Single-Photon Emission Computed Tomography-Computed Tomography Imaging: Foot and Ankle Pathology

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INTRODUCTION

There are many imaging modalities available for the foot and ankle specialist to utilize in their practice, and over the last decade there has been increased interest in single-photon emission computed tomography-computed tomography (SPECT-CT) for the diagnosis of pathologies in the foot and ankle. This modality can be very helpful in certain foot and ankle pathologies, which will be presented below. However, there are downfalls to SPECT-CT including high costs (approximately $1,900 in the US) (1), the length of time required to perform the test, and also lack of availability in many areas. Therefore, it is essential that the foot and ankle specialist be familiar with the appropriate indications and contraindications for this modality (Table 1).

BACKGROUND

Nuclear imaging is useful in detecting physiologic changes in osseous injuries. It is based on injecting radioactive isotopes into a patient, and then detecting the radiation emitted by these isotopes with gamma cameras. Planar two-dimensional images are then created of a three-dimensional anatomic structure (2,3). There are common radiopharmaceutical agents that have been utilized to address various orthopedic conditions (Table 2).

Table 1. Indications and contraindications for SPECT-CT in the foot and ankle.

INDICATIONS	CONTRAINDICATIONS
Accessory bone syndromes	Pregnancy
Avascular necrosis	Breastfeeding*
Bone tumors	Lack of cooperation
Coalitions	Patients that exceed weight limit of machine
Degenerative joint disease	
Diabetic foot infections	
Impingement syndromes	
Osteochondral defects	
Postoperative arthrodesis	
Retained hardware	
Stress fractures	

*Women who are breastfeeding or are sole provider for small children will need to make special preparations after testing until tracer no longer present due to small amount of radioactivity emitted after test.

A technetium-99m (Tc-99m)-methylene diphosphonate (MDP) bone scan is useful in detecting focal osteoblastic activity. There are 3 to 4 phases measured. Phase one, blood flow, is performed immediately after the intravenous (IV) administration of Tc-99m-MDP and provides information of relative arterial supply to the examined area (2). Phase two, blood pool, is obtained 5 to 10 minutes following IV administration and gives information on the arterial blood present in the capillary and venous system, which reveals soft tissue inflammation. Phase three, delayed phase, is acquired 3 to 4 hours later and demonstrates osseous uptake only. A fourth phase, late delayed, is sometimes acquired if improved skeletal detail is necessary (for example in a diabetic foot infection). Bone scans are highly sensitive, but not specific. False positives can be acquired in normal bone healing, or from recent surgery, trauma, or diabetic neuroarthropathy. However, a negative scan in a vascularized area effectively rules out osteomyelitis.

Computed tomography (CT) provides significant osseous detail for the evaluation of foot and ankle pathologies. Scanning is performed in the axial plane, and images can be reformatted in sagittal, coronal, oblique planes, or three-dimensional reconstructions. A collimated beam of x-rays are provided by an x-ray tube that rotates 360

Table 2. Commonly used radiopharmaceuticals.

Radiopharmaceutical	Application	½ Life
Technetium-99m	-Bone Scintigraphy -Lung Investigation -Thyroid -Kidney Function Analysis -Tumor Staging	6 hours
Indium-111	-Abscesses and acute infections (osteomyelitis and septic arthritis) -Reflects inflammatory activity only (not bone turnover)	2.8 days
Gallium-67	-Localization of infection process in bone and joints -Monitoring response to therapy of chronic osteomyelitis and infectious arthritis -Differentiating sarcomas from benign lesions	78 hours

Figure 1A. Preoperative clinical photo.

Figure 1B. Preoperative anterioposterior radiograph.

Figure 1C. Preoperative lateral radiograph.

Figure 1D. Delayed phase Tc-99m MDP bone scan images.

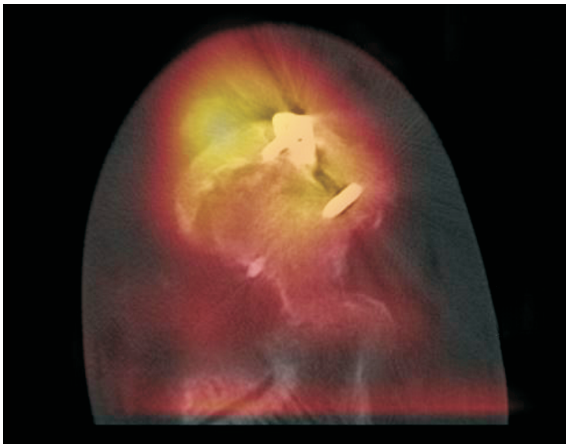

Figure 1E. SPECT-CT imaging showing increased signaling of the distal screw utilized in locking plate for talonavicular joint fusion site.

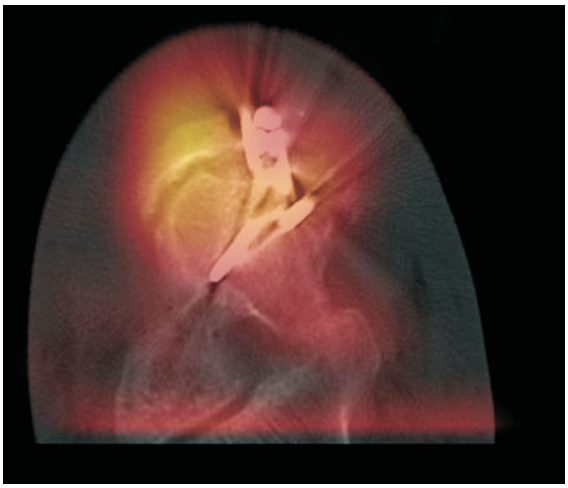

Figure 1F. SPECT-CT imaging showing talonavicular joint fusion site.

degrees around the patient. The x-rays are then captured by detectors in a scanning gantry once they pass through the patient, and a computer then reconstructs a cross-sectional image based on mathematical measurements. The density of imaged tissue is determined by the attenuation or absorption of the x-ray beam (3).

The work performed by Lang et al (4) led to the development of the first commercially available SPECT-CT system (4,5). Initial hybrid SPECT-CT systems utilized a low-end resolution CT unit, which provided limited anatomic detail (6). However, modern multi-slice SPECT-CT units now have the capability to merge the 2 images together that provide a greater level of diagnostic confidence (6). The integration of SPECT with a CT has provided an additional diagnostic tool for the foot and ankle specialist. These scans provide the physiologic information gained by SPECT and combine the anatomic detail provided by a CT. Therefore, SPECT-CT can provide greater specificity in foot and ankle pathologies, which will lead to a more accurate diagnosis and treatment plan.

CURRENT APPLICATIONS

SPECT-CT can be very useful to the foot and ankle specialist in diagnosing challenging pathologies. There have been many applications reported on for the use of SPECT-CT in foot and ankle pathologies. These include accessory bone syndromes, cases with retained hardware, coalitions, degenerative joint disease, diabetic foot infections, evaluation of postoperative arthrodesis, impingement syndromes, osteochondral defects (OCDs), and stress fractures (1,7-10).

SPECT-CT imaging can lead to a different diagnosis and treatment plan. Parthipun et al (11) noted that the site of degenerative joint disease determined by SPECT-CT differed from the initial diagnosed clinical location in 37% of their patients. Another study performed by Singh et al (12) revealed a disagreement between the clinical diagnosis and SPECT-CT imaging in 78% of patients.

The author has found SPECT-CT imaging to be useful in cases of osteomyelitis with retained hardware (Figure 1). Various imaging modalities are used today in diagnosing osteomyelitis. Radiographic changes are nonspecific and nonsensitive, and can be delayed several weeks before changes can be visualized (13). Magnetic resonance imaging (MRI) is more sensitive, provides great anatomic detail, does not use ionizing radiation, and can be performed in a timely manner. However, it will be distorted in cases with retained hardware. MRI can also be less specific in diabetic neuroarthropathy (14-17). Studies have been performed to test the efficacy of MRI in the diagnosis of osteomyelitis. MRI had a sensitivity of 90% and specificity of 71% for the diagnosis of osteomyelitis in diabetic foot infections by using anatomic and histologic studies for reference in one study (16). A prospective study showed a sensitivity of 83% and specificity of 40% when considering osteomyelitis of the mid- or hindfoot with MRI and bone biopsy reference (17).

An imaging protocol has been described by Heiba et al (10) in 2010 for diabetic foot infections. In their study, SPECT-CT imaging showed higher sensitivity and specificity (93% sensitivity 97% specificity) compared with planar (90% sensitivity 66% specificity) or SPECT-alone images (90% sensitivity 76% specificity). They also noted that dual isotope SPECT-CT was advantageous in confirming or excluding foot infections over 3-phase bone scans or Indium-111 leukocyte SPECT-CT scanning alone.

Foot and ankle pathology can be challenging, and SPECT-CT imaging can be beneficial to the foot and ankle specialist in establishing and confirming diagnoses. SPECT is very sensitive in early detection of infectious processes and osseous pathologies, and combining this with CT has enabled a greater specificity. However, there are increased costs and limited availability associated with SPECT-CT. Therefore, understanding the principles and appropriate indications of SPECT-CT can be very useful to the foot and ankle specialist in patients with challenging pathologies.

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