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Preface

For a long time, foot and ankle imaging was limited to the use of standard x-rays, which remain an indispensable technique today. At the end of the 1980s, computed tomography (CT), magnetic resonance imagery (MRI), and ultrasonography (US) allowed for volume imaging which revolutionized the practice of radiology. Radiologists had to learn a new radiological semiology and face an influx of anatomical and pathological information that had not been visualized previously.

This type of revolution is occurring for the nuclear physicians.

Bone scans carried out by traditional gamma cameras were little used for foot imaging due to their lack of specificity and low anatomical resolution. They were primarily used to diagnose algodystrophy, stress fractures, and acute osteomyelitis in children and to assess foot pain when x-rays were normal. A normal bone scan had a rather good negative predictive value to eliminate an osteoarticular etiology. But in the event of increased tracer uptake, it was often impossible to say if the uptake was on a bone or an articulation, or if ankle uptake revealed a talar or a malleolar problem. Single-photon emission computed tomography (SPECT), allowing the capture of 3D images with detection heads that rotate 360°, was technically feasible but unexploitable due to the small structures of the foot and was thus not used.

At the end of the 2000s, the arrival of hybrid scanners with the ability to acquire SPECT and multislice CT data simultaneously opened a wide range of prospects for the nuclear physicians [1]. Combining SPECT and CT considerably increases bone scan image quality (attenuation correction), anatomic localization, and diagnostic accuracy (improved sensitivity and specificity and a reduction in the number of undetermined tests) [2].

Since 2011, the term “bone SPECT” includes the CT study, and these hybrid scanners allow a three-dimensional analysis particularly helpful for foot evaluation, the foot being a complex structure made up of 26 bones.

At the end of 2012 in France, approximately 150 of the 500 gamma cameras installed were hybrid scanners [3], and their proportion continues to increase, demonstrating the clinical impact of this technological advance.

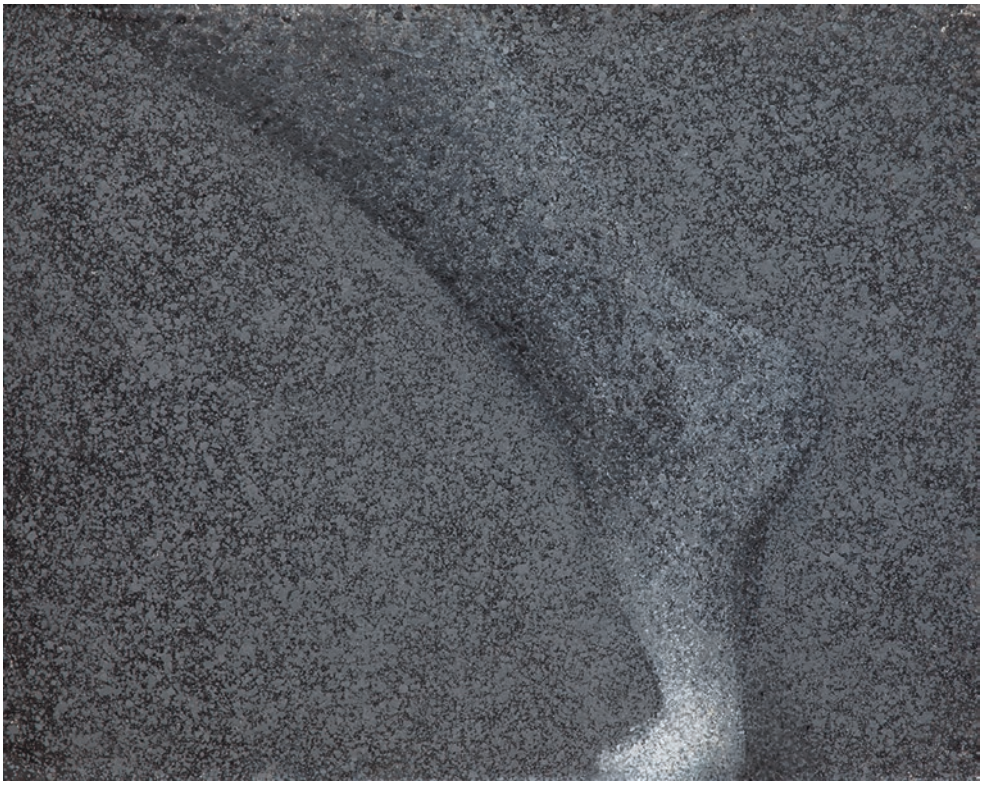
Like their fellow radiologists at the beginning of the 1990s, nuclear physicians are discovering pathologies previously unknown to them and increased tracer uptake that they couldn't previously see. They must in turn learn a new semiology. This is the objective of this book, which was written by nuclear physicians and orthopedic surgeons specialized in the foot and ankle.

This book has two parts:

- The first part is devoted to pathology. The most frequent ankle and foot pathologies that can be seen with a bone scan are described briefly, with a focus on bone scan data. Sidebars highlight information useful to orthopedic surgeons. Bone scan studies of clinical interest are presented. Certain frequent or useful-to-know pathologies that are not diagnosed by bone scan will be also described (such as Morton’s neuroma).
- The second part is devoted to anatomy, covering the bones, joints, and relevant anatomic structures needed to interpret a bone scan of the ankle or foot. They are presented with captioned drawings.

The anatomical nomenclature used is in "Nomina Anatomica," recognized by all the countries.

This book deals with single-photon emission computed tomoscintigraphy (SPECT) with Technetium 99m (^{99m}Tc-HDP), but the data presented can also be used with positron emission tomography (PET) with sodium fluoride-18 (^{18}FNA).



"Taking off" by Jonathan Lane, acrylic resin on paper, 85 × 110 cm, 2015

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Anatomical illustrations are taken from the E-Anatomy Atlas (Copyright ©2008–2015 IMAIOS SAS—all rights of translation, adaptation, and reproduction reserved for all countries.)

The e-Anatomy Atlas is available online on www.imaios.com

Contents

Part I Pathology

Abbreviations

a.	Artery
Ab	Antibody
ACPA	Anti-citrullinated peptide antibody
ACR	American College of Rheumatology
ant.	Anterior
ATB	Antibiotic
ATCD	Antecedent
ATFL	Anterior talofibular ligament
ATT	Action to be taken
BC	Blood culture
BK	Back
BMB	Bone marrow biopsy
BMI	Body mass index
BMP	Bone morphogenetic protein
BS	Bone scan
C°	Centigrade
CBT	Cognitive behavioral therapy
CIC	Change in conditions
cf	Confer
CFL	Calcaneofibular ligament
cm	Centimeter
CNS	Central nervous system
CRP	C-reactive protein
CRPS 1	Complex regional pain syndrome type 1 (previously referred to as algodystrophy)
CT	Computed tomography
$CTDI_{vol}$	Volume computed tomography dose index
D	Day
DHM	Dietetic and hygiene measures
diabetic NOA	diabetic neuropathic osteoarthropathy
DIP	Distal interphalangeal joint
DIS	Disease
dg	Diagnosis
DLP	Dose-length product
DMARDs	Disease-modifying anti-rheumatic drugs
ESR	Erythrocyte sedimentation rate
EULAR	European League Against Rheumatism
F	Front
fat sat	Fat saturation
FDG	^{18}F-Fluorodeoxyglucose
FHL	Flexor hallucis longus
FNA	^{18}F-sodium fluoride

FX	Fracture
g	Gram
Gd	Gadolinium
HU	Hounsfield Units
ICA	Iodinated contrast agents
inf.	Inferior
IPJ	Interphalangeal joint
IV	Intravenous
lat.	Lateral
lig.	Ligament
LN	Lymph node
M1	First metatarsal
MBq	Megabecquerel
MCP	Metacarpophalangeal articulation
med	Medial
M/F	Male/female ratio
MIP	Maximum Intensity Projection
MRI	Magnetic resonance imaging
MTP	Metatarsophalangeal joint
MUS	Muscle
n.	Nerve
NB	Nota bene
NOA	Nervous osteoarthropathy
NR	Not relevant
NSAIDs	Nonsteroidal anti-inflammatory drugs
NTR	Nothing to report
OLT	Osteochondral lesion of the talus
op.	Operational
P1	1st phalanx
PAD	Peripheral arterial disease
PCR	Polymerase chain reaction
PET	Positron emission tomography
PIP	Proximal interphalangeal joint
PN	Polynuclear neutrophil
PNS	Peripheral nervous system
PO	Per os
post.	Posterior
PsA	Psoriatic arthritis
pso	Psoriatic
RA	Rheumatoid arthritis
RF	Risk factor
Se	Sensitivity
SFX	Stress fracture
Sp	Specificity
sup.	Superior
SUV	Standardized Uptake Value
Sv	sievert
TAP	Total ankle prosthesis
THA	Total hip arthroplasty
TNF	Tumor necrosis factor
TNM	T = primary tumor, N = regional lymph nodes, M = distant metastasis
TS	Tendinous sheath
Tx	Treatment

UC	Ulcerous colitis
V	Vein
WB	Whole body
WBC	White blood cells
WBC count	White blood cells count

Abbreviations in Images

AV *(for "avant")*	Front
AR *(for "arrière")*	Back
D *(for "droite")*	Right
G *(for "gauche")*	Left

Part I

Pathology

Lateral Ankle Sprain

Predisposition:
- Sports or daily life accident

Past medical history:
- +/− sprains, ankle instability

Frequency [4, 5]:
- The most frequent injury encountered in traumatology
- 6000/D in France

Mechanism:
- The ankle being forced into too much inversion causes injury to the lateral collateral ligament, predominantly impacting the anterior talofibular ligament (++++, **ATFL**), followed by the calcaneofibular ligament (CFL) and finally the superior fibular retinaculum (Fig. 1).

Types: NR

Interview:
- Inversion twist of the ankle
- Usually three phases of pain: intense pain, sedation, and painful recovery

Clinical examination:
- Lateral malleolus hematoma.
- Walking: possible/impossible.
- Palpation: look for signs of fracture (Ottawa ankle rules).
- **Initial clinical examination can be difficult:**
  - Examination in 5 days is more precise for the diagnosis of lateral ankle sprain, ↗ SE and Sp ≈ 85 and 95%, respectively [6].
  - Initial assessment incorrect in 30% of sprains seen in emergency care [4].

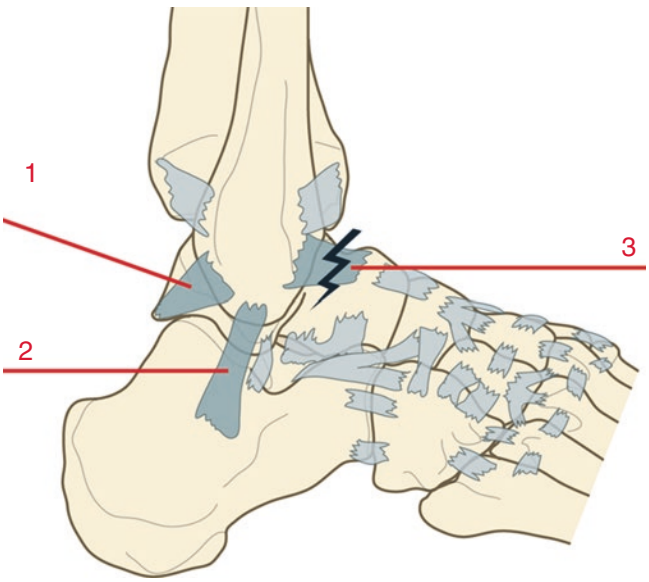

Fig. 1 Lateral ankle sprain. Predominantly impacting the anterior talofibular ligament (black zigzag line). (1) Posterior talofibular ligament (2) Calcaneofibular ligament (3) Anterior talofibular ligament

Paraclinical examination:
- If benign sprain: clinical examination is sufficient.
- If moderate or severe sprain: ultrasound.
- If positive Ottawa ankle rules: X-ray to look for fracture.

Differential:
- There are a number of differential diagnoses and/or related injuries:
  - Malleolus fracture and malleolus avulsion fracture
  - Fracture of the posterior tibial margin (Fig. 2)
  - Fracture of the talus:
    Superolateral fracture of the trochlea of talus
    Fracture of the lateral process
    Fracture of the neck

G. Chuto et al., *Bone SPECT/CT of Ankle and Foot*, https://doi.org/10.1007/978-3-319-90811-3_1

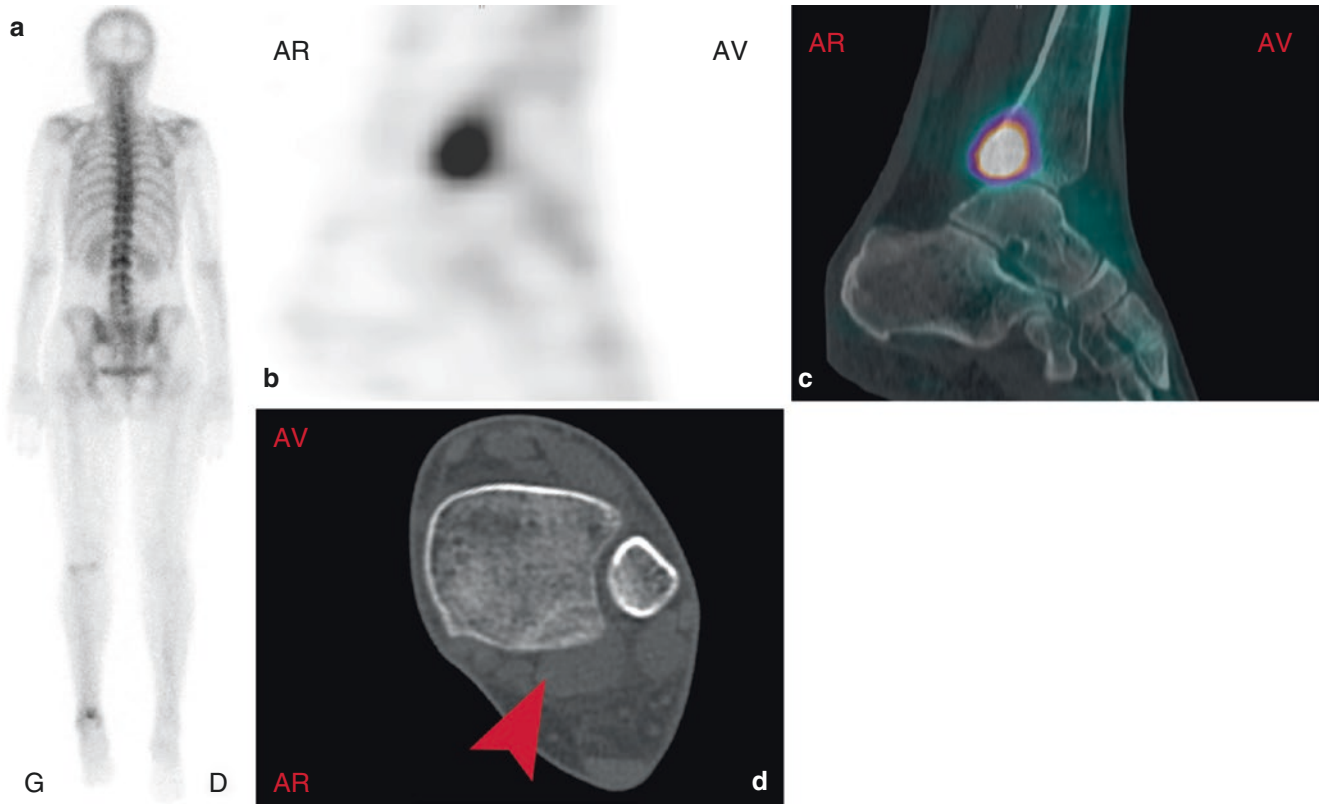

Fig. 2 Fracture of the posterior tibial margin. Back view of WB (**a**), sagittal scintigraphy (**b**), fused slices (**c**), axial CT slice (**d**). Fifty-six-year-old woman, persistent lumbar pain with history of compression of the upper part of L2 5 months earlier: moderate uptake on upper part of L2, isolated and mild (SPECT images not shown). Unexpected uptake in left ankle, still painful following a sprain 2 months prior: non-displaced fracture not seen previously (arrowhead)

- Fifth metatarsal base fracture (fibularis brevis tendon attachment)
- Navicular fracture
- Injury to the ligaments of the transverse tarsal joint
- Injury/dislocation of fibularis tendons
- Injury to anterior tibiofibular ligament +/− interosseous membrane of the leg

Classification: There are different classifications.
- Benign sprain: ecchymotic infiltration of the ligament
- Moderate sprain: partial rupture +/− periosteal stripping
- Severe sprain: complete rupture +/− bone avulsion

Evolution:
- Chronic pain due to:
  - Fibrosis leading to impingement (cf. impingement pages)
  - Lack of ligament healing
  - Diagnostic error/unseen related injury
- Instability: poorly healed severe sprain (Fig. 3)

Treatment [5, 6]**:**
- Initial consultation and **systematic second assessment between D3 and D5**
- Early Tx, **always followed by functional rehabilitation**
- In cases of functional Tx:
  - No immobilization
  - Rapid return to activity
- Benign sprain:
  - **Functional Tx**, RICE protocol
    Rest
    Ice
    +/− Compression: splint (Aircast type) for a few days
    Elevation
- Moderate sprain:
  - Functional Tx: RICE protocol
    Rest + crutches
    Ice
    +/− Compression: splint (Aircast type) for a few weeks
    Elevation
- Severe sprain:
  - Orthopedic Tx: strict immobilization for 6 weeks
  - Or surgery