Technical Considerations
Best Practices for MR Imaging of the Foot and Ankle

Carolyn M. Sofka, MD

KEYWORDS

• Foot • Ankle • Tendons • Ligaments • Short tau inversion recovery (STIR) • Metal artifact reduction • Time resolved imaging of contrast kinetics (TRICKS)

KEY POINTS

- MR imaging can be optimized to image the foot and ankle in both the preoperative and the postoperative settings.
- Contrast-enhanced MR angiographic techniques can be used for vascular mapping of the foot and ankle.
- Appropriate MR technique modifications can provide diagnostic image quality even in the setting of metal.

INTRODUCTION

There are many challenges involved in obtaining diagnostic MR images of the foot and ankle. The complex anatomy and morphology, with curved and angular structures localized to the periphery of the body, make for an inherent challenge, let alone if an added level of complexity (orthopedic instrumentation) is added. This review outlines the technical considerations best designed to produce diagnostic images of the foot and ankle, with an emphasis on the postoperative state, including imaging in the presence of metal.

IMAGING THE PREOPERATIVE FOOT AND ANKLE

Non-contrast-enhanced fast spin-echo proton density–weighted sequences have largely become the workhorse in MR imaging of the musculoskeletal system and have been validated against surgical arthroscopic standards.[1–4] A long repetition time (≥3500 milliseconds) and moderate echo time (TE; 28–34 milliseconds) result in differential contrast between articular cartilage and fluid, producing an inherent "arthrographic effect" without the additional complicating diagnostic hindrances that can accompany a direct MR arthrogram (contrast extravasation into the surrounding soft tissues, air bubbles in the joint being confused as intra-articular bodies, and so forth).[5] These standard sequences are used in foot and ankle imaging as well; however, some limitations arise due to the curved anatomy and morphology of structures about the foot and ankle, specifically with regard to ligaments and tendons.

At the author's institution, which mostly sees populations of sports injuries, arthritis, and foot deformities, the default imaging sequences are outlined in **Tables 1–3**. The inherent magnetization transfer properties induced between slices in fast spin-echo, moderate TE imaging, produce relative increased signal intensity from simple fluid. This results in a distinct contrast between higher signal intensity fluid and intermediate signal intensity of articular cartilage, preventing the need to administer

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Department of Radiology and Imaging, Hospital for Special Surgery, Weill Cornell Medical College, 535 East 70th Street, New York, NY 10021, USA
E-mail address: sofkac@hss.edu

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Table 1
Suggested protocol for imaging the ankle

	Sagittal IR Inversion Time 150	Sagittal PD	Coronal PD	Axial PD
TR	4000	4500	5000	5000
TE	13–15	25	25	24
ST	3.3	3.0	4.0	3.3
ETL	10	12	12	12
FOV	180	150	110	130
Matrix	256 × 192	512 × 384	512 × 384	512 × 256
NEX	2	2	2	2

Abbreviations: ETL, echo train length; IR, inversion recovery; NEX, number of excitations; PD, proton density; ST, slice thickness (mm); TR, repetition time (ms).

intra-articular or intravenous contrast material for routine anatomic imaging. This noninvasive approach, combined with dedicated surface coils, works to provide optimum image quality[5] (**Fig. 1**).

Dedicated surface coils help to improve spatial resolution and field homogeneity, notably when imaging smaller structures such as the foot and ankle.[6] Either a quadrature (circular polarization) knee coil or an 8-channel phased array dedicated foot and ankle coil are suggested to achieve adequate signal to noise. Images are typically obtained with the foot in neutral position, without excessive dorsiflexion or plantarflexion, although some authors have proposed imaging the foot and ankle in positions that may maximally stress regional tendons and ligaments, such as ballet dancers en pointe, in weight-bearing maximum plantar flexion.[7] Kinematic MR examination has also been explored for the evaluation of ankle ligament integrity.[8]

The magic angle effect, often noted in MR interpretation of the rotator cuff of the shoulder, can contribute to a degree of uncertainty when interpreting images of the foot and ankle, and it is always critical to keep this phenomenon in mind when analyzing the status of ligaments and tendons. The magic angle effect is a phenomenon of MR physics and accounts for signal changes that can be seen in anisotropic tissues, including the ordered collagen bundles that comprise tendons.[9,10] It occurs when the collagen bundle orientation is 55° to the main magnetic field (z-axis). The artifact mimics tendon degeneration in that it is visible on sequences with short TEs such as the T1- and proton density–weighted sequences used commonly when imaging the musculoskeletal system,[11–17] but becomes less apparent on MR sequences with longer TE values (>37 milliseconds) such as T2-weighted and short tau inversion recovery (STIR) images.[9,13,17] When the tendon is oriented at approximately 55° to the main magnetic field, the artifact will be visible in all imaging planes. At the author's institution, we have subjectively found that the addition of axial STIR images positively contributes to the diagnostic interpretation of the status of ankle tendons, and this finding has been independently validated by Srikhum and colleagues.[18] Other ways to minimize

Table 2
Suggested protocol for imaging the midfoot

	Coronal IR Inversion Time 150	Coronal PD	Axial PD	Sagittal PD
TR	4500	4500	4500	5000
TE	16	27	26	25
ST	3.0	2.0	3.0	4.0
ETL	12	14	18	14
FOV	160	150	110	160
Matrix	256 × 192	512 × 320	512 × 320	512 × 256
NEX	2	2	2	2

From approximately the mid subtalar joint to the proximal metatarsals.
Coronal, parallel to the bottom of the foot; Axial, transverse to the longitudinal arch of the foot.