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# SPECT/CT in Postoperative Foot and Ankle Pain

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Postoperative pain is a clinically relevant issue in orthopedic patients, affecting more than 40% 1 year after foot and ankle surgery. Because of the very complex anatomy with many different joints and several motion axes, clinical examination and conventional imaging are sometimes not sufficient to identify a local pain generator. Local uptake of bone-seeking radiopharmaceuticals is known to correlate accurately with sites of pain generating foci and, thus, bone scintigraphy has been an established method to evaluate these respective patients for many years. However, the specificity is rather low if only planar images are acquired. The development of SPECT and especially of hybrid SPECT and CT imaging has significantly enhanced the specificity of this technique. The combination of both functional and morphological imaging, ideally performed with a dedicated SPECT/CT system to minimize misregistration owing to motion artifacts and to enhance image quality by attenuation correction, allows an early and reliable detection of pathologic bone processes, even in patients where radiological imaging with MRI or CT is hampered by metal implants. In diabetic patients with a neuropathic Charcot osteoarthropathy, infection can be differentiated from inflammatory bone alterations (causing bone marrow edema) almost certainly using SPECT/CT with radiolabeled white blood cells and antigranulocyte antibodies, allowing an individual and precise treatment planning either in the initial course of the disease or even after surgery.

This article reviews the most frequent clinical challenges in patients after foot and ankle surgery, including a description of the various surgical procedures, the different imaging options with their advantages and disadvantages, and aims to integrate bone SPECT/CT into the clinical diagnostic workup.

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## Introduction

Because of the very complex anatomy and function of the foot and ankle with multiple joints and different movement axes, many different surgical procedures exist to treat both acute and chronic clinical issues (Table 1). Apart from acute care of patients after trauma aimed at hemostasis, and prevention of infection or severe tissue damage, orthopedic surgery is mainly indicated to restore joint function and to reduce or eliminate pain, especially in the long term. Studies on postoperative pain in an ambulatory setting showed the highest incidence in orthopedic patients (16.1%), followed by urologic (13.4%), general surgery (11.5%), and plastic surgery (10.0%) patients.<sup>1</sup> Chronic moderate to severe pain one year after orthopedic surgery of the foot was documented in 21% of patients (55 of 260) at rest and in 43% (111 of 260) during walking, with higher pain intensity after surgery of the ankle and the hind foot compared with interventions for hallux valgus or other toe pathologies.<sup>2</sup> Neuropathic pain was comparatively rare with only 3%.

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**Table 1** Important Clinical Issues and Interventions in Foot and Ankle Surgery

Condition	Key Characteristics, Localization
Trauma	Wound closure, axial stabilization, preservation of joint function and movement
Forefoot deformities	Especially TMT and MTP I (hallux valgus, hallux rigidus), hammer, or claw deformation
Degeneration of mid- and hind foot	Arthrodesis of upper and lower ankle joint, Chopart/Lisfranc arthrodesis, skewfoot, flatfoot, etc.
End-stage joint deterioration (trauma, osteoarthritis, long-term arthritis)	Arthroplasty of the ankle joint, MTP I joint
Diabetic foot	Infection (soft tissue vs osteomyelitis), Charcot's osteoarthropathy

MTP I, first metatarsophalangeal joint; TMT I, first tarsometatarsal joint.

Interestingly, the intensity of postoperative pain 3 days after foot and ankle surgery depended on both the preoperative pain and the anticipated postoperative pain in a prospective study of 98 orthopedic surgery patients.<sup>3</sup> The majority of patients did not complain of pain 6 weeks after surgery.

Postoperative pain is a frequent and multifactorial clinical issue, and the complex anatomy and function of the foot and ankle sometimes accounts for difficulties in finding the true pain generator. Pain immediately after surgery is usually caused by an overly tight bandage or cast. Besides general postoperative issues like delayed healing, local edema, sensory changes from nerve trauma, or scarring, more severe complications serve as potential pain generators especially in orthopedic patients. Acute or chronic infection of bone or adjacent soft tissue, misalignment, delayed or absent bone fusion after fracture or arthrodesis, loosening of metal implants after osteosynthesis or prosthetic joint surgery, and fractures of neighboring bones because of an altered biomechanical load may be a cause of recurrent pain. Thus, a fast and reliable diagnosis is mandatory after bone and joint surgery of the foot and ankle to not jeopardize clinical outcomes.

Following a thorough clinical examination, conventional radiographs (including standardized weight-bearing images) are the imaging modality of choice to exclude major structural abnormalities like (postoperative) bone fractures, misalignment, or displacement of metal implants like screws or prosthesis components. MRI has the advantage of a high soft tissue contrast and its ability to detect bone marrow abnormalities like edema or infectious foci.<sup>4</sup> CT is very useful to exclude structural bone pathologies like heterotopic ossification, bone cysts, or loosening of implanted material, and to a lesser extent also soft tissue pathology.<sup>5</sup> However, quality and resolution of both MRI and CT images are often impaired by artifacts from metal implants or even from microscopic metal wear.<sup>6</sup>

Bone scintigraphy using Technetium-99m-labeled bisphosphonates is performed to evaluate bone pathology on

a functional level with the intensity of tracer uptake depending on regional blood flow, osteoblastic activity, and on altered sympathetic nerve supply.<sup>7</sup> With regard to the clinical situation, a correlation between bone pain and the degree of radionuclide uptake was described more than 30 years ago.<sup>8</sup> A high sensitivity was accompanied by the disadvantage of a low specificity in the earlier years of bone scintigraphy because of its low resolution and the nonspecific mechanism of uptake, simply depending on an elevated perfusion and bone metabolism regardless of the underlying pathology. This problem was reduced to some extent by routinely acquired tomographic images (SPECT) and especially by the introduction of hybrid imaging generating fused images of the SPECT and simultaneously acquired CT datasets. This SPECT/CT method combines both the functional and the morphological information on the same area of interest at the same time, leading to additional information and a potential change of clinical management in a high number of patients.<sup>6,9</sup> Because patient repositioning is not necessary when using hybrid SPECT/CT devices, impaired image interpretation caused by misalignment of both datasets is significantly reduced in dedicated hybrid systems compared with software-based fusion of conventional SPECT and CT images. Moreover, a significantly improved intra- and inter-reader agreement was documented for SPECT/CT compared with planar imaging and stand-alone CT in patients presenting with a painful foot.<sup>10</sup>

The same imaging technique using a combined detection of pathophysiology and anatomy may also be performed using radiolabeled tracer for infection imaging, including both Tc-99m-labeled white blood cells (WBCs) and antibodies directed against leukocytes for intravascular labeling. Infections after foot and ankle surgery rank among the most frequent causes of morbidity and mortality, and the incidence is reported to be between 0.5% and 6.5%,<sup>11</sup> dependent on several risk factors like extent and duration of the surgical intervention, amount of blood loss, or patient age. An infection usually originates from the skin or soft tissue in the area of the surgical wound, and treatment by oral antibiotics might suffice in early stages. However, if the chosen antibiotic drug is not effective against the infective agent (resistant bacterial strains) or if the drug cannot reach deeper sites of infection, abscess formation or involvement of the underlying bone may lead to more severe complications. In patients with metallic implants in the foot or ankle, infection treatment may be hampered by a biofilm around the material. Especially patients with infected diabetic foot ulcers are at a high risk of bone infection, which is the most frequent cause for hospitalization and amputation in diabetic patients.<sup>12</sup> Because bone biopsy is the reference standard to diagnose bone involvement, patients may be spared this undesirable procedure, if imaging would reliably exclude osteomyelitis and demonstrate that an inflammatory process is restricted to the surrounding soft tissue.

## Foot and Ankle Surgery

In patients after skeletal trauma, reconstruction of anatomical axes and injured joints is mandatory to maintain functional

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