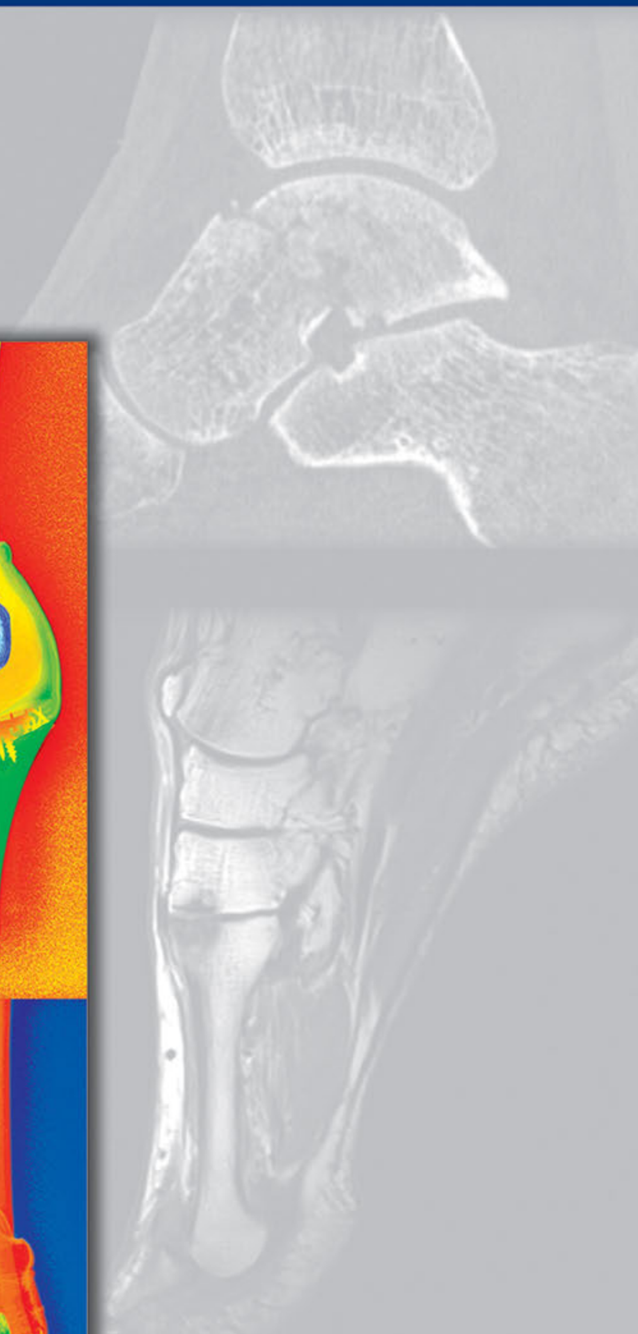
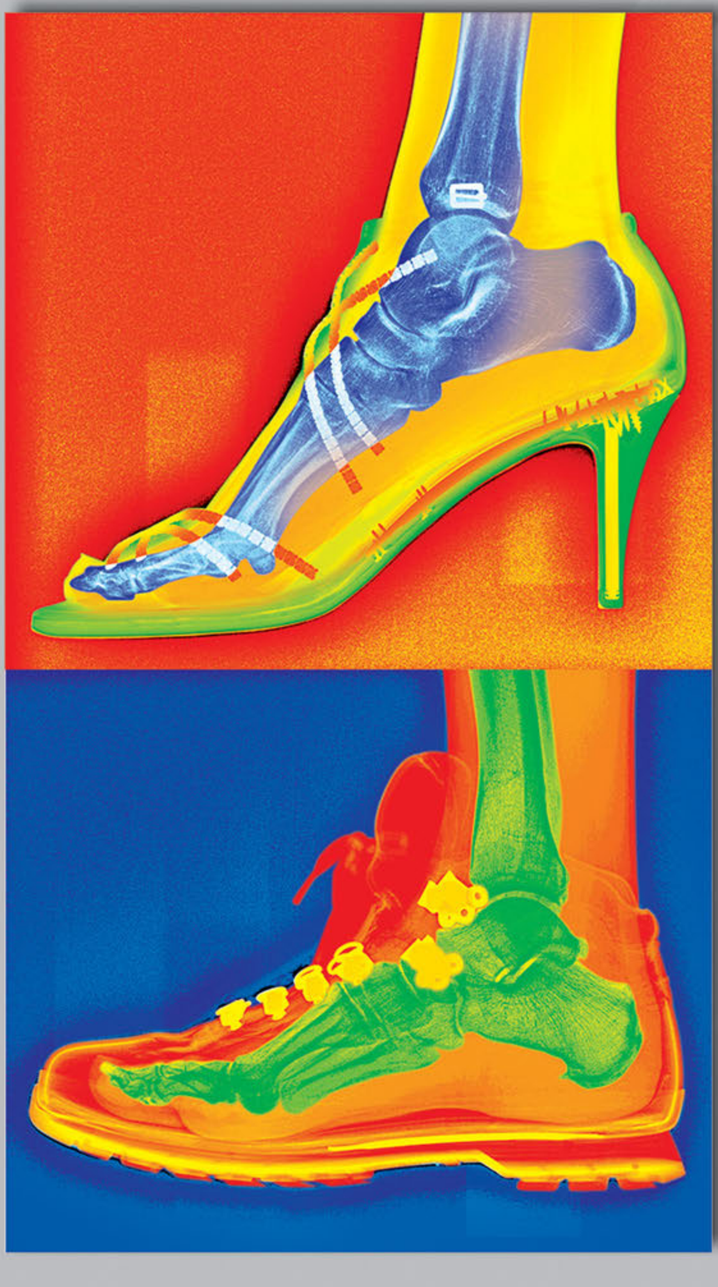
Diagnostic Imaging of the Foot and Ankle

Ulrike Szeimies
Axel Staebler
Markus Walther





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Ulrike Szeimies, MD
Head of Department
München-Harlaching Imaging Center
Munich, Germany

Axel Staebler, MD
Professor of Radiology
München-Harlaching Imaging Center
Munich, Germany

Markus Walther, MD
Professor of Orthopedic Surgery
Medical Director
Head of the Department of Foot and Ankle Surgery
Schön Klinik München-Harlaching
FIFA Medical Center Munich
Munich, Germany

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Translator: Terry C. Telger, Fort Worth, TX, USA

Illustrator: Roland Geyer, Weilerswist, Germany

Thieme Publishers Stuttgart
Rüdigerstrasse 14, 70469 Stuttgart, Germany
+49 [0]711 8931 421, customerservice@thieme.de

Thieme Publishers New York
333 Seventh Avenue, New York, NY 10001 USA
+1 800 782 3488, customerservice@thieme.com

Thieme Publishers Delhi
A-12, Second Floor, Sector-2, Noida-201301
Uttar Pradesh, India
+91 120 45 566 00, customerservice@thieme.in

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Rio de Janeiro 22250-040 Brazil
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To my beloved daughter Emilia
Ulrike Szeimies

To my beloved wife Susann
Axel Staebler

To all those dedicated to treating patients with foot and ankle disorders
Markus Walther

Contents

Preface

"Help, a difficult foot in MRI!" — Surely this is a common thought, especially if the referring foot surgeon is known for requesting very specific information. In creating this book, the editors (two radiologists and one foot surgeon) agreed that only clinical–radiologic correlation combined with expertise in the treatment of foot disorders could lead to an improved interpretation of pathologic findings. As in many areas of medicine, in radiology we are experiencing a trend toward subspecialization, as we move from method-centered to organ-centered diagnosis. The exchange of specialized knowledge with a clinical colleague is crucial in understanding such a biomechanically complex joint system as the foot. This book is intended to provide a concise, practical, fully illustrated guide to image interpretation from a clinical perspective, and always with reference to therapeutic options. Recommendations on protocols and diagnostic routines are based mainly on considerations of patient care, giving due attention to theoretical background while keeping an eye on the economic pressures that bear on a radiology practice.

The editors and authors hope that this guide to foot imaging will be of significant practical help in the everyday practice of image interpretation and will awaken in some readers a passion for the diagnosis of foot disorders.

Ulrike Szeimies, MD
Axel Staebler, MD
Markus Walther, MD

Contributors

Ruediger Degwert, MD
Department of Individual Back Therapy
Ambulatory Sports Trauma Center
Munich, Germany

Hartmut Gaulrapp, MD
Specialty Practice for Orthopedics and Pediatric Orthopedics
Munich, Germany

Sigurd Kessler, MD
Professor of Surgery
Center for Foot and Ankle Surgery
Schön-Klinik Hospital at München-Harlaching
Munich, Germany

Anke Roeser, MD
Center for Foot and Ankle Surgery
Schön-Klinik Hospital at München-Harlaching
Munich, Germany

Axel Staebler, MD
Professor of Radiology
München-Harlaching Imaging Center
Munich, Germany

Ulrike Szeimies, MD
Head of Department
München-Harlaching Imaging Center
Munich, Germany

Markus Walther, MD
Professor of Orthopedic Surgery
Medical Director
Head of the Department of Foot and Ankle Surgery
Schön Klinik München-Harlaching
FIFA Medical Center Munich
Munich, Germany

Abbreviations

ACR	American College of Rheumatology
AO	Arbeitsgemeinschaft für Osteosynthese
AOFAS	American Orthopedic Foot and Ankle Society
AP	Anteroposterior
ASIF	Association for the Study of Internal Fixation
AVN	Avascular necrosis
CRPS	complex regional pain syndrome
CT	computed tomography
3D	three dimensional
DMARD	disease-modifying antirheumatic drug
DNOAP	diabetic neuropathic osteoarthropathy
DP	dorsoplantar
fat-sat	fat saturated
HLA	human leukocyte antigen
ICI	Integral Classification of Injuries
IV	intravenous
MPR	multiplanar reformatting
MRI	magnetic resonance imaging
NOAP	neuropathic osteoarthropathy
NSAID	nonsteroidal anti-inflammatory drug
OTA	Orthopaedic Trauma Association
PA	posteroanterior
PD	proton density
PVNS	pigmented villonodular synovitis
STIR	short-tau inversion recovery
TNF	tumor necrosis factor
VR	volume rendering
WHO	World Health Organization

Chapter 1

Imaging Techniques

1 Imaging Techniques

1.1 Magnetic Resonance Imaging (MRI)

U. Szeimies

1.1.1 Imaging Strategy

MRI of the Foot: General Aspects

MRI System

It is still basically true that higher field intensity in MRI means higher resolution, and thus better image quality. The advantages of a 3-tesla (3-T) system are obvious, and its ability to depict fine details still has the power to fascinate the observer. The direct visualization of neural structures, tiny fascicles in the ligaments, and especially the hyaline articular cartilage, provides a high confidence level in the detection of pathology. On the other hand, a 3-T system is more susceptible to artifacts than a 1.5-T system in patients with internal fixation materials, and this may be a significant problem at large foot and ankle centers, for example. It should be added that modern 1.5-T MRI systems with multi-channel coil technology can achieve a resolution comparable to that of a 3-T system. The 1.5-T field does involve a more time-consuming protocol, however.

Coil, Positioning

A high-resolution multi-channel coil for the detailed evaluation of fine structures in a high-field system (1.5 T or higher) delivers high anatomical precision. Whenever possible, the patient is positioned prone with the foot in plantar flexion and optimally padded within the coil. That position is comfortable for the patient and should cause fewer motion artifacts than imaging in the supine position. It can also prevent artifacts that appear when the tendon is at a 54.7° angle to the B_0 magnetic field ("magic angle" phenomenon), causing increased intratendinous signal intensity that can mimic pathologic changes.

Sequences

Standard MR sequences are available for foot imaging and are especially useful for investigating generalized foot pain and evaluating the bone marrow and soft tissues. Special sequences are also available in which the sequence parameters and slice selection are individually tailored for a specific investigation. See examples under Special Sequences for Specific Investigation (p. 2).

The standard MR sequences are as follows:

- Coronal > T1-weighted
- Sagittal and coronal PD (proton-density) weighted fat-sat (with fat saturation)
- > Axial T2-weighted
- Axial and sagittal T1-weighted fat-sat after intravenous (IV) contrast administration

A high-resolution square matrix (384 × 384, 448 × 448, or 512 × 512) is generally recommended for high-resolution imaging of the foot and ankle. Thin imaging sections are also advised, using a maximum slice thickness of 2 to 2.5 mm.

Contrast Medium

Except in acute trauma cases, MR images should be acquired with IV contrast medium, because conditions such as chronic overuse syndromes (affecting joints, tendons, capsuloligamentous structures, or fibro-osseous junctions) can be appreciated only on contrast-enhanced images showing increased uptake in the fibrovascular tissue. Recently, it has been stressed that contrast-enhanced MRI should include an assessment of renal function (creatinine clearance). If current blood work is not available, the clearance value can be quickly determined with a test kit by taking a small blood sample from the finger tip or earlobe.

Special Sequences for Specific Investigations

- *Anterior syndesmosis* (oblique sagittal/axial PD-weighted fat-sat sequence; ▶ Fig. 1.1 a): This oblique sagittal/axial angulation can display the full course of the anterior syndesmosis, which descends obliquely from the distal tibia to the fibula. This sequence will clearly show any fiber discontinuity or hemorrhagic areas in the tibiofibular syndesmosis.
- *Tendon pathology in the hindfoot and midfoot* (axial oblique T1-weighted fat-sat after contrast administration; ▶ Fig. 1.1 b): The tendons in the hindfoot (flexor and extensor tendons, and peroneal tendons) run at a 45° angle to the ankle joint. The axial oblique T1-weighted fat-sat sequence after contrast administration is prescribed at a 90° angle to the course of the tendons to give an optimum cross-sectional view of the tendons and their sheaths. This sequence and orientation will clearly show increased contrast uptake in the tendon sheaths or abnormal enhancement within those tendons that would indicate increased vascularity due to advanced intratendinous degeneration.
- *Morton neuroma* (axial and coronal T1-weighted sequences without contrast administration): These are the most important sequences for the evaluation of Morton neuroma. Due to its high cellularity, this mass appears hypointense within the hyperintense fat on unenhanced T1-weighted images and is often conspicuous by its bulbous or fusiform shape in the interdigital space. Often contrast administration adds little information, because Morton neuromas may show a variable degree of vascularity. The key identifying feature is the interdigital location of the mass (between the second and third or third and fourth metatarsal heads on the plantar side) and its shape (usually bulbous in the axial T1-weighted sequence and fusiform in the coronal sequence, extending into the plantar soft tissue).

In summary, an optimum MRI examination of the foot can be performed easily and routinely. Compromised image quality is often a result of economic constraints. High image quality requires a considerable investment of time, which is not always justifiable on purely economic grounds.

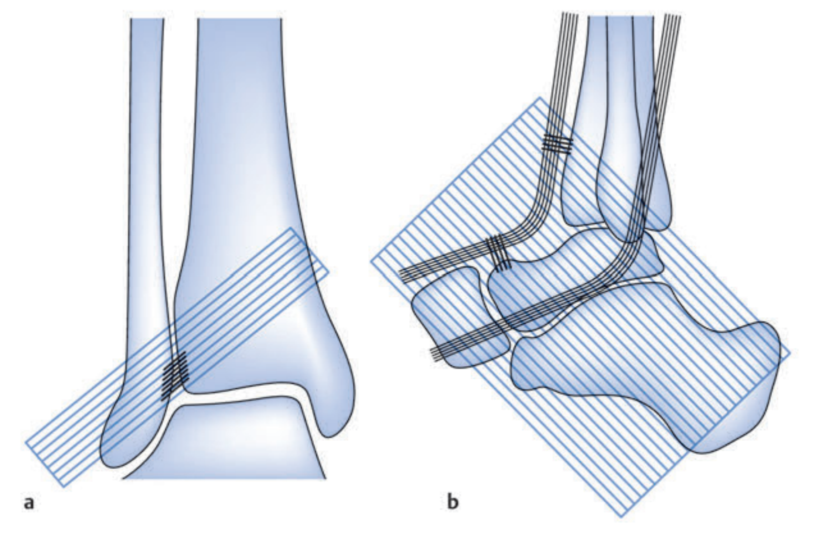

Fig. 1.1 a, b Special sequences for MRI of the foot.
a The anterior syndesmosis is evaluated with an oblique sagittal scan.
b Tendon pathology is evaluated with an oblique axial scan.

1.1.2 Post-Exercise MRI

A common problem in patients with foot pain is the intermittent nature of the complaints in response to weight bearing and exercise. Patients are often advised to rest the affected foot on their initial visit to a foot specialist, and a subsequent MRI examination is usually performed during a stress-free interval. Consequently, most patients are scanned at a time when they are not experiencing symptoms. They give a history of complaints that occur during or after physical exertion or athletic activity. In some cases MRI performed during an asymptomatic interval may fail to detect the pathology (e.g., deeply situated ganglia in the tarsal tunnel that exert a mass effect only during exercise, or instability of the peroneal tendons).

For a post-exercise MRI study, the patient is told to perform the exercise that typically causes the painful symptoms. If necessary the study is preceded by one or more units of running or training exercises that are likely to reproduce the pain. MRI scans are initiated only after the complaints have been elicited, and IV contrast administration should be used.

Post-exercise MRI has not yet been fully evaluated in studies, and its capabilities relative to “standard MRI” have not yet been definitively assessed. Also, studies should be done only by an experienced foot radiologist who will not misinterpret possible epiphenomena such as physiologic joint effusions or venous dilatation. Nevertheless, post-exercise MRI may be a helpful study, especially in athletes, in cases where prior images acquired elsewhere were negative and there is a new indication for MRI.

1.2 Multidetector-Row Spiral Computed Tomography (CT)

U. Szeimies

1.2.1 Positioning

- Comfortable supine position
- Avoid motion artifacts
- Scan only the affected foot in the supine position or with the foot resting on the cassette

1.2.2 Protocol

Isotropic voxels are necessary for optimum multiplanar reformatting (MPR) of the acquired data sets. Sample protocol:

- Slice thickness 0.5 mm
- Reconstruction increment 0.25 mm
- Pitch 0.875
- 120 kV
- 80 to 150 mA (use a reduced dose and strict selection criteria in children)

Images are reconstructed in three standard planes (axial, coronal and sagittal), while areas of special concern are evaluated in selected magnified views.

1.2.3 Indications

- *Initial work-up*:
  - Fractures (to assess axial malalignment in ankle fractures while clearly defining the fragments and looking for step-offs), especially metatarsal fractures
  - Severe sprains with equivocal radiographic features
  - Neuroarthropathy
  - Osteoarthritis (evaluating the extent of degenerative changes)
  - CT as an adjunct to MRI (ganglion cyst, unexplained bone marrow edema, further differentiation of tumors)
  - Coalition
  - As an aid to preoperative planning (e.g., calculation of the tibial torsion angle)
- *Postoperative imaging* (axial alignment, step-off in an articular surface, internal fixation materials)
- *Follow-up:*
  - Bony consolidation of fractures and nonunions
  - Localization and evaluation of internal fixation material (screw in the joint space, loosening; ▶ Fig. 1.2)

1.2.4 Special Techniques

- *3D imaging*; indications:
  - Complex fractures
  - Calcaneal fracture, evaluation of the subtalar joint surface

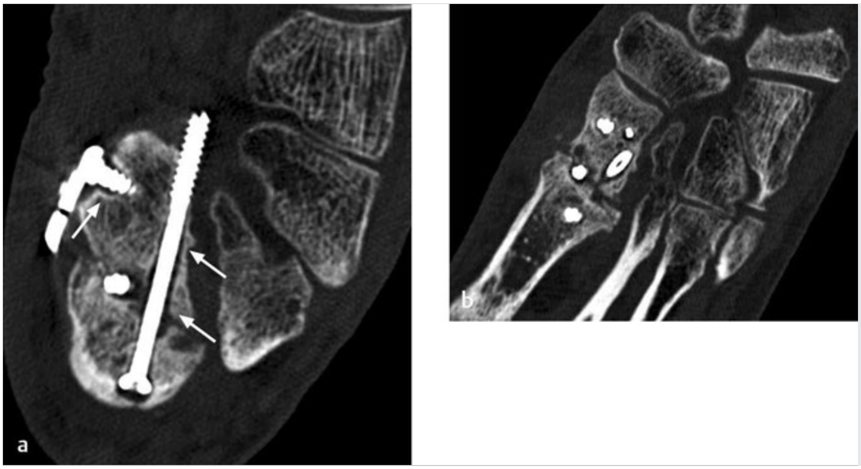

Fig. 1.2 a, b Persistent pain after fusion of the first tarsometatarsal joint in a 72-year-old woman.
a Oblique coronal multiplanar reformatting (MPR) image reconstructed along the screw through the first tarsometatarsal joint shows a fine zone of bone resorption around the arthrodesis screws (arrows). Bony consolidation around internal fixation material and the bony attachment of the material can be assessed accurately and with relatively few artifacts, even in small joints.
b Coronal MPR of the midfoot demonstrates nonunion of the first tarsometatarsal joint.

  - Tarsometatarsal (Lisfranc) and midtarsal (Chopart) joint lines
  - Interrelationship of the fragments
  - Axial malalignment
- *Side-to-side comparison:* Considered obsolete due to excessive radiation exposure
- *CT examinations in children:* Whenever possible, CT should be replaced by MRI due to radiation concerns (e.g., for investigating epiphyseal plate injuries, bone fractures involving the epiphyseal plate, or coalition). CT should be used only if MRI findings are equivocal.

1.3 Radiography

M. Walther

1.3.1 Forefoot

Weight-Bearing Radiographs of the Foot in Three Planes (▶ Fig. 1.3)

Indications

Standard radiographic series for the foot. Non–weight-bearing views of the foot are obtained only after trauma or surgery.

Positioning

- *DP (dorsoplantar) projection*:
  - Film flat on the floor
  - Patient standing on the cassette
  - Beam centered on the second tarsometatarsal joint
  - Tube 0° vertical
- *Lateral view*:
  - Film perpendicular to the floor, touching the medial side of the foot
  - Patient standing on the floor
  - Beam directed lateromedially, centered on the calcaneocuboid joint
  - Tube 0° horizontal

The determination of axial relationships on radiographs is subject to considerable variability. Couglin et al (2002) published a technique for determining bone axes based on designated reference points in the diaphysis. This technique was adopted by the AOFAS (American Orthopedic Foot and Ankle Society) as its standard for surgery of the forefoot.

Non–Weight-Bearing Radiographs of the Foot, Stress Radiographs

Indications

Non–weight-bearing radiographs of the foot are obtained in patients with suspected fractures and for postoperative evaluations and stress views.

Positioning

The patient lies on the X-ray table in a supine or lateral decubitus position (non–weight-bearing views are obtained only after trauma or surgery):

- *DP projection:*
  - Film horizontal on the X-ray table
  - Foot position: patient lies supine with the foot flat on the cassette
  - Beam centered on the second tarsometatarsal joint
  - Tube 0° vertical
  - If necessary, a forefoot adduction stress can be applied manually or with a mechanical apparatus (e.g., Telos device or Scheuba device).
- *Lateral view* (▶ Fig. 1.4 a):
  - Film horizontal on the X-ray table
  - Foot position: patient lies in lateral decubitus on the X-ray table with the affected foot down and resting on the cassette
  - Central ray focused on the calcaneocuboid joint
  - Tube 0° vertical
- *45° oblique views from the lateral side* (▶ Fig. 1.4 b):
  - Film horizontal on the X-ray table
  - Foot position: foot standing on the cassette and tilted 45° medially
  - Beam centered on the second tarsometatarsal joint
  - Tube 0° vertical
- *45° oblique view from the medial side* (e.g., an extra 45° inversion view is taken to evaluate the first tarsometatarsal joint after surgical fusion):
  - Film horizontal on the X-ray table

Fig. 1.3 a–c Weight-bearing radiographs of the foot in three planes. Standard series for evaluating deformities and degenerative diseases. These radiographs are the basis for most reconstructive surgical procedures on the foot. Angle determinations are all performed on weight-bearing radiographs. This series illustrates a hallux valgus deformity with degenerative changes in the subsesamoid joint space.
a Lateral view.
b Oblique view.
c DP view.

- ○ Foot position: foot standing on the cassette and tilted 45° laterally
- ○ Beam centered on the first tarsometatarsal joint
- ○ Tube 0° vertical

! Note

The stability of the calcaneocuboid joint can be evaluated on a non–weight-bearing DP radiograph while a forefoot adduction stress is applied. More than 10° of joint space opening is considered abnormal.

Toe Radiographs

Indications

Toe radiographs are obtained to evaluate toe injuries and other pathology.

Positioning

- DP projection
- Lateral oblique projection
- True lateral projection (rarely taken because the toes overlap in that projection)

Fig. 1.4 a, b Non–weight-bearing radiographs of the forefoot in two planes. A weight-bearing radiograph could not be obtained in this patient due to severe arthritis of the first metatarsophalangeal joint.
a DP view.
b Oblique view.

Fig. 1.5 Radiographic view of the sesamoids in their sulci, usually combined with radiographs of the foot in three planes. This view can demonstrate degenerative changes in the subsesamoid joint space, fragmentation due to sesamoid necrosis, subluxation of the sesamoids due to hallux valgus, or sesamoid irritation by metal following hallux surgery. The present image shows no abnormalities.

Toe projections are analogous to projections of the foot, except that the beam is centered on the second toe or on the toe with the presumed pathology.

Sesamoid Radiographs

Indications

Radiographs of the foot in three planes should be obtained in all patients with presumed sesamoid pathology.

Positioning

- *AP (anteroposterior) axial view of the sesamoids:*
  - Horizontal film position
  - Foot position: patient lies supine with the heel on the film plate, the ankle joint in 105° of plantar flexion, and traction applied with a strap to produce maximum dorsiflexion of the toes
  - Beam centered on the first metatarsophalangeal joint
  - X-ray tube 0° vertical
- *PA (posteroanterior) axial view of the sesamoids* (▶ Fig. 1.5):
  - Horizontal film position
  - Foot position: patient lies prone with the knee supported on a foam pad and the toes in maximum dorsiflexion
  - Beam centered on the first metatarsophalangeal joint
  - X-ray tube 0° vertical

! Note

Visualization of the sesamoids in their sulci is particularly helpful for evaluating degenerative changes in the subsesamoid joint space, unexplained complaints after hallux surgery, and sesamoid osteonecrosis. The sesamoid views are supplemented by radiographs of the big toe in three planes.

1.3.2 Hindfoot

Radiographs of the Ankle Joint in Two Planes

Indications

These are the standard projections for evaluating pathology in the talocrural joint.

Positioning

- *AP weight-bearing radiograph* (▶ Fig. 1.6):
  - Film is vertical and behind the ankle joint
  - Foot position: patient stands with the heel against the cassette and the axis of the foot parallel to the central ray
  - Beam centered on the ankle joint
  - X-ray tube 0° horizontal
- *Weight-bearing mortise view:*
  - Film is vertical and behind the ankle joint

Fig. 1.6 **AP weight-bearing radiograph of the ankle joint** reveals degenerative joint changes with varus deformity.

 ◦ Foot position: patient stands with the heel against the cassette and the foot rotated internally until the axis of the ankle joint is parallel to the cassette
 ◦ Beam centered on the ankle joint
 ◦ X-ray tube 0° horizontal
- *Lateral ankle view:*
 ◦ Film is vertical and medial to the ankle joint
 ◦ Foot position: patient stands with the medial side against the cassette
 ◦ Beam centered on the ankle joint
 ◦ X-ray tube 0° horizontal

! Note

Oblique views in 45° of internal and external rotation supply additional information on the ankle mortise and talus. The internal rotation view is good for evaluating the distal fibula and subfibular region. The external rotation view clearly displays the posteromedial talus.

Non–Weight-Bearing Radiographs of the Ankle joint, Stress Radiographs

Indications

- Suspected fracture after trauma
- Stress views for evaluating (chronic) capsuloligamentous instabilities about the ankle joint

Positioning (▶ Fig. 1.7 and ▶ Fig. 1.8)

- *Non–weight-bearing AP projection:*
 ◦ Film horizontal on the X-ray table
 ◦ Foot position: patient lies supine on the table with the heel resting on the cassette (axis of the foot is parallel to the central ray)
 ◦ Beam centered on the ankle joint
 ◦ X-ray tube 0° vertical
 ◦ If desired, a varus or valgus stress can be applied to the ankle manually or with a mechanical apparatus (e.g., Telos device or Scheuba device).
- *Non–weight-bearing mortise view:*
 ◦ Film horizontal on the X-ray table
 ◦ Foot position: patient lies supine on the table with the heel resting on the cassette (axis of the ankle joint is parallel to the cassette)
 ◦ Beam centered on the ankle joint
 ◦ X-ray tube 0° vertical
 ◦ If desired, a varus or valgus stress can be applied manually or with a mechanical apparatus (e.g., Telos or Scheuba device).
- *Non–weight-bearing ankle lateral view:*
 ◦ Film horizontal on the X-ray table
 ◦ Foot position: patient is in lateral decubitus on the X-ray table with the affected foot down and resting on the cassette (axis of the foot is parallel to the central ray)
 ◦ Beam centered on the ankle joint
 ◦ X-ray tube 0° vertical
 ◦ If desired, a drawer test can be performed by applying pressure to the front of the distal tibia while manually or mechanically stabilizing the calcaneal tuberosity.

Stress radiographs can be obtained by applying the stress manually or with a mechanical device. The standard pressure is 15 kPa. In an acute injury, stress radiographs are rewarding only when analgesia is administered (e.g., local anesthesia of the

Fig. 1.7 a, b Stress radiograph of the ankle joint. Stress views are feasible only in patients without ankle pain. Increased joint space opening is diagnostic of capsuloligamentous laxity or a ligament tear. False-negative results are a possibility. Stress radiographs have become largely obsolete in the acute diagnosis of ligament tears.
a DP view.
b Lateral view.

Fig. 1.8 a, b Non–weight-bearing radiographs of the ankle joint in two planes. These are the standard views for acute injuries, especially for suspected fractures. These radiographs show a fracture of the fibula and a chip fracture of the posterior tibial margin.
a DP view.
b Lateral view.

capsule and ligaments). Today, stress radiographs are of minor importance in the treatment algorithm for a lateral ankle sprain. Equivocal findings may be resolved by a side-to-side comparison, but this requires a higher radiation dose and should never be carried out to compensate for a lack of knowledge in radiographic anatomy or morphology.

! Note

The following signs on stress radiographs are considered abnormal:

- Anterior displacement of the talus > 2 mm in a side-to-side comparison
- Absolute talar displacement > 4 mm
- Lateral joint space opening > 10° in a side-to-side comparison
- Difference in the distance from the lateral distal talar margin to the fibular articular surface > 3 mm

Lateral radiographs are obtained in maximum dorsiflexion or plantar flexion with anterior or posterior impingement. AP radiographs are taken with eversion and dorsiflexion in patients with a suspected syndesmotic injury.

Broden View (▶ Fig. 1.9)

Indications

The Broden view is used to display the posterior facet of the subtalar joint.

Positioning

- *Medial oblique view:*
  - Film position horizontal on the X-ray table
  - Foot position: patient lies supine with the foot in internal rotation (45°) and the ankle joint at a 90° angle supported on a foam wedge

Fig. 1.9 Broden stress view. The Broden view is used to evaluate the stability of the subtalar joint in response to an inversion stress. This image shows slight joint space opening with rounded bone fragments on the lateral process of the talus following a sprain injury.

- Central ray is focused between the fibular apex and base of the fifth metatarsal
- X-ray tube: views are taken at 10°, 20°, 30°, and 40° angles from the vertical with the central ray angled cephalad

• *Lateral oblique view:*
  - Film position horizontal on the X-ray table
  - Foot position: patient lies supine with the foot in external rotation (45°) and the ankle joint at a 90° angle supported on a foam wedge
  - Central ray is focused between the medial malleolus and the tuberosity of the navicular bone
  - X-ray tube: views are taken at a 15° and 18° angle from the vertical with the central ray angled cephalad

! Note

The Broden view is a helpful intraoperative view during the open reduction and internal fixation of calcaneal fractures. CT has largely replaced the Broden view as a preoperative study. The medial oblique view can be obtained with a varus stress to evaluate subtalar joint stability.

Radiographs of the Calcaneus in Two Planes

Indications

Radiographs of the calcaneus in two planes are performed in patients with calcaneal fractures, after bony corrections, and in the diagnosis of Haglund exostosis and traction spurs.

Positioning

- *DP calcaneus axial projection:*
  - Film position horizontal on the X-ray table
  - Foot position: patient stands on the film with the tube behind the leg
  - Central ray is focused between the Achilles tendon insertion and the ankle joint
  - X-ray tube is angled anteriorly at a 25° angle from the vertical
- *Calcaneus lateral view:*
  - Film is perpendicular to the floor, placed against the medial aspect of the foot
  - Foot position: patient stands on the floor
  - Central ray from lateral to medial, centered on the calcaneus
  - X-ray tube: 90° from the perpendicular

! Note

Lateral views taken with 30° of internal and external rotation can detect calcifications on the calcaneal margins. Alternatively, CT or MRI can be used in clinically suspicious cases with negative radiographs.

Hindfoot Alignment View (Saltzman View, ▶ Fig. 1.10)

Indications

The Saltzman view is for evaluating the axial alignment of the hindfoot.

Positioning

- Film position: angled 20° from the vertical and 90° to the central ray
- Foot position: patient stands on a platform with the tube behind the leg and the cassette anterior to the foot
- Beam is centered on the ankle joint
- X-ray tube is angled 20° from the horizontal in a plantar direction

! Note

Hindfoot alignment views are an important aid in the work-up of calcaneal varus or valgus deformity and in the planning of hindfoot corrections.

Fig. 1.10 a, b Saltzman view. The Saltzman view is used to evaluate calcaneal alignment. It has become increasingly important in recent years in the treatment of hindfoot deformities and is performed with weight bearing along with radiographs of the ankle joint in two planes.
a Patient with hindfoot valgus and forefoot abduction.
b Appearance following surgical correction by a calcaneal sliding osteotomy and calcaneal lengthening.

1.4 Ultrasound

H. Gaulrapp

Even in the foot and ankle, diagnostic ultrasound provides an “extended clinical finger,” which should be performed personally by the clinical examiner in order to gain maximum information.

The patient is placed in a supine or prone position, supported if necessary with a padded roll. The affected structure is always scanned in two planes—longitudinal and transverse—using a 7.5- to 15-MHz linear transducer. A stand-off may be used on irregular surfaces and will improve resolution in the unfavorable near-field region, though it may sometimes cause troublesome reverberations. The use of a fluid-filled glove is not recommended owing to the presence of small air bubbles. The field of view and focus should be optimized for the region of interest (size, depth).

Besides the few standard sections recommended for the ankle joint by the DEGUM (German Society for Ultrasound in Medicine), additional planes have proven useful for scanning specific joint areas, tendons, and especially ligamentous structures.

Strengths of ultrasound:

- It can demonstrate fluids, soft tissues, joints, and bony surfaces.
- The power Doppler mode provides information on vascularity (e.g., angiogenesis in synovitis).
- Real-time imaging permits a unique dynamic–functional analysis of mobility and stability in joint compartments and of the muscle–tendon apparatus under constant visual control.
- Aspirations, injections, and biopsies are safer and more accurate when performed with ultrasound guidance or assistance.
- The technique is rapidly available at low cost.

Weaknesses of ultrasound:

- Inability to penetrate bony or calcified structures
- Poor visualization of deeper structures
- Poorer lateral resolution than MRI, with comparable axial resolution

Ultrasound can provide the experienced examiner with a wealth of additional information within a short time, allowing for the prompt and purposeful initiation of treatment while eliminating the need for costly or invasive tests:

- It can detect and differentiate between articular or periarticular swelling, effusion or hemarthrosis, seroma or hematoma, and exudative or proliferative synovitis.
- It can determine accessibility to percutaneous aspiration or biopsy; compression and pressure-release testing with the probe.

The following can also be discerned:

- Tears of the joint capsule and ligaments: complete, partial, stability testing, measurements
- Heel pain: differentiation of lesions affecting the Achilles tendon, bursa, traction spur, exostosis, Haglund heel
- Tendon lesions: differentiation of complete, partial, tendinopathy, peritendinous changes, displacement, reparability

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Chapter 2

Clinical Evaluation

2 Clinical Evaluation

R. Degwert and M. Walther

A patient with foot pain, whether due to an acute injury or a chronic cause, always presents a certain challenge. This challenge is rooted in the complex anatomy and biomechanics of the foot and in the importance of the foot for the musculoskeletal system as a whole. A detailed knowledge of biomechanics and anatomy is essential for purposeful history-taking and an effective clinical examination.

Foot complaints are often part of a more complex problem. For example, 50% of all lower limb injuries that are missed in multiply injured patients involve the foot. It is common for injuries to occur at a variety of locations in the foot and ankle, and an examination that is not thorough and systematic is likely to miss some pathology.

Pre-existing complaints or degenerative changes can hamper the search for new pathology. All of these factors call for a highly systematic and logically structured approach to clinical examination. We recommend the routine use of an algorithm as outlined below.

2.1 Diagnostic Algorithm

2.1.1 Clinical Examination

1. History
2. Inspection
3. Palpation
4. Motion tests
5. Translation tests and sensory testing
6. Muscle function tests
7. Special tests
8. Stress tests
9. Examination of other structures

2.1.2 Imaging and Other Tests

- Ultrasound
- Radiography (may include stress views)
- MRI
- CT
- Other imaging modalities (scintigraphy, etc.)
- Laboratory tests
- Analysis of stance/gait/running, 3D motion analysis

Diagnostic arthroscopy has become almost entirely obsolete owing to the excellent quality of MR images.

2.1.3 Referral for Further Evaluation

- Neurology, angiology, phlebology, rheumatology, dermatology, etc.
- Possible referral for evaluation by an alternative health care provider
- Examination for craniomandibular dysfunction

! Note

The physician should always personally examine the patient before ordering imaging studies or reviewing the findings, diagnoses, or images from other examiners to avoid compromising his or her own judgment and differential diagnosis. Clinical examination based on a standard algorithm will ensure that nothing is missed on inspection and manual examination. Even when faced with obvious pathology, the examiner should still keep to the algorithm and proceed with a systematic examination of the whole foot.

2.2 History

History-taking should cover general elements as well as specific, current details. The balance of these elements will depend on the timing of the history and the nature of the injury or complaints.

2.2.1 Relevant Questions

Take a personal history and ask specific questions regarding age, occupation, sex, family and social history, occupational and/or athletic activities, and leisure activities. If necessary, include information elicited from a third party. The following questions are particularly important:

- What? Where? When? How? How long?
- What triggers the pain?
- Risk factors, older injuries, scars, systemic underlying or accompanying diseases, medication use?
- In athletic patients, ask about activity level and any recent increase in exercise level. Ask about the intensity of training and its content. The answers may provide clues to stress fractures or other sports-related injuries.
- Trauma mechanism: It is helpful to reconstruct the trauma mechanism as accurately as possible, as this may call attention to specific patterns of injury or complaints.
- High-impact trauma? Other traumatizing forces?
- Mental status: vague or exaggerated description, constant repetition, patient claims “everything hurts,” etc.
- Prior illnesses, injuries, previous and current treatments or operations?

Certain mechanisms are known to produce specific injury patterns in the foot. To a degree, this can aid in determining the extent of foot and ankle injuries and may suggest the presence of injuries to other body structures. For example, jumping or falling from a height and landing on both feet may produce injuries that include vertebral compression fractures of the lumbar spine. Thus, the whole body axis should be examined in addition to both heels.

2.2.2 Pain History

- Pain location
- Pain intensity
- Weight-bearing capabilities or limitations
- Disability in everyday activities, work, or sports
- Braces, shoe inserts, crutches, or other aids
- With chronic diseases and follow-up examinations after acute onset of complaints, ask about the patient's current complaints
- In some cases administration of a pain questionnaire may be deemed appropriate

2.3 Inspection

The goal of inspection is to detect externally visible changes and distinguish them from normal findings. It is helpful to compare the affected foot with the opposite foot as a reference. The patient should be inspected while walking, standing, and with the foot hanging over the edge of the table. Pants (trousers) should be removed for evaluating the axial skeleton and musculature.

- Surface contours, swelling, skin color (e.g., postthrombotic changes)
- Hematoma, open wounds, injuries
- Foreign bodies
- Position, deformities, malalignment, longitudinal and transverse arches
- Asymmetry, atrophy of muscles and skin
- Hematoma, swelling, visible bony landmarks
- Calluses, thickening, scars, nail bed
- Special signs (e.g., the "too many toes" sign)

2.4 Palpation

Palpation should also follow a structured protocol and documentation. This includes:

- Palpation site
- Intensity and quality of palpation
- Area of palpation
- Palpation technique

Selecting the correct palpation site is crucial for establishing contact. The examiner should not start with the area that is apparently (by history and/or inspection) affected by the injury or complaint. It is better to start by palpating structures that are less sensitive or painful. Also, beyond physiological aspects, it is important to consider that different patients will respond differently to physical contact. Thus, a firm pressure may be interpreted as pleasant, confident, or threatening, while a gentle touch may be perceived as respectful or indecisive.

Palpation of the tissues should begin with a light pressure that is carefully increased in both its area and intensity. It should be kept in mind that tactile sensation will dwindle if palpation starts with a heavy pressure and whenever the pressure is increased. Only after completing a "superficial" assessment should the examiner progress to deeper levels while gradually increasing the intensity of the palpation. Individual structures are identified while the site(s) of any pain are explored as accurately as possible.

It should also be noted that the moving hand is better for identifying shapes and structures than a stationary hand. Movement activates significantly more skin receptors in the palpating hand; this prevents or limits their adaptation while supplying more detailed sensory information. A moving-hand technique also allows proprioception to contribute more to the recognition of shapes and surfaces. It improves temperature sensation as well.

The palpable structures of the foot are listed in ▶ Table 2.1.

Another factor that should be considered when palpating the foot is that accessory tarsal bones occur as normal anatomic variants in up to 30% of the population. They have no pathologic significance in themselves, but they may easily be mistaken for fractures, and this should be considered during the interpretation of subsequent imaging studies (see 11.2 Accessory Ossicles in Chapter 11). The four most common accessory bones are:

- Os trigonum
- Os tibiale externum (accessory navicular bone)
- Os peroneum
- Os vesalianum

2.5 Motion Tests

Motion tests, whether active or passive, supply information on the mobility of specific joint compartments. As in inspection and palpation, a systematic routine should be followed because the cumulative mobility of multiple joints can occasionally mask motion deficits in a single joint. Again, the opposite side provides a useful reference standard for comparison.

To avoid the misinterpretation of limited motion, the examiner should understand that it may have both structural and functional causes:

- *Structural:*
  - Fractures, dislocations
  - Contractures due to a chronic process (e.g., rheumatoid arthritis)
  - Contractures due to chronic functional (e.g., neurologic) deficits
  - Congenital deformities
  - Growth abnormalities
  - Postoperative scarring
  - Posttraumatic deformities
- *Functional:*
  - Pain-induced
  - Neurologic
  - Caused by intra-articular effusion or hematoma

As a rule, active range of motion should be tested first, as it is reasonable to assume that the patient will not exceed the range that can be subjectively tolerated. This is then followed by passive range-of-motion testing by the examiner.

The neutral-0 method, which forms the basis of normal-value tables for various joints, has become established only for the ankle joint and first metatarsophalangeal joint when applied to the foot. Movements in the midfoot and hindfoot are described as a fraction of the normal range of motion (e.g., subtalar joint = 1/3).