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REVIEW

Bone marrow imaging: follow-up after treatment in cancer patients

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Abstract

The evaluation of bone marrow of patients treated for cancer is complicated by age-related changes in the distribution of normal (red) and fatty (yellow) marrow and by the changes induced by treatments. The treatments used in oncology modify pathological marrow but also normal marrow and may sometimes lead to complications. The knowledge of bone marrow physiological status and post-therapeutic patterns is important for the interpretation of marrow disorders and effects of therapy.

Keywords: *bone marrow; diagnostic imaging; cancer therapy.*

Effect of radiation on normal bone marrow

Radiation-induced changes on normal bone marrow

Early and late bone marrow changes after irradiation

After radiation therapy, the signal intensity of normal bone marrow depends on the dose delivered and the interval between the treatment and the MR study. During the first two weeks of fractionated irradiation (after a dose of 30 Gy) there is no definite change in the appearance of the marrow on T1W and T2W images. On the STIR images there is an increase in signal intensity apparently reflecting early bone marrow oedema. After three weeks, fatty replacement begins, the marrow shows an increasingly heterogeneous signal and the vertebral body shows a prominence of the signal from central marrow fat on T1W images. Six weeks after therapy, there are two distinct types of late marrow pattern: homogeneous fatty replacement or a band-like pattern (sandwich vertebral body). Marrow regeneration is more likely to occur in children than in adults and when a large volume of marrow is irradiated than when radiation therapy is localised[1]. Bone marrow which received 50 Gy is definitively damaged and exhibits a fatty signal on MR images. This pattern is due to decreased cellularity associated with loss of bone trabeculae[2].

Changes after extensive radiation therapy

In patients who received extensive radiation therapy, the reconversion phenomenon occurs in the non-irradiated skeleton. Consequently, a diffuse hyposignal of normal red marrow (T1W) should not be interpreted as diffuse infiltration; signal intensity of this reconversion is always greater than that of muscles.

Radiation-induced complications

Radiation therapy may cause changes in the skeletal system depending on the age of the patient, absorbed dose, size of the radiation field, beam energy, and fractionation[3,4].

Bone growth disturbances are observed after irradiation of the immature skeleton and are greater in younger patients and with high doses.

Osteoradionecrosis (OR) is usually diagnosed within two to three years after treatment and appears to be dose-related. MR imaging shows that uncomplicated OR is not accompanied by a soft tissue mass. The differential diagnosis includes osteomyelitis, recurrent primary disease, and radiation-induced second malignancies. The majority of cases of OR occur in the mandibule, clavicle, humeral head, ribs and femur.

Pathologic fracture and collapsed vertebral body are frequently associated with OR. Recent collapsed vertebral bodies show a low signal intensity on T1W images (oedema) and therefore cannot be differentiated from malignant infiltration. Other MR sequences are useful to characterise a benign fracture.

Stress fractures on the sacral bone may occur after radiation therapy for pelvic cancers.

Avascular necrosis of the femoral head is most often associated with corticosteroid administration, but has also been described following radiation therapy.

Radiation-induced neoplasms

Benign tumours

Osteochondroma (OC) is the most common benign radiation-induced tumour. It occurs in children treated by radiation therapy under the age of two years. Any bone within the treatment field may be affected and most lesions appear within five years of therapy. Radiation-induced OC are histologically and radiologically identical to OC that arise spontaneously.

Radiation-induced sarcomas

Osteosarcoma is the most common type of secondary malignant neoplasm (SMN). The radiation dose is usually greater than 30 Gy. Children are more susceptible to tumour induction. Radio-induced sarcomas may arise in both pre-existing bone lesions and in normal bones included in the radiation field. The diagnosis criteria include a long latency period and histologically proven sarcoma, distinct from the original lesion and arising within the radiation field.

Effect of chemotherapy on normal bone marrow

Chemotherapy changes on normal bone marrow

Chemotherapy causes a myeloid depletion. The decrease of marrow cellularity leads to an increase of fatty content: an increased signal intensity is observed on T1W images and a hypo-intense signal intensity on fat-suppression sequences.

Complications of chemotherapy

Chemotherapy may be responsible for skeletal effects, particularly methotrexate osteopathy, and ifosfamide-induced rickets.

After intensive chemotherapy, granulocytopenic patients can develop multifocal osteomyelitis. Bone infarction appearing after systemic or intra-arterial chemotherapy may mimick tumour progression[5].

Bone marrow transplantation

Knowledge of the normal MR pattern of marrow regeneration after transplantation may be useful in screening for residual marrow disease, determining marrow engraftment, and differentiating marrow repopulation with normal versus malignant cells.

Effect of hematopoietic growth factor

Granulocyte-colony stimulating factor (GCSF) is used to stimulate myeloid cell production in patients undergoing aggressive chemotherapy. It gives rise to a recolonisation of the fatty marrow by red marrow.

The MRI changes may be diffuse or patchy; although usually symmetrical, they may be asymmetric[6]. Awareness of these findings is important to avoid false-positive diagnosis of marrow metastases or tumour progression[7].

Effect of corticosteroïd

Avascular osteonecrosis is seen in patients who have undergone bone marrow transplantation or prolongated corticosteroid therapy, and also after radiation therapy. The most frequently affected regions are the hips, shoulders, and knees. MR imaging is sensitive for detection of early ischemic necrosis.

Effects of treatments on pathologic bone marrow

Effect of chemotherapy or radiotherapy on bony metastases

In a large series, Brown *et al.*[8] reported that T1W MR response assessment, based on changes in size and number of vertebral metastases, accurately predicts progression of disease in 79% of cases and stable disease in 75% of cases. It did not predict regression of disease. In a series of 62 affected vertebral bodies, Sugimura *et al.*[9] observed a considerable diminution of lesion

enhancement in responding lesions after irradiation or chemotherapy.

Effect of therapy on disseminated bone marrow involvement: lymphomas, leukaemias, myeloma

When treatment is efficient in lymphomas and leukaemias, the signal intensity of the involved marrow increases and the pathological enhancement after injection of contrast medium decreases on T1W images.

In multiple myeloma, response patterns associate normal aspects of bone marrow or persistent marrow abnormality, without enhancement or with peripheral rim. MR images may be helpful in monitoring the response to treatment [10].

Conclusion

MRI is a valuable tool for the evaluation of response under treatment and the diagnosis of bone marrow complications. The radiologists must recognize therapy-related changes in bone marrow and differentiate them from recurrent disease.

Key points

Imaging characteristic patterns of treatment-induced changes in the skeletal system allows the distinction of complications from recurrent or metastatic disease. MR imaging can differentiate residual disease and guide the biopsy, and may influence the treatment.

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