

Whole-body MRI for Detecting Bone Marrow Metastases

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• Whole-body • Magnetic resonance imaging • MRI
• Bone marrow • Metastases

Cancer is a major public health problem in the United States and many other parts of the world. This is reflected in the high number of new cancer cases (1,479,350) and the 562,340 deaths from cancer that are projected to occur in the United States in 2009.¹ The bone marrow is a common site for metastasis in cancer.¹ For example, autopsy studies have shown that bone marrow metastases can be found in approximately 70% of patients with prostate or breast cancer and in approximately 35% to 40% of patients with renal, lung, or thyroid cancer.² Accurate detection of (the number of) bone marrow metastases is of crucial importance because of its therapeutic and prognostic implications.² Furthermore, timely recognition and subsequent treatment of bone marrow metastases may prevent or reduce associated complications, such as pain, hypercalcemia, pathologic fractures, compression of the spinal cord or cauda equina, and spinal instability.²

Cancer cells are lodged in the bone marrow as the initial site for skeletal metastasis by means of hematogenous spread. In addition, bone marrow metastases are most frequently localized in the hematopoietic (red) marrow because of its richer blood supply compared with fatty (yellow) marrow. Consequently, the localization of bone marrow metastases is dependent on the distribution of the red marrow. At birth, visually, all marrow is of the red type. Conversion of red to yellow marrow

begins in the postnatal period, first in the extremities, progressing from the peripheral toward the axial skeleton and from diaphysis to the metaphysis of individual long bones. By the age of 25 years, marrow conversion is usually complete, and red marrow is predominantly seen in the axial skeleton and in the proximal part of the appendicular skeleton. Consequently, in adults, the most common sites for bone marrow metastases are the vertebrae (69%), pelvis (41%), proximal femoral metaphyses (25%), and skull (14%).^{3,4} A study in 62 patients (mean age: 64 years; age range: 33–87 years) with metastatic bone disease, however, showed that although 60% of bone lesions were located in the axial skeleton, 40% were located in the appendicular skeleton (**Fig. 1**).⁵ In this series of patients, most lesions in the appendicular skeleton were asymptomatic.⁵ In children, the expected rate of bone marrow metastases in the appendicular skeleton is even higher because they have higher amounts of red marrow in this part of the skeleton. For these reasons, there is a need for a diagnostic test that allows (1) direct visualization of metastatic lesions in the bone marrow and (2) assessment of the bone marrow throughout the entire body.

Commonly used diagnostic tests for the detection of bone (marrow) metastases include bone marrow biopsy (BMB) and imaging modalities, such as conventional radiography, CT, and bone

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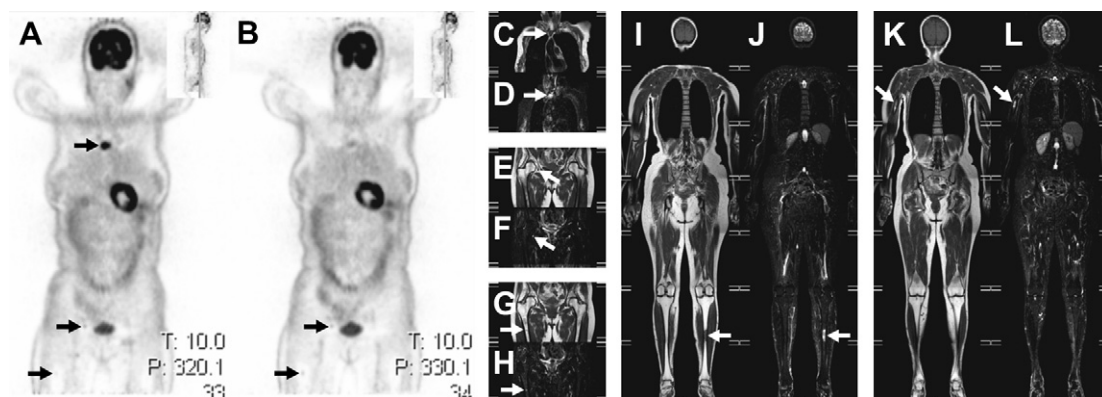


Fig. 1. ^{18}F -FDG-PET and whole-body MRI in a 71-year-old woman with Waldenström macroglobulinemia and bone metastatic disease. Coronal ^{18}F -FDG-PET images (A, B) show foci with increased ^{18}F -FDG uptake in the sternal manubrium, right acetabulum, and right femur (arrows), indicating bone marrow metastases. The same lesions are seen on coronal T1-weighted (C, E, G) and STIR (D, F, H) images of the whole-body MRI examination; the low signal intensity (comparable to muscle) on T1-weighted images and the high signal intensity on STIR images is highly suggestive for bone marrow metastases. Coronal T1-weighted (I, K) and STIR (J, L) whole-body MRI-detected additional bone marrow metastases in the left tibia (I, J) (arrows) and in the right humerus (K, L) (arrows). FDG-PET could not depict these lesions because they were outside its field of view.

scintigraphy. BMB has a high specificity, but it is an invasive and painful procedure with a small but non-negligible risk of (hemorrhagic) complications.⁶ Furthermore, a BMB allows evaluation of only a limited portion of the entire bone marrow. Consequently, BMB is prone to sampling errors and has a limited sensitivity.⁷ Conventional radiography is inexpensive and widely available. Although conventional radiography is of great value in the assessment of cortical and trabecular bone,⁸ it yields projection images only, and a change of 30% to 50% in mineral density is needed before a bone lesion becomes visible.⁹ Consequently, sensitivity for the detection of small lesions may be impaired.^{10,11} CT provides cross-sectional images, allows for whole-body imaging, is suitable to visualize cortical and trabecular bone, and is more sensitive than conventional radiography.^{10,11} A significant limitation of CT, however, is that it is not suitable for bone marrow assessment. Furthermore, the considerable radiation that is associated with CT is a non-negligible issue.¹² Bone scintigraphy is frequently performed to screen for bone metastatic disease in patients with a proved malignancy. Metastases confined to the bone marrow and metastases that do not induce any osteoblastic reaction, however, are missed by bone scintigraphy. Moreover, conventional planar and single-photon emission CT images have limited spatial resolution, which further impairs sensitivity.^{13,14}

Two other cross-sectional imaging modalities that may be of value for the assessment of bone marrow metastases are MRI^{15,16} and PET.^{13,14,17}

MRI allows direct visualization of all bone marrow components at a good spatial resolution.^{15,16} Furthermore, technologic advances, including the development of high-performance magnetic field gradients, parallel imaging, faster MRI sequences, and new coil and table concepts, have made MRI of the entire body clinically feasible. PET can be performed using a wide variety of radiotracers, including ^{18}F -fluoride and ^{18}F -fluoro-2-deoxyglucose (^{18}F -FDG).¹⁸ The use of ^{18}F -FDG-PET may be of particular value, because it directly images tumor cells based on their metabolic activity.^{13,14,17} When using a state-of-the-art combined PET/CT system, whole-body PET imaging can be performed in 20 minutes or less. Furthermore, the CT component of a PET/CT study facilitates anatomic localization of sites with abnormal radiotracer uptake, thereby improving diagnostic performance. An important advantage of whole-body MRI and FDG-PET compared with conventional radiography, CT, and bone scintigraphy is their ability to visualize bone marrow metastases at an early stage, before bone remodelling has occurred.^{13–17} This article reviews whole-body MRI techniques and the diagnostic performance of whole-body MRI compared with PET for the detection of bone marrow metastases.

WHOLE-BODY MRI TECHNIQUES

Anatomic Coverage and Imaging Planes

In routine clinical practice, MRI is usually performed as a second-line imaging modality after conventional radiography or bone scintigraphy.

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