CHAPTER 4

Imaging techniques
4.1. Conventional radiographic findings

Conventional radiography, tomography, arthrography and stress views have traditionally been used for imaging the ankle and hindfoot. Although these techniques have been used for years, especially for the subtalar joint, they lack anatomic detail. Several supplemental radiographic techniques were developed and new procedures were introduced to improve diagnostic accuracy.

Routine conventional radiography remains the primary diagnostic method to study the twisted ankle, (when a fracture is clinically suspect) and should include lateral and internal oblique views [1, 2]. However, some fractures (occult), occurring most frequently in the talus and calcaneus, are not seen on routine plain radiographs [3].

Stress radiography of the ankle joint may be useful for evaluating ligamentous injury after inversion trauma of the ankle. Stress radiographs most often utilized are AP projection, applying varus stress and lateral projection applying vertical stress (drawer sign). Radiological examination of the contralateral ankle joint is useful to differentiate between posttraumatic or congenital relaxation. Normal range of talar tilt varies, ranging from 0-15° [4, 5]. In case of instability the range has been reported between 1-24°. So, there is substantial overlap between the normal and pathologic tilt [6].

The subtalar joint has a very complex, multi-faceted surface which makes evaluation with plain radiography and conventional tomography difficult [7].

Subtalar stress views are used to assess the presence of subtalar instability during inversion of the hindfoot [8]. Oblique radiograph (Brodén view) is performed with the x-ray beam rotated 30° in lateromedial and 40° in caudocranial direction, with the subtalar joint inverted by a dedicated stress device [9]. Instability of the subtalar joint is believed to be present when stress radiographs demonstrate loss of parallelity of the posterior articular surfaces of the subtalar joint [4, 9, 10]. However, there is no general consensus regarding the best method for evaluating subtalar instability [9].

Ankle arthrography is the most commonly performed arthrogram in the foot and ankle. It allows assessment for articular anatomy, loose bodies, ligamentous integrity and capsular abnormalities. Ankle arthrography has been used in diagnosing acute ligamental injury [11]. Tears of the anterior talofibular ligaments can be detected by leakage of contrast material out of the ankle joint into the spaces around the tibial malleolus [11]. However, arthrography has many limitations in diagnosing ankle ligament injuries [11]. Indications for arthrography became more limited with the developing role of MR imaging [12].
4.2. Ultrasound
Ultrasound is the main alternative to MR imaging in the evaluation of soft-tissue abnormalities. Its main advantage includes wide availability, low cost, direct correlation of sonographic findings with the site of symptoms, dynamic evaluation and feasibility in examining anxious and noncooperative patients [13]. Specific soft-tissue pathology such as ganglia, ligamentous injury and joint effusion are easily detected (Fig. 1) [14]. The main disadvantages of ultrasound are its operator dependence, failure to image bone abnormalities consistently and limited acceptance by referring clinicians as a basis for making surgical decisions [13].

4.3. Bone scintigraphy
Prior to the introduction of MR imaging and CT, nuclear-medicine bone scintigraphy was the next step after conventional radiography in the investigation of foot and ankle pain of unknown cause [15]. By bone scanning anatomic and physiologic information can be obtained. $^{99m}$Technetium methylene diphosphonate ($^{99m}$Tc-HDP) is a commonly used bone-scanning agent. The primary option for focal areas of interest is three-phase bone

Figure 1.
Complete anterior talofibular ligament (ATFL) tear. Longitudinal ultrasound of the lateral ankle joint with a hypo-echoic gap in the tendon fibers (arrows) consistent with a complete rupture of the anterior talofibular ligament. Effusion (*) distends the joint capsule (arrowhead). Adapted from E. Meijerman.
scanning, with this technique, early vascular phase, blood pool image and delayed images can be obtained (Fig. 2) [15]. However, the spatial resolution of bone scintigraphy is low and cannot distinguish bone bruises from osteochondral fractures [1].

4.4. Computed tomography

With the introduction of CT, the investigation of joints of ankle and hindfoot has been given new opportunities for the investigation of bony anatomic details. The advent of helical CT has markedly increased speed of modern CT systems and has found use in a variety of musculoskeletal applications. In imaging the foot and ankle it is of critical importance that those planes are chosen that are based on an erect anatomic position [16].

Generally, in foot and ankle, 5-mm thick or thinner sections are required. When osseous details are important or reconstructions are planned, very thin contiguous sections (i.e., 1.5-mm thick) or overlapping thin sections (i.e., 3-mm thick, obtained at 2-mm intervals) are useful. Helical CT has made it easier to use multiplanar reconstructions, reduce artifacts and perform dynamic contrast studies [16]. It is regarded as superior to MR imaging in the way it shows (high) contrast between calcific structures and soft tissue. However CT has its limitations for evaluation of soft tissue and bone marrow abnormalities.

Figure 2.
Early vascular phase of three-phase bone scintigraphy. Increased activity in medial OD lesion of right talar dome (arrow). Left foot is normal.
4.5. MR imaging

The introduction of MR imaging has had a major impact on musculoskeletal imaging. Subtle detection and more precise characterization of soft tissue and bony details coupled with multiplanar imaging capability are ideally suited to evaluate the complex anatomy of foot and ankle [17]. High quality images may be obtained with the use of intermediate or high field strength magnets (0.5-1.5 Tesla). High field strength magnets are currently preferred because of their higher signal-to-noise ratio [18]. With the patient in supine position, the ankle to be examined is placed in neutral position, although partial plantar flexion may be useful when comparing MR images to a CT made in 45° of tibiotalar angulation. With a dedicated extremity surface coil (quadrature or phased-array design), using a 12 to 14 cm field of view (FOV) and a 512 x 256 or 256 x 256 acquisition matrix, thin (3 mm or less) coronal T1 and STIR images are most useful. By placing both legs within the circular extremity coil, comparison of the pathological side with the contralateral ankle and foot can be achieved. Alternatively, when smaller FOVs are needed, extremities can be imaged one at a time by repositioning the surface coil. Kinematic techniques with the ankle in inversion and eversion in the coronal plane, in plantar flexion and dorsiflexion in the sagittal plane, and in internal or external rotation in the coronal or axial plane may also be used. However, these techniques are not routinely employed, and kinematic motion is not physiologic. Restricted range of motion, ligamentous instabilities, and tendon subluxations may necessitate the use of kinematic protocols.

The selection of specific sequences depends on the suspected pathological condition. Most ankle and foot MR imaging studies can be performed using a limited number of pulse sequences, such as two-dimensional multissection spin-echo (SE) techniques. Routine T1-weighted axial, sagittal, and coronal images are obtained with a short repetition time (TR) of 500 to 600 ms and a short echo time (TE) of 15 to 20 ms. Thin (3 mm) sections, either contiguous interleaved or with a 0.5 mm interslice gap, are preferred. With this technique, excellent depiction of the normal or abnormal anatomical structures of the tendons, ligaments, cortical bone, and bone marrow is obtained. T2-weighted (long TR, long TE SE pulse sequences) axial images are obtained with conventional T2-weighted or fat-suppressed T2-weighted fast spin-echo sequences which can detect pathological conditions such as edema, soft-tissue tumors, ligamentous injuries and bone marrow abnormalities [19]. T1- and T2-weighted sequences can be performed at one excitation. T1-weighted images may be supplemented with coronal and sagittal images obtained using either fast STIR or fat-suppressed T2-weighted fast spin-echo sequences.

Gradient-echo pulse sequences with two-dimensional (2D) or three-dimensional (3D) acquisitions can be used to obtain images with contrast in T2*-weighted images in a
relatively brief acquisition time. Effective T2*-weighted contrast can be generated with gradient-echo techniques, using a partial flip angle of less than 90° (20° to 30°). Two-dimensional Fourier-transform multiplanar gradient-echo protocols use a TR of 400 to 600 ms, a TE of 15 to 20 ms, and a flip angle of 20° to 30°. Axial three-dimensional Fourier-transform (3DFT) T2* volume images with 1 to 2 mm slice thickness may also be used to evaluate medial or lateral ligamentous structures. Short T1 inversion recovery (STIR and fast spin-echo STIR) images provide superior contrast in evaluating osteochondral lesions, bone contusions, and tendinitis.

Intravenous administration of a paramagnetic contrast agent, used in association with fat-suppression sequences, has demonstrated usefulness in the evaluation of inflammatory synovial processes, and certain tendon pathologies (partial tear, healing, and infiltrative disorders). Intravenous and intra-articular contrast agents (MR arthrography) has been used on a limited basis in the study of osteochondral lesions and other intra-articular pathology. Articular cartilage is evaluated using a variety of techniques, including fat-suppressed T2-weighted fast spin-echo, fast spin-echo STIR, and MR arthrography. Fat-suppressed T2-weighted fast spin-echo [17]. The introduction of fast MR techniques has allowed better evaluation of the blood flow to the tissues. With gadolinium-enhanced subtraction MR imaging the viability of bone can be depicted. Lack of arterial enhancement of the bone marrow correlated with lack of blood perfusion and thus to ischemia [18,19]. Pre-injection images, followed by a series of images per minute using a TR/TE/of 40/10 and a 90° flip angle (see chapter eight) [20].

References
