ankle. *J Foot Ankle Surg*. 2006;45(5):304-307.
62. Lee JC, Calder JD, Healy JC. Posterior impingement syndromes of the ankle. *Semin Musculoskelet Radiol*. 2008;12(2):154-169.
63. Messiou C, Robinson P, O'Connor PJ, Grainger A. Subacute posteromedial impingement of the ankle in athletes: MR imaging evaluation and ultrasound guided therapy. *Skeletal Radiol*. 2006;35(2):88-94.
64. Robinson P, White LM, Salonen D, Ogilvie-Harris D. Anteromedial impingement of the ankle: using MR arthrography to assess the anteromedial recess. *AJR Am J Roentgenol*. 2002;178(3):601-604.
65. Robinson P, White LM, Salonen DC, Daniels TR, Ogilvie-Harris D. Anterolateral ankle impingement: mr arthrographic assessment of the anterolateral recess. *Radiology*. 2001;221(1):186-190.
66. Subhas N, Vinson EN, Cothran RL, Santangelo JR, Nunley JA, 2nd, Helms CA. MRI appearance of surgically proven abnormal accessory anterior-inferior tibiofibular ligament (Bassett's ligament). *Skeletal Radiol*. 2008;37(1):27-33.
67. Donovan A, Rosenberg ZS. MRI of ankle and lateral hindfoot impingement syndromes. *AJR Am J Roentgenol*. 2010;195(3):595-604.
68. Bui-Mansfield LT, Kline M, Chew FS, Rogers LF, Lenchik L. Osteochondritis dissecans of the tibial plafond: imaging characteristics and a review of the literature. *AJR Am J Roentgenol*. 2000;175(5):1305-1308.
69. Lee KB, Bai LB, Park JG, Yoon TR. A comparison of arthroscopic and MRI findings in staging of osteochondral lesions of the talus. *Knee Surg Sports Traumatol Arthrosc*. 2008;16(11):1047-1051.
70. Magee TH, Hinson GW. Usefulness of MR imaging in the detection of talar dome injuries. *AJR Am J Roentgenol*. 1998;170(5):1227-1230.
71. Naran KN, Zoga AC. Osteochondral lesions about the ankle. *Radiol Clin North Am*. 2008;46(6):995-1002, v.
72. Bae S, Lee HK, Lee K, et al. Comparison of arthroscopic and magnetic resonance imaging findings in osteochondral lesions of the talus. *Foot Ankle Int*. 2012;33(12):1058-1062.
73. Griffith JF, Lau DT, Yeung DK, Wong MW. High-resolution MR imaging of talar osteochondral lesions with new classification. *Skeletal Radiol*. 2012;41(4):387-399.
74. Gatlin CC, Matheny LM, Ho CP, Johnson NS, Clanton TO. Diagnostic accuracy of 3.0 tesla magnetic resonance imaging for the detection of articular cartilage lesions of the talus. *Foot Ankle Int*. 2015;36(3):288-292.
75. Allen JM, Greer BJ, Sorge DG, Campbell SE. MR imaging of neuropathies of the leg, ankle, and foot. *Magn Reson Imaging Clin N Am*. 2008;16(1):117-131, vii.
76. Chung KW, Suh BC, Shy ME, et al. Different clinical and magnetic resonance imaging features between Charcot-Marie-Tooth disease type 1A and 2A. *Neuromuscul Disord*. 2008;18(8):610-618.
77. Delfaut EM, Demondion X, Bieganski A, Thiron MC, Mestdagh H, Cotten A. Imaging of foot and ankle nerve entrapment syndromes: from well-demonstrated to unfamiliar sites. *Radiographics*. 2003;23(3):613-623.
78. Finkel JE. Tarsal tunnel syndrome. *Magn Reson Imaging Clin N Am*. 1994;2(1):67-78.
79. Frey C, Kerr R. Magnetic resonance imaging and the evaluation of tarsal tunnel syndrome. *Foot Ankle*. 1993;14(3):159-164.

80. Dong Q, Jacobson JA, Jamadar DA, et al. Entrapment neuropathies in the upper and lower limbs: anatomy and MRI features. *Radiol Res Pract.* 2012;2012:230679.
81. Grasel RP, Schweitzer ME, Kovalovich AM, et al. MR imaging of plantar fasciitis: edema, tears, and occult marrow abnormalities correlated with outcome. *AJR Am J Roentgenol.* 1999;173(3):699-701.
82. Jeswani T, Morlese J, McNally EG. Getting to the heel of the problem: plantar fascia lesions. *Clin Radiol.* 2009;64(9):931-939.
83. Yu JS. Pathologic and post-operative conditions of the plantar fascia: review of MR imaging appearances. *Skeletal Radiol.* 2000;29(9):491-501.
84. Yu JS, Spigos D, Tomczak R. Foot pain after a plantar fasciotomy: an MR analysis to determine potential causes. *J Comput Assist Tomogr.* 1999;23(5):707-712.
85. Lektrakul N, Chung CB, Lai Y, et al. Tarsal sinus: arthrographic, MR imaging, MR arthrographic, and pathologic findings in cadavers and retrospective study data in patients with sinus tarsi syndrome. *Radiology.* 2001;219(3):802-810.
86. Bottger BA, Schweitzer ME, El-Noueam KI, Desai M. MR imaging of the normal and abnormal retrocalcaneal bursae. *AJR Am J Roentgenol.* 1998;170(5):1239-1241.
87. Maillefert JF, Dardel P, Cherasse A, Mistrih R, Krause D, Tavernier C. Magnetic resonance imaging in the assessment of synovial inflammation of the hindfoot in patients with rheumatoid arthritis and other polyarthritis. *Eur J Radiol.* 2003;47(1):1-5.
88. Rochwerger A, Groulier P, Curvale G, Launay F. Pigmented villonodular synovitis of the foot and ankle: a report of eight cases. *Foot Ankle Int.* 1999;20(9):587-590.
89. Weishaupt D, Schweitzer ME, Morrison WB, Haims AH, Wapner K, Kahn M. MRI of the foot and ankle: prevalence and distribution of occult and palpable ganglia. *J Magn Reson Imaging.* 2001;14(4):464-471.
90. Elias I, Zoga AC, Raikin SM, et al. Bone stress injury of the ankle in professional ballet dancers seen on MRI. *BMC Musculoskelet Disord.* 2008;9:39.
91. Fernandez-Canton G, Casado O, Capelastegui A, Astigarraga E, Larena JA, Merino A. Bone marrow edema syndrome of the foot: one year follow-up with MR imaging. *Skeletal Radiol.* 2003;32(5):273-278.
92. Schmid MR, Hodler J, Vienne P, Binkert CA, Zanetti M. Bone marrow abnormalities of foot and ankle: STIR versus T1-weighted contrast-enhanced fat-suppressed spin-echo MR imaging. *Radiology.* 2002;224(2):463-469.
93. Sijbrandij ES, van Gils AP, Louwerens JW, de Lange EE. Posttraumatic subchondral bone contusions and fractures of the talotibial joint: occurrence of "kissing" lesions. *AJR Am J Roentgenol.* 2000;175(6):1707-1710.
94. Zanetti M, Steiner CL, Seifert B, Hodler J. Clinical outcome of edema-like bone marrow abnormalities of the foot. *Radiology.* 2002;222(1):184-188.
95. Beltran J, Shankman S. MR imaging of bone lesions of the ankle and foot. *Magn Reson Imaging Clin N Am.* 2001;9(3):553-566, xi.
96. Lee IS, Choi JA, Oh JH, et al. Microscopy coil for preoperative MRI of small soft-tissue masses of the hand and foot: comparison with conventional surface coil. *AJR Am J Roentgenol.* 2008;191(6):W256-263.
97. Llauger J, Palmer J, Monill JM, Franquet T, Bague S, Roson N. MR imaging of benign soft-tissue masses of the foot and ankle. *Radiographics.* 1998;18(6):1481-1498.
98. Maldjian C, Rosenberg ZS. MR imaging features of tumors of the ankle and foot. *Magn Reson Imaging Clin N Am.* 2001;9(3):639-657, xii.
99. Ganguly A, Aniq H, Skiadas B. Lumps and bumps around the foot and ankle: an assessment of frequency with ultrasound and MRI. *Skeletal Radiol.* 2013;42(8):1051-1060.
100. Ledermann HP, Morrison WB, Schweitzer ME. Pedal abscesses in patients suspected of having pedal osteomyelitis: analysis with MR imaging. *Radiology.* 2002;224(3):649-655.
101. Ledermann HP, Morrison WB, Schweitzer ME, Raikin SM. Tendon involvement in pedal infection: MR analysis of frequency, distribution, and spread of infection. *AJR Am J Roentgenol.* 2002;179(4):939-947.
102. Godoy-Santos AL, Bordalo-Rodrigues M, Rosemberg L, et al. Kager's fat pad inflammation associated with HIV infection and AIDS: MRI findings. *Skeletal Radiol.* 2014;43(9):1257-1262.
103. Chan VO, Morrison WB, Kavanagh EC. Postoperative infection in the foot and ankle. *Semin Musculoskelet Radiol.* 2012;16(3):241-253.
104. Cahuzac JP, Baunin C, Luu S, Estivalezes E, Sales de Gauzy J, Hobatho MC. Assessment of hindfoot deformity by three-dimensional MRI in infant club foot. *J Bone Joint Surg Br.* 1999;81(1):97-101.

105. Cheung Y, Rosenberg ZS. MR imaging of the accessory muscles around the ankle. *Magn Reson Imaging Clin N Am*. 2001;9(3):465-473, x.
106. Miller TT, Staron RB, Feldman F, Parisien M, Glucksman WJ, Gandolfo LH. The symptomatic accessory tarsal navicular bone: assessment with MR imaging. *Radiology*. 1995;195(3):849-853.
107. Newman JS, Newberg AH. Congenital tarsal coalition: multimodality evaluation with emphasis on CT and MR imaging. *Radiographics*. 2000;20(2):321-332; quiz 526-327, 532.
108. Patel CV. The foot and ankle: MR imaging of uniquely pediatric disorders. *Magn Reson Imaging Clin N Am*. 2009;17(3):539-547, vii.
109. Zammit J, Singh D. The peroneus quartus muscle. Anatomy and clinical relevance. *J Bone Joint Surg Br*. 2003;85(8):1134-1137.
110. Lehtinen A, Paimela L, Kreula J, Leirisalo-Repo M, Taavitsainen M. Painful ankle region in rheumatoid arthritis. Analysis of soft-tissue changes with ultrasonography and MR imaging. *Acta Radiol*. 1996;37(4):572-577.
111. Erdem CZ, Tekin NS, Sarikaya S, Erdem LO, Gulec S. MR imaging features of foot involvement in patients with psoriasis. *Eur J Radiol*. 2008;67(3):521-525.
112. Eshed I, Althoff CE, Feist E, et al. Magnetic resonance imaging of hindfoot involvement in patients with spondyloarthritides: comparison of low-field and high-field strength units. *Eur J Radiol*. 2008;65(1):140-147.
113. Weishaupt D, Schweitzer ME, Alam F, Karasick D, Wapner K. MR imaging of inflammatory joint diseases of the foot and ankle. *Skeletal Radiol*. 1999;28(12):663-669.
114. Yu JS, Chung C, Recht M, Dailiana T, Jurdi R. MR imaging of tophaceous gout. *AJR Am J Roentgenol*. 1997;168(2):523-527.
115. Bancroft LW, Peterson JJ, Kransdorf MJ. Imaging of soft tissue lesions of the foot and ankle. *Radiol Clin North Am*. 2008;46(6):1093-1103, vii.
116. American College of Radiology. ACR–SSR practice parameter for the performance and interpretation of magnetic resonance imaging (MRI) of bone and soft tissue tumors. 2015; Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-SoftTissue-Tumors.pdf>. Accessed July 22, 2015.
117. Petit P, Paniel M, Faure F, et al. Acute fracture of the distal tibial physis: role of gradient-echo MR imaging versus plain film examination. *AJR Am J Roentgenol*. 1996;166(5):1203-1206.
118. Robbins MI, Wilson MG, Sella EJ. MR imaging of anterosuperior calcaneal process fractures. *AJR Am J Roentgenol*. 1999;172(2):475-479.
119. Umans H, Pavlov H. Insufficiency fracture of the talus: diagnosis with MR imaging. *Radiology*. 1995;197(2):439-442.
120. Nikken JJ, Oei EH, Ginai AZ, et al. Acute ankle trauma: value of a short dedicated extremity MR imaging examination in prediction of need for treatment. *Radiology*. 2005;234(1):134-142.
121. Tochigi Y, Yoshinaga K, Wada Y, Moriya H. Acute inversion injury of the ankle: magnetic resonance imaging and clinical outcomes. *Foot Ankle Int*. 1998;19(11):730-734.
122. Anderson SE, Weber M, Steinbach LS, Ballmer FT. Shoe rim and shoe buckle pseudotumor of the ankle in elite and professional figure skaters and snowboarders: MR imaging findings. *Skeletal Radiol*. 2004;33(6):325-329.
123. Dunfee WR, Dalinka MK, Kneeland JB. Imaging of athletic injuries to the ankle and foot. *Radiol Clin North Am*. 2002;40(2):289-312, vii.
124. Hillier JC, Peace K, Hulme A, Healy JC. Pictorial review: MRI features of foot and ankle injuries in ballet dancers. *Br J Radiol*. 2004;77(918):532-537.
125. Zoga AC, Schweitzer ME. Imaging sports injuries of the foot and ankle. *Magn Reson Imaging Clin N Am*. 2003;11(2):295-310.
126. Alparslan L, Chiodo CP. Lateral ankle instability: MR imaging of associated injuries and surgical treatment procedures. *Semin Musculoskelet Radiol*. 2008;12(4):346-358.
127. Kanamoto T, Shiozaki Y, Tanaka Y, Yonetani Y, Horibe S. The use of MRI in pre-operative evaluation of anterior talofibular ligament in chronic ankle instability. *Bone Joint Res*. 2014;3(8):241-245.
128. Chien AJ, Jacobson JA, Jamadar DA, Brigido MK, Femino JE, Hayes CW. Imaging appearances of lateral ankle ligament reconstruction. *Radiographics*. 2004;24(4):999-1008.

129. Liem MD, Zegel HG, Balduini FC, Turner ML, Becker JM, Caballero-Saez A. Repair of Achilles tendon ruptures with a polylactic acid implant: assessment with MR imaging. *AJR Am J Roentgenol.* 1991;156(4):769-773.
130. Zeiss J, Fenton P, Ebraheim N, Coombs RJ. Magnetic resonance imaging for ineffectual tarsal tunnel surgical treatment. *Clin Orthop Relat Res.* 1991(264):264-266.
131. Zanetti M, Saupe N, Espinosa N. Postoperative MR imaging of the foot and ankle: tendon repair, ligament repair, and Morton's neuroma resection. *Semin Musculoskelet Radiol.* 2010;14(3):357-364.
132. Bude RO, Adler RS, Bassett DR. Diagnosis of Achilles tendon xanthoma in patients with heterozygous familial hypercholesterolemia: MR vs sonography. *AJR Am J Roentgenol.* 1994;162(4):913-917.
133. Dussault RG, Kaplan PA, Roederer G. MR imaging of Achilles tendon in patients with familial hyperlipidemia: comparison with plain films, physical examination, and patients with traumatic tendon lesions. *AJR Am J Roentgenol.* 1995;164(2):403-407.
134. American College of Radiology. ACR practice parameter for performing and interpreting magnetic resonance imaging (MRI). 2011; Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Perf-Interpret.pdf>. Accessed January 22, 2015.
135. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *J Magn Reson Imaging.* 2013;37(3):501-530.
136. Shellock FG. *Reference Manual for Magnetic Resonance Safety, Implants, and Devices.* 2009 ed. Los Angeles, Calif: Biomedical Research Publishing; 2009.
137. Shellock FG, Crues JV. MR procedures: biologic effects, safety, and patient care. *Radiology.* 2004;232(3):635-652.
138. American College of Radiology. ACR–SPR practice parameter for the use of intravascular contrast media. 2012; <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/IVCM.pdf>. Accessed January 22, 2015.
139. American College of Radiology. ACR–SIR practice parameter for sedation/analgesia. 2015; <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Sed-Analgesia.pdf>. Accessed July 20, 2015.
140. Barr C, Bauer JS, Malfair D, et al. MR imaging of the ankle at 3 Tesla and 1.5 Tesla: protocol optimization and application to cartilage, ligament and tendon pathology in cadaver specimens. *Eur Radiol.* 2007;17(6):1518-1528.
141. Schibany N, Ba-Ssalamah A, Marlovits S, et al. Impact of high field (3.0 T) magnetic resonance imaging on diagnosis of osteochondral defects in the ankle joint. *Eur J Radiol.* 2005;55(2):283-288.
142. Muhle C, Frank LR, Rand T, et al. Collateral ligaments of the ankle: high-resolution MR imaging with a local gradient coil and anatomic correlation in cadavers. *Radiographics.* 1999;19(3):673-683.
143. Crooks LE, Arakawa M, Hoenninger J, McCarten B, Watts J, Kaufman L. Magnetic resonance imaging: effects of magnetic field strength. *Radiology.* 1984;151(1):127-133.
144. Erickson SJ. High-resolution imaging of the musculoskeletal system. *Radiology.* 1997;205(3):593-618.
145. Hottya GA, Peterfy CG, Uffmann M, et al. Dedicated extremity MR imaging of the foot and ankle. *Eur Radiol.* 2000;10(3):467-475.
146. Verhoek G, Zanetti M, Duester S, Zollinger H, Hodler J. MRI of the foot and ankle: diagnostic performance and patient acceptance of a dedicated low field MR scanner. *J Magn Reson Imaging.* 1998;8(3):711-716.
147. Kulkarni MV, Patton JA, Price RR. Technical considerations for the use of surface coils in MRI. *AJR Am J Roentgenol.* 1986;147(2):373-378.
148. Rubin DA. MR imaging technique and principles. In: Spoung AR, Pope TL, ed. *Practical MRI of the Foot and Ankle.* Boca Raton, Fla: CRC Press LLC; 2001:1-36.
149. 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(5):1155-1163.
150. Feighan J, Towers J, Conti S. The use of magnetic resonance imaging in posterior tibial tendon dysfunction. *Clin Orthop Relat Res.* 1999(365):23-38.
151. Mengiardi B, Pfirrmann CW, Schottle PB, et al. Magic angle effect in MR imaging of ankle tendons: influence of foot positioning on prevalence and site in asymptomatic subjects and cadaveric tendons. *Eur Radiol.* 2006;16(10):2197-2206.
152. Tokuda O, Awaya H, Taguchi K, Matsunga N. Kinematic MRI of the normal ankle ligaments using a specially designed passive positioning device. *Foot Ankle Int.* 2006;27(11):935-942.
153. Hricak H, Amparo EG. Body MRI: alleviation of claustrophobia by prone positioning. *Radiology.* 1984;152(3):819.

154. Rubin DA, Towers JD, Britton CA. MR imaging of the foot: utility of complex oblique imaging planes. *AJR Am J Roentgenol.* 1996;166(5):1079-1084.
155. Klein MA. Reformatted three-dimensional Fourier transform gradient-recalled echo MR imaging of the ankle: spectrum of normal and abnormal findings. *AJR Am J Roentgenol.* 1993;161(4):831-836.
156. Duc SR, Mengiardi B, Pfirrmann CW, Hodler J, Zanetti M. Improved visualization of collateral ligaments of the ankle: multiplanar reconstructions based on standard 2D turbo spin-echo MR images. *Eur Radiol.* 2007;17(5):1162-1171.
157. Soila K, Karjalainen PT, Aronen HJ, Pihlajamaki HK, Tirman PJ. High-resolution MR imaging of the asymptomatic Achilles tendon: new observations. *AJR Am J Roentgenol.* 1999;173(2):323-328.
158. Bush CH. The magnetic resonance imaging of musculoskeletal hemorrhage. *Skeletal Radiol.* 2000;29(1):1-9.
159. Ba-Ssalamah A, Schibany N, Puig S, Herneth AM, Noebauer-Huhmann IM, Trattinig S. Imaging articular cartilage defects in the ankle joint with 3D fat-suppressed echo planar imaging: comparison with conventional 3D fat-suppressed gradient echo imaging. *J Magn Reson Imaging.* 2002;16(2):209-216.
160. Tan TC, Wilcox DM, Frank L, et al. MR imaging of articular cartilage in the ankle: comparison of available imaging sequences and methods of measurement in cadavers. *Skeletal Radiol.* 1996;25(8):749-755.
161. Murphey MD, Rhee JH, Lewis RB, Fanburg-Smith JC, Flemming DJ, Walker EA. Pigmented villonodular synovitis: radiologic-pathologic correlation. *Radiographics.* 2008;28(5):1493-1518.
162. Jacobson JA, Andresen R, Jaovisidha S, et al. Detection of ankle effusions: comparison study in cadavers using radiography, sonography, and MR imaging. *AJR Am J Roentgenol.* 1998;170(5):1231-1238.
163. Huh YM, Suh JS, Lee JW, Song HT. Synovitis and soft tissue impingement of the ankle: assessment with enhanced three-dimensional FSPGR MR imaging. *J Magn Reson Imaging.* 2004;19(1):108-116.
164. Smith DK, Wright J. Water bags: an inexpensive method for improving fat suppression in MR imaging of the extremities. *AJR Am J Roentgenol.* 1994;162(5):1252-1253.
165. Fleckenstein JL, Archer BT, Barker BA, Vaughan JT, Parkey RW, Peshock RM. Fast short-tau inversion-recovery MR imaging. *Radiology.* 1991;179(2):499-504.
166. Fuller S, Reeder S, Shimakawa A, et al. Iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) fast spin-echo imaging of the ankle: initial clinical experience. *AJR Am J Roentgenol.* 2006;187(6):1442-1447.
167. Lu A, Grist TM, Block WF. Fat/water separation in single acquisition steady-state free precession using multiple echo radial trajectories. *Magn Reson Med.* 2005;54(5):1051-1057.
168. Maas M, Dijkstra PF, Akkerman EM. Uniform fat suppression in hands and feet through the use of two-point Dixon chemical shift MR imaging. *Radiology.* 1999;210(1):189-193.
169. Reeder SB, McKenzie CA, Pineda AR, et al. Water-fat separation with IDEAL gradient-echo imaging. *J Magn Reson Imaging.* 2007;25(3):644-652.
170. Huo D, Li Z, Aboussouan E, Karis JP, Pipe JG. Turboprop IDEAL: a motion-resistant fat-water separation technique. *Magn Reson Med.* 2009;61(1):188-195.
171. Simon JH, Szumowski J. Chemical shift imaging with paramagnetic contrast material enhancement for improved lesion depiction. *Radiology.* 1989;171(2):539-543.
172. Bauer JS, Banerjee S, Henning TD, Krug R, Majumdar S, Link TM. Fast high-spatial-resolution MRI of the ankle with parallel imaging using GRAPPA at 3 T. *AJR Am J Roentgenol.* 2007;189(1):240-245.
173. Stevens KJ, Busse RF, Han E, et al. Ankle: isotropic MR imaging with 3D-FSE-cube--initial experience in healthy volunteers. *Radiology.* 2008;249(3):1026-1033.
174. Peh WC, Chan JH. Artifacts in musculoskeletal magnetic resonance imaging: identification and correction. *Skeletal Radiol.* 2001;30(4):179-191.
175. Van Hecke PE, Marchal GJ, Baert AL. Use of shielding to prevent folding in MR imaging. *Radiology.* 1988;167(2):557-558.
176. Haacke EM, Lenz GW. Improving MR image quality in the presence of motion by using rephasing gradients. *AJR Am J Roentgenol.* 1987;148(6):1251-1258.
177. Du J, Pak BC, Znamirovski R, et al. Magic angle effect in magnetic resonance imaging of the Achilles tendon and enthesis. *Magn Reson Imaging.* 2009;27(4):557-564.
178. Erickson SJ, Cox IH, Hyde JS, Carrera GF, Strandt JA, Estkowski LD. Effect of tendon orientation on MR imaging signal intensity: a manifestation of the "magic angle" phenomenon. *Radiology.* 1991;181(2):389-392.

179. Peh WC, Chan JH. The magic angle phenomenon in tendons: effect of varying the MR echo time. *Br J Radiol.* 1998;71(841):31-36.
180. Schulte-Altendorneburg G, Gebhard M, Wohlgemuth WA, et al. MR arthrography: pharmacology, efficacy and safety in clinical trials. *Skeletal Radiol.* 2003;32(1):1-12.
181. American College of Radiology. ACR practice parameter for communication of diagnostic imaging findings. 2014; <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CommunicationDiag.pdf>. Accessed January 22, 2015.
182. Shellock FG. *Guide to MR Procedures and Metallic Objects.* 7th ed. Philadelphia, Pa: Lippincott Williams and Wilkins; 2001.
183. Shellock FG, Spinazzi A. MRI safety update 2008: part 2, screening patients for MRI. *AJR Am J Roentgenol.* 2008;191(4):1140-1149.
184. American College of Radiology. ACR–AAPM technical standard for diagnostic medical physics performance monitoring of magnetic resonance imaging (MRI) equipment. 2014; <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Equip.pdf>. Accessed January 22, 2015.

*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 4, 35)

Revised 2011 (Resolution 20)

Amended 2014 (Resolution 39)

Revised 2016 (Resolution 3)