Case 9
Therapy-Induced Marrow Changes

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History

A 20-year-old female with Hodgkin lymphoma, presents following chemotherapy and chest radiation (Fig. 9.1). The patient also has autoimmune hemolytic anemia treated with multiple blood tranfusions.

Diagnosis

Therapy-induced bone marrow changes

Findings

- Hypermetabolic foci involving T11, L4, and S1 vertebrae representing malignant marrow infiltration (white arrowheads). Other milder foci are seen in the cervical spine and T1 vertebra.
- Low diffuse STIR signal in multiple vertebrae including L1 through L3 due to iron deposition from blood transfusions. These vertebrae show mild FDG activity from benign red marrow stimulation.
- Heterogeneous STIR signal at L5 vertebra represents a healed neoplastic lesion which is undergoing fat conversion (thin white arrow). Other treated vertebrae are seen including T9 and T12.
- Extensive hypermetabolic retroperitoneal adenopathy consistent with malignancy (curve white arrow).
- Large volume pelvic ascites with high STIR signal no FDG uptake (black asterisk). The bladder located inferior to the ascites has intense FDG activity due to physiological urinary excretion.

Discussion

Normal bone marrow is composed of red and yellow marrow, with red marrow containing a majority of hematopoietic cells and yellow marrow consisting of a majority of fat cells. During infancy, the majority of marrow is hematopoietic, and a normal red to yellow marrow conversion takes place beginning peripherally in the phalanges and proceeding centrally to the axial skeleton (spine, pelvis, ribs, and skull). By the age of 25, most of the red marrow is limited to the axial skeleton with yellow marrow located in the appendicular skeleton. In the adult, residual appendicular red marrow can be seen in the proximal humeri and neck of femurs. During vertebral red to yellow marrow conversion, focal deposits of yellow marrow can be seen around the basivertebral vein, at the endplates, at the anterior and posterior margins, or scattered throughout the vertebral body. Yellow marrow can reconvert to red marrow as a physiological response to increased hematopoietic needs

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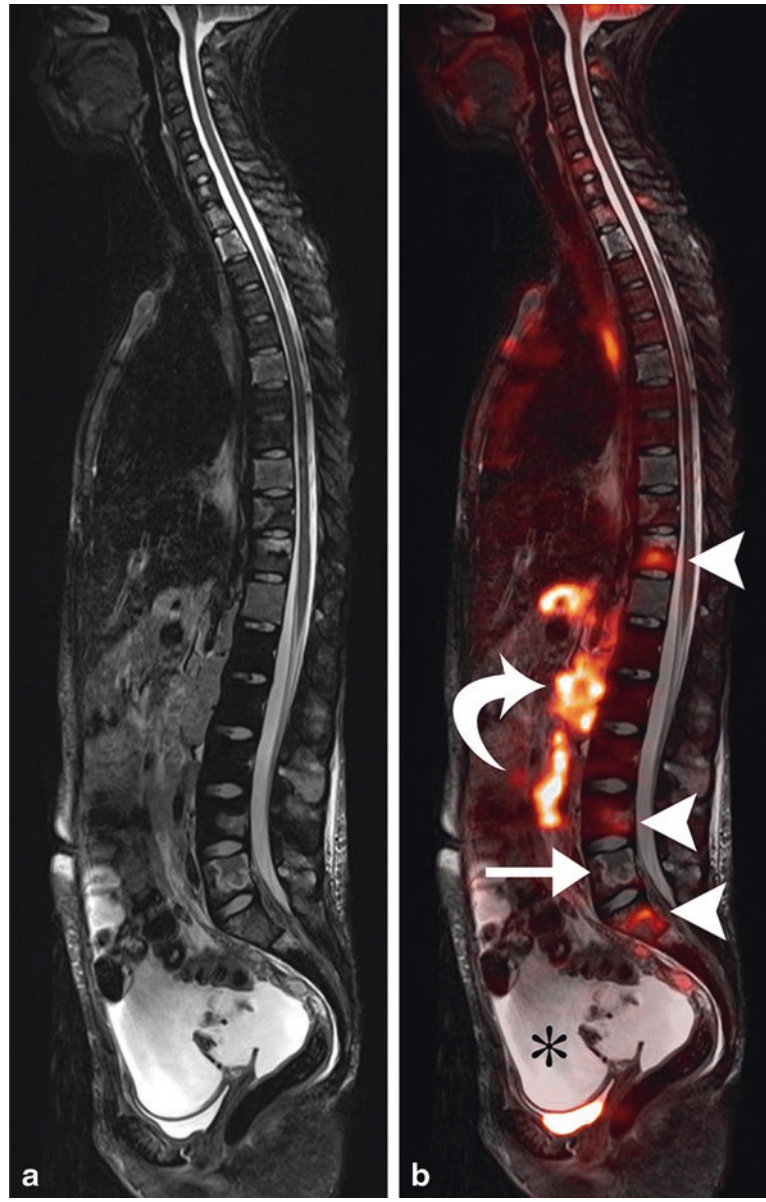

Fig. 9.1 STIR sagittal (**a**), and PET/MR STIR sagittal fusion (**b**)

and oxygen debt in the body, for example, in heavy tobacco smokers, endurance sports, obesity, chronic anemic conditions, and patients treated with hematopoietic growth factors.

The varying distribution of fat and nonfat cellular components in marrow provides for different MR imaging features. T1-weighted sequences are the most sensitive in evaluating bone marrow changes as the signal is easily influenced by fat. Bone marrow signal intensity is determined in relation to skeletal muscle or intervertebral disc signal. In adults, with predominately yellow marrow, the high fat content and low cellularity demonstrate relatively high signal on T1-weighted images and low signal on STIR and fat-suppressed T2-weighted images. Conversely, red marrow exhibits lower relative T1 and higher T2-weighted and STIR signal intensity. As red to yellow conversion occurs,

gradual changes in T1 and T2-weighted signal intensity of vertebral bodies take place to reflect the change in cellular components.

Neoplastic infiltration of bone marrow results in replacement of the fatty marrow with tumor cells resulting in decreased Dixon T1-weighted in-phase and increased T2-weighted marrow signal. The distribution of neoplastic bone marrow involvement may be focal, multifocal, or diffuse. Both radiation treatment and chemotherapy have similar effects on marrow signal. In the acute period, they induce bone marrow edema leading to low T1 and high T2-weighted and STIR signal. However, the bone marrow eventually undergoes fatty replacement characterized by high T1-weighted signal close to subcutaneous fat signal and low fat-suppressed T2-weighted and STIR signals. During the post-treatment course, the bone marrow can undergo focal areas of hemorrhage. Depending on the radiation dose, the fatty conversion is often irreversible. With chemotherapy, the bone marrow can normalize with regeneration of normal hematopoietic cells in a multifocal pattern. Red blood cell transfusion therapy, administration of granulocyte colony-stimulating factor, and stem cell transplant treatment can all be accompanied by iron overload which can deposit into bone marrow and lead to diffusely decreased signal on T1, T2, and STIR sequences.

PET/MRI allows for the evaluation of benign or malignant processes within the bone marrow. It provides for precise anatomic localization, high contrast and spatial resolution, and accurate quantification of metabolic activity. Active red marrow conversion is a benign process that can have increased FDG uptake which varies based on age and level of marrow function. Likewise, malignant marrow infiltration will also usually have increased FDG uptake. Cytokine therapy can also induce increased bone marrow FDG activity. Although PET/MR imaging is a powerful tool that can help elucidate bone marrow changes, correlation with clinical history and treatment timing is essential.

Suggested Reading

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