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CONTINUING EDUCATION

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SPINAL MR IMAGING IN ONCOLOGY

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The objectives of the present review are to understand the value and limits of spinal marrow MR imaging in oncology, to present MR imaging protocols and elementary lesion patterns at MR imaging, and to emphasize indications for marrow MR imaging in clinical practice.

Key-word: Spine neoplasms, MR.

Neoplastic marrow diseases

Metastases

Bone metastases, the most frequent neoplastic lesion of the adult skeleton most frequently derive from breast, prostate and lung cancer, but virtually all organ neoplasms may metastasize to the bone marrow. Metastases usually involve the red-marrow containing areas of the body, and complex cellular behaviors (neoangiogenesis, cell wall characteristics) account for their propensity to locate and grow in the skeleton. Unusual distribution patterns include involvement of cortical bone (lung cancer?), of limb extremities (lung cancer?), of lower limbs (uro-gynecologic cancer?) and multiple lesions in a single limb (angiosarcoma?).

Marrow-borne cancers

Multiple myeloma (Kahler's disease) is characterized by uncontrolled proliferation and accumulation of monoclonal plasma cells in the bone marrow and presence in serum and/or in urine of a monoclonal immunoglobulin ("paraprotein" or "M component") or immunoglobulin fragment (light chain or Bence-Jones protein). Conventional radiographs maintain a key role for staging along with blood levels of calcium, hemoglobin, and immunoglobulin (Durie and Salmon classification system). Indirect assessment of tumor mass and disease aggressivity guide therapeutic decisions. Patients with at least two lytic foci are classified in advanced disease subgroups and aggressive systemic treatment is indicated. Bone scintigraphy remains frequently normal in patients with purely lytic lesions and PET imaging does not appear to contribute to patient staging.

Lymphomas include different diseases, the classification of which is rapidly evolving due to progress in molecular biology. Hodgkin and non-Hodgkin diseases differ with respect to age peaks of incidence and patterns of bone involvement. In Hodgkin disease, bone involvement is rare at diagnosis but may occur at relapse. Staging mainly relies on determination of topography of enlarged lymph nodes by CT

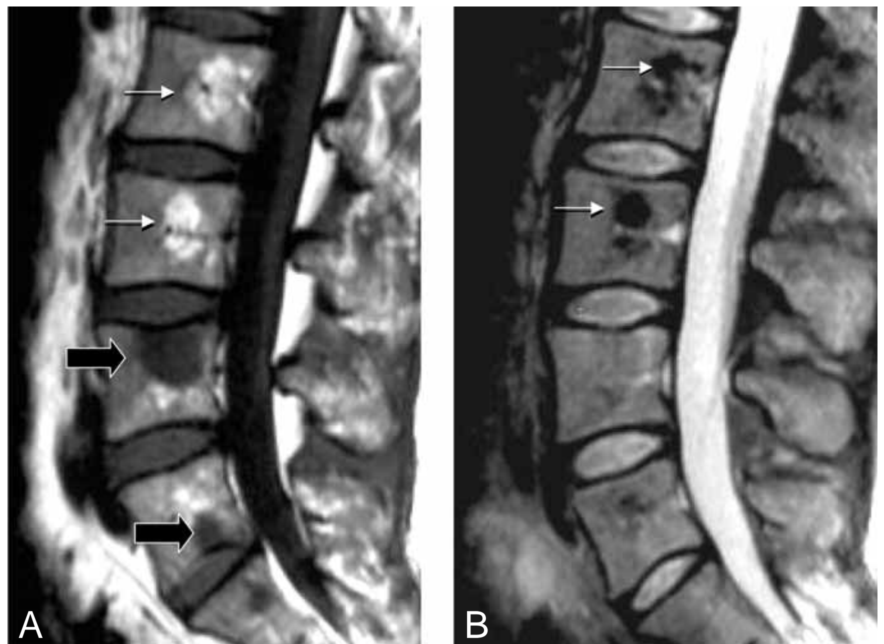

Fig. 1. — Lesion detection. Sagittal T1-weighted spin-echo MR image of the lumbar spine of a 53-year-old woman with breast cancer shows areas of low signal intensity (marrow replacement- large arrows) compatible with metastases and high signal intensity areas (marrow depletion – white arrows). (b) On the corresponding fat-saturated T2-weighted spin-echo image, the areas of focal marrow replacement are not visible (better detection of lesion on T1- than on T2-weighted images). The low signal intensity areas on the fat-saturated images (white arrows) with high signal intensity on T1-weighted images correspond to areas of fatty marrow and lack clinical significance.

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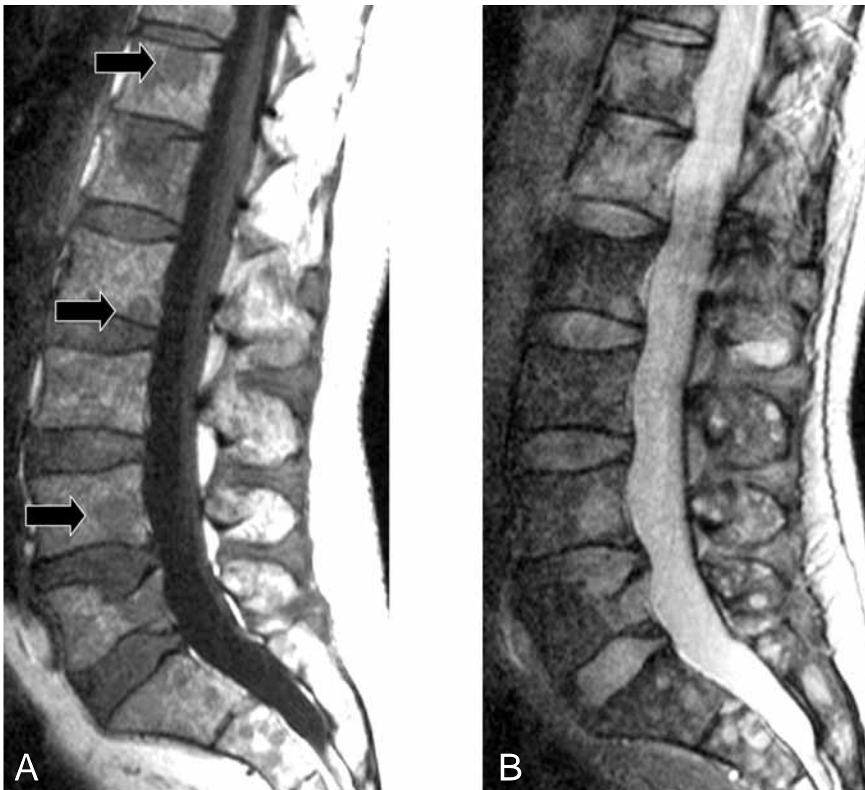

Fig. 2. — Lesion patterns. (a) Sagittal T1-weighted spin-echo and (b) T2-weighted gradient echo images of the lumbar spine of a patient with lumbar pain show focal marrow changes consisting of areas of low and high signal intensity on T1- and T2-weighted images respectively (arrows). Diffuse marrow changes are also visible on the T1-weighted image as disseminated spots of low signal intensity. MR findings lack specificity but the triad of focal lesion, diffuse infiltration and vertebral fracture suggests multiple myeloma (confirmed at iliac crest biopsy).

or PET. In non-Hodgkin disease, bone involvement is frequent in a diffuse or focal manner (hence the performance of blind bone biopsy at staging). The staging of patients with Hodgkin and non-Hodgkin lymphomas more and more depends on PET evaluation without or with CT for better delineation of the involved organ. The place of MR imaging is not clear except in the setting of spontaneous vertebral fracture for delineation of spinal cord compression and assessment of adjacent vertebral bodies.

Leukemias are a group of several neoplasms derived from multipotent marrow cells. Medical imaging plays little or no role in the diagnosis, staging or follow-up during treatment. These diseases usually infiltrate the red-marrow containing areas in a diffuse manner.

MR imaging findings

The pattern of marrow involvement may be either diffuse or focal, but it is non-specific. In case of diffuse marrow infiltration, a blind iliac crest biopsy may be sufficient for diagnosis, if needed. In case of focal lesion, a guided biopsy may be mandatory, except in patients with possible myelomatous infiltration.

Focal pattern

The focal pattern consists of a localized area of decreased signal intensity on T1-weighted images (signal lower than intervertebral discs) and of variable signal intensity on T2-weighted images and gadolinium-enhanced T1-weighted images (Fig. 1). Lesion margins are generally sharp, with a background of an otherwise normal appearing bone marrow. Peripheral edema may be present mainly in lymphoma and metastases, but rarely in non-fractured myeloma lesions. Exceptionally, focal myeloma lesions have relatively high signal intensity on T1-weighted images and are best visible on T2- or T2*-weighted images.

Diffuse pattern

The diffuse pattern of marrow involvement is characterized on T1-weighted images by a diffuse decrease in marrow signal intensity (signal lower than that of adjacent intervertebral discs). Signal is variable on T2-weighted images, and marked enhancement is usually seen on post contrast T1-weighted images. The diffuse pattern may be homogeneous or heterogeneous. The variegated or "pepper and salt" pattern is characterized by the presence of multiple tiny foci of low signal intensity on T1-weighted images, intermediate to high signal intensity on T2-weighted images. This pattern is seen almost exclusively in myeloma (Fig. 2) and lymphoma but rarely in metastases.

Normal pattern

MR appearance of marrow may remain normal at diagnosis in 50 to 75 per cent of patients with early untreated (Salmon-Durie stage I) myeloma, in about 20 per cent of patients with advanced and treated (Salmon-Durie stage III) disease and in some chronic lymphomas (paratrabecular CLL). Preservation of this normal appearance despite biopsy proven cell infiltration of marrow spaces most likely results from an insufficient alteration of the balance between fat and non fat cells, with a ratio of hematopoietic (and neoplastic cells) to fat cells in the bone marrow that does not exceed the ratio observed in healthy individuals.

Imaging protocols

The T1-weighted spin echo sequence is the best method to detect focal lesions. T2*- or fat-saturated proton-density weighted sequences may occasionally help for lesion detection, mainly in patients with cellular marrow (children…). Contrast enhanced T1-weighted sequence may be mandatory for detection of diffuse marrow infiltration but it barely contributes for focal lesion detection.

Spine MR imaging.

The shortest MR imaging protocol includes sagittal T1-weighted SE images of the spine and enables screening of a high proportion of hematopoietic marrow in a limited time with detection of potential threat for the spinal cord.

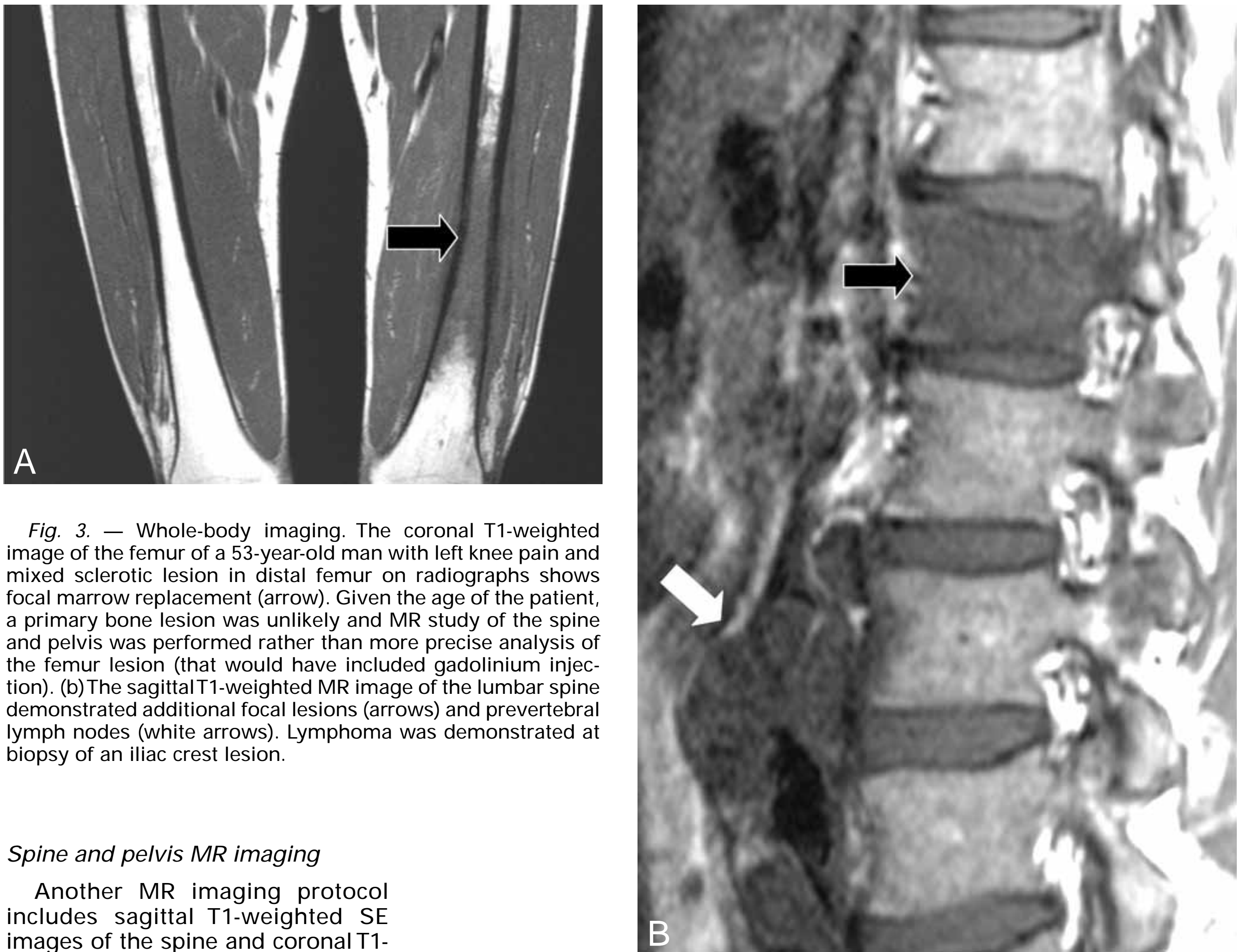

Fig. 3. — Whole-body imaging. The coronal T1-weighted image of the femur of a 53-year-old man with left knee pain and mixed sclerotic lesion in distal femur on radiographs shows focal marrow replacement (arrow). Given the age of the patient, a primary bone lesion was unlikely and MR study of the spine and pelvis was performed rather than more precise analysis of the femur lesion (that would have included gadolinium injection). (b) The sagittal T1-weighted MR image of the lumbar spine demonstrated additional focal lesions (arrows) and prevertebral lymph nodes (white arrows). Lymphoma was demonstrated at biopsy of an iliac crest lesion.

Spine and pelvis MR imaging

Another MR imaging protocol includes sagittal T1-weighted SE images of the spine and coronal T1-weighted SE images of the pelvis and proximal femurs (Fig. 3). Imaging of the pelvic area enables evaluation of about one more third of the red marrow amount in an adult. In patients with a normal or equivocal spinal bone marrow MR appearance, these images may demonstrate unquestionable focal lesions or increase the confidence with which diffuse abnormalities are identified, showing abnormal expansion of red marrow within the femoral shaft and epiphyses, which is normally very limited in adults. Moreover, these images may enable detection of lesions – potentially at risk for fracture – in the femoral heads, necks and proximal shafts.

Whole-body MR imaging

Whole-body MR imaging that becomes available provides coronal fat-saturated T2-weighted images of the entire skeleton (direct acquisition or reconstruction derived from axial T2-weighted images with a rolling table). The place of Whole-body MR imaging is not clear yet. As a significant limitation, the exclusive use of fat-saturated T2-weighted fast SE images may decrease the sensitivity for detection of diffuse marrow infiltration because of the lack of internal standards to assess marrow signal intensity. In addition, a complementary assessment may be needed if the spinal cord must be assessed (compression ? meningeal spread ?) or if a lesion must be characterized (benign or pathological vertebral fracture ?). Finally, vertebral hemangiomas may be confused with vertebral metastases on fat-saturated MR images.

Definite indications for MR imaging

MR imaging is the diagnostic procedure of choice for the diagnostic work-up of patients with neurological symptoms. It enables prompt and accurate diagnosis of focal complicated spinal lesions, delineation of soft-tissue or epidural extension, assessment of the level and extent of spinal cord or nerve root compression. In case of radicular pain without obvious nerve root compression, intravenous injection of gadolinium is mandatory for the detection of neoplastic meningeal spread on post-contrast T1-weighted MR images.

MR imaging is superior to bone scintigraphy and conventional radiography for the detection of bone involvement in patients with cancer, lymphoma and multiple myeloma. The role of MR imaging in the staging of lymphoma (at presentation or at relapse) is debated because PET imaging enables assessment of all involved organs (except the brain). In cancer patient, the systematic performance of MR images in unselected patients with cancer has not gained general acceptance.

MR imaging has major clinical implication in the setting of a solitary bone plasmocytoma that is characterized by the presence of an isolated lytic bone lesion and absence of detectable systemic

involvement, with fewer than five per cent plasma cells in iliac crest biopsies, very low monoclonal immunoglobulin levels in the serum, and an otherwise normal appearing radiographic bone survey. Most of the patients will ultimately develop multiple myeloma. MR screening of the spine and pelvis will reveal radiographically unsuspected lesions in up to 80% of patients, thus suggesting disseminated disease - true myeloma - from the beginning. This finding may lead to earlier systemic therapy along with localized radiation therapy.

Reliable MR imaging criteria are available for the differentiation between benign and pathological vertebral fractures, which can be difficult and sometimes impossible with plain radiographs and even CT. Application of these criteria to vertebral fractures enables recognition of pathological fractures in metastases and in lymphoma. The exact role of diffusion MR imaging remains debated. In Multiple myeloma however, about two thirds of spontaneous vertebral fractures are benign-appearing at MR imaging despite plasma cell marrow infiltration. Since the bone marrow may keep a normal appearance at MR imaging in myeloma, benign appearing fractures may thus be the only imaging finding at diagnosis of the disease.

Residual indications for spiral CT or radiographs

Other indications include lesion characterization (Paget disease, bone island, benign or pathological fracture, early infection, vertebral osteonecrosis, ankylosed spine..), assessment of fracture risk and possible sensitivity to radiation therapy, and pretherapeutic assessment of biomechanical stability of fracture, sensitivity to radiation therapy, cementoplasty.

Take-home points

MR imaging has little diagnostic power. Its impact on patient management derives from its high sensitivity for the detection of marrow involvement. However, a normal MR appearance of the marrow cannot exclude the presence of diffuse marrow infiltration.

The spine and pelvis are the most important body areas to screen for lesion detection and for the assessment of fracture risk.

The T1-weighted spin-echo sequence best provides a valuable overview of the marrow content.

Contrast-enhanced MR imaging plays a role in the work-up of spontaneous vertebral fracture, in the detection of meningeal spread, and in case of suspected infection. It plays a secondary role in the detection of diffuse marrow infiltration and of focal lesions in hypercellular marrow (children, ...).

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