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Simultaneous ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT Clearly Delineates Infection Sites

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Abstract

A 22-year-old man sustained a complex left ankle fracture following a motor vehicle collision and underwent external and internal fixation with transfixation-pinning. Several weeks after surgery, the patient presented with clinical concerning for infection at the fracture sites. Initial radiographic evaluation of the left lower extremity showed no evidence of osteomyelitis. The patient underwent SPECT/CT with a novel imaging protocol, using simultaneous acquisition of ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT, which clearly delineated the infection sites along the orthopedic hardware track and adjacent soft tissues. This new combined SPECT/CT protocol offers advantages of shorter scanning time, easy patient positioning, expedited diagnostic workup, and more accurate localization of infection sites compared to the conventional protocol of separately acquiring ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT images.

Keywords: ^{111}In-oxinelabeled leukocytes; SPECT-CT; ^{99m}Tc-sulfur colloid; Intramedullary hardware; Infection

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Introduction

Orthopedic hardware infection presents diagnostic challenges. The anatomic imaging modalities including plain radiography, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) may be significantly hindered by artifact from metal implants, and MRI may be contraindicated for many reasons. Additionally, structural changes revealed by anatomic imaging may be nonspecific or become apparent only during the later stages of an infectious process, particularly in patients with a complicated trauma or surgical intervention history and in those with metallic hardware in place [1,2,3]. Nuclear Medicine (NM) imaging has the capability to detect functional changes. Therefore, NM studies are preferred by many clinicians to establish an early diagnosis of infection and to guide treatment [3,4]. Traditional NM imaging for the diagnosis of osteomyelitis in the complicated trauma setting employs a sequence of technetium-99m-methylene diphosphonate (^{99m}Tc-MDP), indium-111 oxine-labeled leukocytes (^{111}In-WBC), and ^{99m}Tc-sulfur colloid (^{99m}Tc-SC) scans. This combined imaging technique can overcome the low specificity of ^{99m}Tc-MDP scans due to reactive or remodeling bones and the limitation of ^{111}In-WBC scans due to variations in bone marrow distribution [5]. The newer NM technique of single-photon emission computed tomography-computed tomography (SPECT/CT) fuses NM functional images and anatomical CT images and offers improved anatomical localization as well as confers a lower radiation dose than bone scans. The conventional scanning protocol consists of the acquisition of ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT images separately with the conclusions drawn from the comparison of images from the two complementary studies. Our novel scan protocol uses the simultaneous acquisition of ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT images, which provides additional advantages over conventional SPECT/CT scanning technique.

Case Presentation

A 22-year-old man was involved in a motor vehicle crash, sustaining a left ankle fracture-dislocation involving the medial malleolus, talus, and calcaneus. His injury required internal transfixation of the calcaneus, talus, and tibia as well as external fixation. After 7 weeks, the external hardware was removed, and the patient was scheduled to undergo outpatient ankle reconstruction. Days before the scheduled reconstruction, the patient sustained a minor trauma to the injured ankle.

On day of surgery, he presented with pain, swelling, and erythema to the left ankle. Thus, the reconstructive surgery was cancelled. Plain radiographs of the left ankle were negative for osteomyelitis (Figure 1). Subsequently, simultaneous ^{111}In- WBC and ^{99m}Tc-SC SPECT/CT imaging showed foci of ^{111}In-WBC activity within the superficial soft tissues around the left ankle and mid foot, indicating an infectious process within the soft tissues (Figure 2). Foci of increased ^{111}In-WBC uptake were also noted along the orthopedic hardware transfixing the left tibia, talus, and calcaneus. These foci of ^{111}In-WBC uptake corresponded with areas of absent or less intense ^{99m}Tc-SC uptake, or discordant uptake. These findings are compatible with osteomyelitis along the mid-to-distal portion of the hardware (Figure 3). Treatment choices of staged debridement, culturing and salvage, reconstructive procedures, as well as amputation were discussed with the patient. The patient ultimately chose below-the-knee amputation in order to forgo the lengthy process of treatment. Surgical pathology confirmed the diagnosis of soft tissue infection and osteomyelitis.

Methods

To perform simultaneous ^{111}In-WBC and ^{99m}Tc-SC imaging, ^{111}In-WBC was injected intravenously, and ^{99m}Tc-SC was injected on the following day. Thirty minutes post-^{99m}Tc-SC administration, ^{111}In-WBC and ^{99m}Tc-SC planar as well as SPECT/CT images of the ankles and feet were obtained concurrently with a pair of medial-energy collimators. The SPECT/CT imaging was acquired by setting up multiple photo peaks in the camera including a 10% window centered on 140 keV, a 10% window centered on 171 keV, and a 15% window centered on 245 keV in the Optima NM/CT 640 (GE Healthcare) camera. Three-dimensional SPECT images were reconstructed using a Xeleris Work station with Volumetrix MI Evolution software (GE Healthcare). A low-dose CT scan, at 120 kV and 20 mAs, was obtained immediately following the SPECT scan. The radiation dose of this low-dose CT scan is about 2.7 mSv.

Discussion

The ^{111}In-WBC scan is highly sensitive in detecting osteomyelitis and soft tissue infection as the ^{111}In-WBC radiopharmaceutical accumulates via chemotaxis at the sites of acute infection. However, the specificity of the ^{111}In-WBC scan is compromised by its physiologic distribution in the bone marrow due to reticuloendothelial cells phagocytosis. In most conditions, the distribution of the reticuloendothelial component of the bone marrow closely parallels that of the hematopoietic component. Consequently, the specificity of ^{111}In-WBC is hampered, because WBCs uptake varies between patients and among non-infected stimulated conditions. Alterations of ^{111}In-WBC uptake could represent infection or merely hematopoietically active bone marrow [2,3,6]. A logical method for distinguishing infection from non-infected bone marrow is to combine WBC imaging with bone marrow imaging. In the absence of infection, ^{111}In-WBC and ^{99m}Tc-SC distributions in the bone marrow are similar. However, in osteomyelitis, ^{111}In-WBC accumulation in bone marrow is increased, while ^{99m}Tc-SC is inhibited. Therefore, the presence of tracer activity on ^{111}In-WBC imaging without corresponding activity on ^{99m}Tc-SC imaging, a discordant uptake pattern, is diagnostic for osteomyelitis [6,7]. The highest diagnostic accuracy for bone and joint infections is achieved when combined ^{111}In-WBC and ^{99m}Tc-SC imaging is used, which is superior to making a diagnosis from isolated ^{99m}Tc-MDP scan or ^{111}In-WBC combined with ^{99m}Tc-MDP scans [3,7]. Although the highest diagnostic accuracy of bone and joint infections is achieved with combined ^{111}In-WBC and ^{99m}Tc-SC imaging, soft tissue infections will also present as discordant uptake on this combined scan, as ^{99m}Tc-SC does not accumulate in normal or abnormal soft tissues. This can lead to a false-positive result in the detection of osteomyelitis [5,7].

Figure 1: Frontal, oblique, and lateral radiographs of the left ankle show an intramedullary rod transfixing the tibia, talus, and calcaneus. The healing fractures of the medial malleolus, talus, and calcaneus with surrounding soft tissue swelling were noted. There was no radiographic evidence of osteomyelitis.

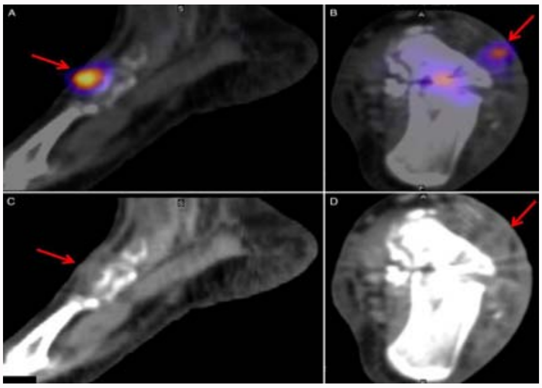

Figure 2: Fusion SPECT/CT images (A,B): of the left foot show a focus of increased ^{111}In-WBC uptake within the soft tissues adjacent to the medial cuneiform and talus, which corresponds with soft tissue swelling on the low-dose CT images (C,D): and indicate infection within the soft tissues (arrows).

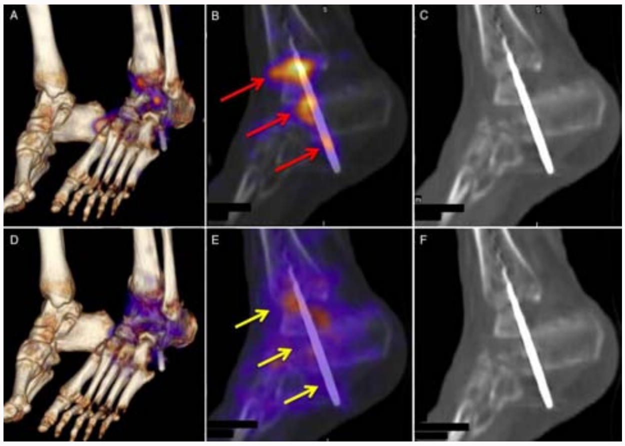

Figure 3: 3D reconstruction (A): fusion SPECT-CT (B): and low-dose CT (C): ^{111}In-WBC images of the feet show that foci of increased ^{111}In-WBC uptake are along the orthopedic hardware transfixing the left tibia, talus, and calcaneus (red arrows). These foci of ^{111}In-WBC uptake correspond with areas of absent or less intense ^{99m}Tc-SC uptake (yellow arrows) on the 3D reconstruction (D): fusion SPECT-CT (E): and low-dose CT (F): ^{99m}Tc-SC images,which constitute discordant uptake. These findings are compatible withan infectious process along the mid-to-distal regions of the hardware.

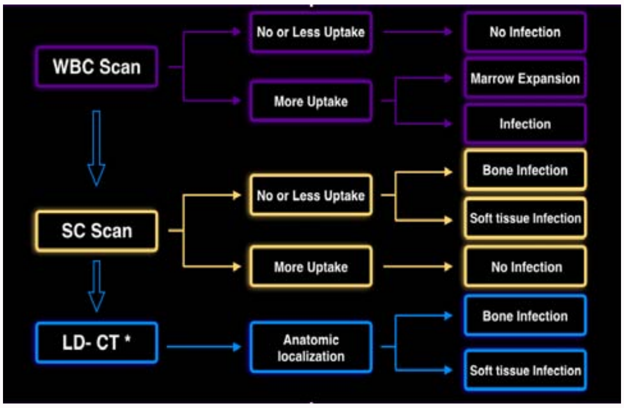

Figure 4: An overall approach to interpretation of combined ^{111}In-WBC and ^{99m}Tc-SC images using a simultaneous dual-tracer SPECT-CT imaging technique. *LD-CT: low-dose CT.

Prior to SPECT/CT, the addition of the bone scan to the combined WBC-bone marrow imaging can overcome this limitation as increased ^{111}In-WBC activity corresponds to increased ^{99m}Tc-MDP activity in osteomyelitis, while increased ^{111}In-WBC activity in soft tissue infection does not correlate with increased ^{99m}Tc-MDP uptake. However, the disadvantages of performing the bone scan in addition to the combined WBC-bone marrow imaging are prolonged scanning time and increased radiation dose. The effective radiation dose of the bone scan is 5.6 mSv as compared to 2.7 mSv from a low-dose CT scan in this case [8]. Furthermore, the bone scan has a lower resolution than that of the low-dose CT. Therefore, the low-dose CT portion of the combined ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT imaging sufficiently achieves the bone scan's purpose while avoiding its disadvantages; low-dose CT improves the anatomical localization of infection as compared to the bone scan. Thus, the combined ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT is a powerful technique (Figure 4). Conventionally, the ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT imaging has been obtained separately. The novel scan protocol used in this case, simultaneous acquisition of ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT imaging, provides precise anatomic characterization through point-to-point comparison between two sets of images. Particularly, this technique allows the generation of WBC/SC subtraction images in order to objectively evaluate the sites of discordant ^{111}In-WBC and ^{99m}Tc-SC uptake, increasing the diagnostic confidence in determining areas of mismatched activity. Additionally, this new protocol can shorten scanning time, save an additional imaging appointment, and avoid challenges of patient repositioning in between the two scans. The treatment of acute osteomyelitis in the presence of orthopedic hardware lends itself to several options. It has been suggested that if there is unstable fixation, the hardware should be removed, and if fixation is stable, the hardware may remain in place and be treated with debridement accompanied by a prolonged course of antibiotics. However, there is debate on whether or not to retain the hardware [9]. Chronic osteomyelitis requires a multidisciplinary, complicated, and prolonged course of treatment, including more intense debridement, irrigation, antimicrobial therapy, and possible bone grafting [9]. Although this patient declined an attempt at limb-sparing treatment and opted for amputation, the information gathered from the SPECT-CT scan led to an expeditious diagnosis of osteomyelitis and would have been valuable in guiding surgical debridement, if the patient had wished to pursue treatment.

Conclusion

This case showed the utility of simultaneous ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT scanning in clearly delineating the sites of infection along the orthopedic hardware track and within soft tissues. The discordant pattern of uptake between the ^{111}In-WBC and ^{99m}Tc-SC SPECT/CT imaging confirmed that increased ^{111}In-WBC uptake within the bones was not due to variations of bone marrow distribution. This novel combined imaging scanning technique offers advantages of shorter scanning time, easier patient positioning, easy patient positioning, expedited diagnostic workup, and more accurate localization of the sites of infection compared to the conventional protocol of separate acquisition of the^{111}In-WBC and ^{99m}Tc-SC SPECT/CT imaging.

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