INTRODUCTION

Several imaging modalities can be used for the detection of inflammation, such as computed tomography (CT), magnetic resonance imaging (MRI), gamma scintigraphy and positron emission tomography/computed tomography (PET/CT) (1). Among the nuclear medicine imaging modalities, three-phase bone scan, radioisotope-labeled white blood cell (WBC) scan, and 18F-fluorodeoxyglucose PET/CT are commonly used to detect the inflammation site (1, 2). The 18F-sodium-fluoride (18F-NaF) bone PET/CT is preferred as it provides additional early image acquisition within the first 10 min after injection and therefore, can be used to detect osteomyelitis (3). These early-phase scan images can substitute for the perfusion and blood pool phases of the three-phase bone scan (3). Moreover, conventional imaging modalities including CT and MRI have a limited role in evaluating patients with metallic implants. In contrast, PET/CT can be used to overcome this artifact using non-attenuation corrected (NAC) images (4).

We report a case of a 76-year-old woman with elevated serum C-reactive protein levels for two weeks after spinal surgery. 99mTc-labeled white blood cell scan and dual 18F-sodium-fluoride (18F-NaF) bone positron emission tomography/computed tomography (PET/CT) were used to detect the site of inflammation. Using non-attenuation corrected images, soft tissue inflammation was detected without metal artifact. Antibiotic treatment attenuated inflammation as seen in an early-phase scan using follow-up 18F-NaF bone PET/CT. This case demonstrates the role of 18F-NaF bone PET/CT in the detection of inflammation sites, and can be used to evaluate treatment response in patients with metallic implants.
including early-phase scan and additional NAC images, we accurately detected the inflammation site and evaluated early treatment response.

CASE REPORT

A 76-year-old woman presented with low back pain for 3 years. She was diagnosed with spinal stenosis at the L3–S1 spinal level. She underwent partial discectomy of the L3–S1 spine and posterior lumbar interbody fusion of the L3–L5 spine. An additional operation to remove postoperative hematoma was performed six days after surgery. After hematoma removal, the blood tests revealed an elevated CRP level of 60.82 mg/L (normal range; 0–3.0 mg/L). Elevation of the CRP level persisted for

![Image of a 76-year-old woman with perioperative inflammation detected on 18F-NaF bone PET/CT.](image)

**Fig. 1.** A 76-year-old woman with perioperative inflammation detected on 18F-NaF bone PET/CT.

A. MIP images of WBC SPECT. Upper row shows anterior view and lower row displays oblique view. Uptake of the soft tissue area in the early phase of 18F-NaF bone PET/CT is also observed in the WBC scan (arrow).

B. MIP of early-phase 18F-NaF bone PET/CT scan shows increased radiotracer uptake around the hematoma removal site (arrows) and the spinal operation site, both on attenuation corrected (left) and non-attenuation corrected (right) images.

C. MIP of standard 18F-NaF bone PET/CT scan shows an increase in radiotracer uptake at the operation site of spine.

D. T2-weighted sagittal image of L-spine magnetic resonance imaging, using the Dixon technique. Image shows post-operative hematoma (arrow) and low signal intensity around the operation site due to metal artifact.

E. The follow-up images of MIP of early-phase 18F-NaF bone PET/CT scan show decreased radiotracer uptake around the hematoma removal site (arrows), both on attenuation-corrected (left) and non-attenuation corrected (right) images.

F. The follow-up image of MIP in standard 18F-NaF bone PET/CT scan shows diffuse radiotracer uptake due to post-operative changes without any significant difference compared with previous images.

18F-NaF = 18F-sodium-fluoride, MIP = maximum intensity projection, PET/CT = positron emission tomography/computed tomography, SPECT = single-photon emission computed tomography, WBC = white blood cell.
more than 2 weeks. Chest X-ray and urine examination were performed to evaluate the inflammatory focus, however, no abnormal findings were found. Wound cultures obtained from the operation site following irrigation reported no bacterial growth. In this case, initial early-phase $^{18}$F-NaF bone PET/CT images showed radiotracer uptake at the operation site. However, it should be confirmed whether the radiotracer uptake detected in attenuation-corrected PET/CT images indicates a true lesion because the patient underwent surgery with metallic implants in place. NAC images showed a pattern similar to the attenuation-corrected images, confirming the finding of a true inflammatory lesion. The diagnosis of soft tissue inflammation around the operation site without bone involvement was established using a two-phase $^{18}$F-NaF bone PET/CT. Follow-up with attenuation-corrected imaging of early-phase $^{18}$F-NaF bone PET/CT showed a decrease in uptake intensity of pre-existing radiotracer uptake, although a mild radiotracer uptake was still found. However, the NAC images showed a markedly decreased radiotracer uptake without a residual uptake in the lesion, suggesting resolution of active inflammation. The standard $^{18}$F-NaF PET/CT images showed diffusely increased radiotracer uptake without any significant difference from previous PET/CT findings.

DISCUSSION

The utility of $^{18}$F-NaF bone PET/CT has been established in several studies that evaluated osteomyelitis as well as bone metastasis (5). The intravenously administered $^{18}$F-NaF is adsorbed into the hydroxyapatite crystalline structure, which is comprised of calcium and phosphate crystals (6). According to Freesmeyer et al. (7), early-phase images of $^{18}$F-NaF PET/CT show blood distribution similar to the blood-pool phase in the three-phase bone scan.

In this case, $^{18}$F-NaF bone PET/CT elucidated the inflammation in the WBC scan and excluded the possibility of osteomyelitis. Moreover, $^{18}$F-NaF bone PET/CT images show higher spatial resolution and facilitate the evaluation of the spine region, compared with WBC scan (3, 8). Until now, MRI has been the preferred modality for evaluation of soft tissue lesions (9). However, in many cases treated with orthopedic surgery, metals are used, which cause artifacts and limit the accuracy of MRI (10). In our case, the Dixon technique was used to overcome artifacts, however, MRI images still showed a limitation in evaluation of the inflammation site. During PET/CT, the CT-based attenuation correction using the Hounsfield unit number leads to overestimation of radiotracer uptake in patients carrying metallic implants (4). Comparison with NAC PET images allows the interpretation of metal-induced artifacts (4).

Following a diagnosis of soft tissue inflammation around the operation site, intravenous rifampin treatment was started. Two months after the antibiotic treatment, the serum CRP level decreased to the normal range (2.23 mg/L) and follow-up $^{18}$F-NaF bone PET/CT was performed. Early-phase scan images demonstrated a decrease in the intensity of uptake of pre-existing radiotracer, however, a mild uptake was still observed (Fig. 1E, left). In contrast, markedly decreased radiotracer uptake without discernible residual uptake was seen on NAC PET/CT images (Fig. 1E, right). The standard $^{18}$F-NaF PET/CT images (Fig. 1F) revealed a diffused radiotracer uptake due to post-operative changes without any significant difference from previous PET/CT findings.
around the operation site without any interval change after antibiotic treatment, suggesting the limited role of standard bone PET/CT in evaluating bony lesions postoperatively.

In the present case, 18F-NaF bone PET/CT images with early phase scan were used to elucidate the inflammation site. The strategy facilitated accurate diagnosis and treatment response evaluation using NAC images without the effect of metal artifacts.

Acknowledgments

This work was supported in part by the Soonchunhyang University Research Fund.

REFERENCES

1. Basu S, Zhuang H, Torigian DA, Rosenbaum J, Chen W, Alavi A. Functional imaging of inflammatory diseases using nuclear medicine techniques. Semin Nucl Med 2009;39:124-145
2. El-Maghraby TA, Moustafa HM, Pauwels EK. Nuclear medicine methods for evaluation of skeletal infection among other diagnostic modalities. Q J Nucl Med Mol Imaging 2006;50:167-192
3. Bastawrous S, Bhargava P, Behnia F, Djang DS, Haseley DR. Newer PET application with an old tracer: role of 18F-NaF skeletal PET/CT in oncologic practice. Radiographics 2014;34:1295-1316
4. Sureshbabu W, Mawlawi O. PET/CT imaging artifacts. J Nucl Med Technol 2005;33:156-161
5. Shim JJ, Lee JW, Jeon MH, Lee SM. Recurrent surgical site infection of the spine diagnosed by dual 18F-NaF-bone PET/CT with early-phase scan. Skeletal Radiol 2016;45:1313-1316
6. Wong KK, Piert M. Dynamic bone imaging with 99mTc-labeled diphosphonates and 18F-NaF: mechanisms and applications. J Nucl Med 2013;54:590-599
7. Freesmeyer M, Stecker FF, Schierz JH, Hofmann GO, Winkens T. First experience with early dynamic 18F-NaF-PET/CT in patients with chronic osteomyelitis. Ann Nucl Med 2014;28:314-321
8. Palestro CJ, Love C, Tronco GG, Tomas MB, Rini JN. Combined labeled leukocyte and technetium 99m sulfur colloid bone marrow imaging for diagnosing musculoskeletal infection. Radiographics 2006;26:859-870
9. Kransdorf MJ, Murphey MD. Radiologic evaluation of soft-tissue masses: a current perspective. AJR Am J Roentgenol 2000;175:575-587
10. Hargreaves BA, Worters PW, Pauly KB, Pauly JM, Koch KM, Gold GE. Metal-induced artifacts in MRI. AJR Am J Roentgenol 2011;197:547-555