MR imaging of spinal bone marrow - how to interpret abnormalities

Poster No.: C-1202
Congress: ECR 2015
Type: Educational Exhibit
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Keywords: Metastases, Infection, Education and training, Normal variants, Localisation, Education, MR, Musculoskeletal spine, Bones
DOI: 10.1594/ecr2015/C-1202

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Learning objectives

To learn how to systematically analyze bone marrow abnormalities in the vertebral bodies of the spinal column seen on MRI, depending on associated findings such as fractures or intervertebral disc involvement.
Background

The bone marrow is one of the largest organs of the human body accounting for about 5% of body weight. Numerous systemic diseases manifest with bone marrow abnormalities (1). MRI is the most sensitive imaging modality to display focal or diffuse alterations. Bone marrow consists (in general) of fat, water and blood products. Since its components change with age, knowledge of normal bone marrow appearance on MRI is essential in order to detect alterations. Once observing an abnormality in bone marrow intensity, its interpretation can be difficult because benign entities can mimic malignancy and vice versa. Associated fractures and intervertebral disc changes in the spinal column can indicate the correct diagnosis. In this poster, we present how to systematically analyze and categorize bone marrow intensity in the vertebral bodies of the spine in order to differentiate benign from malignant entities.
Findings and procedure details

The most sensitive sequence for the interpretation of spinal bone marrow changes will be the T1-weighted images (2)(3). Due to its fatty components normal adult bone marrow has a slightly hyperintense appearance on T1-weighted images compared to the intervertebral disc. Many disorders manifest as an abnormal low intensity in the vertebral body, although some alterations may also show abnormal high intensity. In order to find the right differential diagnosis it is helpful to look for two associated findings:
1. Intervertebral disc involvement
2. Vertebral body fracture

According to these two findings three types of abnormalities can be differentiated:
1) Bone marrow abnormality without disc abnormality and without associated fracture of the vertebral body
2) Bone marrow abnormality with intervertebral disc involvement
3) Fracture of the vertebral body

Within the third category we can differentiate benign from malignant fractures by the presence of bone marrow intensity abnormalities (complete, partial or no replacement) (4).

Starting with the first category (bone marrow abnormality without involvement of the intervertebral disc and without associated fracture) we have to differentiate between abnormal low and abnormal high intensity as well as between focal and diffuse lesions.

A combination of focal lesions with low intensity on T1- and high intensity on T2- weighted images without disc abnormality or compression is suggestive of metastasis (4) (Fig. 2). An alternative possibility is lymphoproliferative disease such as lymphoma, multiple myeloma or plasmocytoma (in case of a solitary lesion respectively)(5) (Fig. 3 and 4).

Primary malignant bone tumors other than multiple myeloma or plasmocytoma are far less common in the spinal column. Spinal osteosarkoma accounts for 3,6-14,5% of primary spinal tumors and tends to show expansive growth and soft tissue involvement (6).

Focal lesions with low intensity on both T1- and T2- weighted images without disc abnormality or compression suggest sclerotic metastasis. Most often, these are caused by prostate or breast cancer (4).

A benign differential diagnosis for focal hypointense lesions on both T1- and T2-weighted images is enostosis. Enostosis (also known as "bone island") is a focal hypointense lesion. Frequently, it is oval-shaped, with trabeculated margins unlike sclerotic metastasis, which are usually round and show smooth margins (6) (Fig. 5).

Diffuse hypointensities on T1 weighted images in combination with generalized increase in intensity on T2-weighted images can be a sign of multiple myeloma and lymphoma or even diffuse metastatic disease, but can also represent hematopoietic bone marrow hyperplasia seen in benign entities such as anemia, Gaucher´s disease or myelofibrosis (4) (Fig. 6 and 7).
Hyperintense changes in the vertebral bodies on T1 weighted images without disc involvement are usually benign. Focal hyperintense lesions without other abnormalities can be hemangiomas, focal fatty changes or lipomas (2) (Fig. 8). Diffuse hyperintensities can be seen in patients who underwent radiation therapy and typically has well-defined limits corresponding to the radiation port (7).

The second category is bone marrow abnormality with intervertebral disc involvement which means that the disc shows abnormal configuration or loss of height. Confluent decreased intensity of two contiguous vertebral bodies combined with an abnormal configurated intervertebral disc on T1-weighted images is a typical finding in spondylodiscitis, whereas involvement of the disc in neoplastic disease is exceptional (8) (Fig. 9). In spondylodiscitis, heavily T2-weighted or STIR sequences show high signal in the affected disc which differentiates spondylodiscitis from degenerative changes type Modic 1. Modic et al. describe degenerative disc disease according to signal changes of the adjacent vertebral bodies as Modic type 1, 2 and 3 (8). Type 1 exhibits reduced paradiscal marrow signal on T1-weighted images and increased signal on T2-weighted images representing bone marrow edema, combined with an intervertebral disc that is reduced in height and shows signal loss on T2-weighted images due to diminished water content of the nucleus pulposus (in contrast to the high signal of the intervertebral disc seen in spondylodiscitis) (Fig. 10). Modic type 2 is the progression of the degeneration with fatty replacement of normal bone marrow along the paradiscal endplates showing a band like high signal appearance on T1- and T2-weighted images (Fig. 11). Modic type 3 is the end stage degeneration with endplate sclerosis seen as low signal intensity on T1- and T2-weighted images.

The third category comprises vertebral body fractures. If there is a compression of the vertebral body we have to differentiate between benign and malignant fractures. Signal intensity changes indicate the differential diagnosis. In case of a complete replacement of normal bone marrow signal with diffuse hypointensity on T1-weighed images, malignant affection should be strongly considered (Fig 12). Additional findings such as spinal process involvement and a clinical history excluding mayor trauma are helpful to confirm malignancy. In case of incomplete replacement there will be a more random distribution of abnormal bone marrow with irregular shape in malignant fractures. In recent benign fractures there are hypointensities along the fracture lines due to bone marrow edema, seen as hyperintensities on T2-weighted images (Fig. 13). The alignment parallel to the fracture line is characteristic of recent benign fracture. Older fractures of benign origin usually do not show signal abnormalities (4) (Fig. 14 and 15).
Fig. 1: Normal bone marrow: T1- and T2-weighted images of normal adult bone marrow. Note that vertebral bodies are slightly hyperintense on T1-weighted images compared to the intervertebral disc. Smaller images in between show the column of a 3 year old child: Note that the bone marrow is hypointense on T1-weighted image and hyperintense on T2-weighted image, a normal finding in pediatric patients due to its high component of blood products.

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Fig. 2: Vertebral body metastasis L2-L4 in a patient with lung cancer. T1- and T2-weighted sagittal images and STIR sequence of the lumbar spine: There is hypointense replacement of the normal signal on the T1-weighted image of the vertebral body L3 extending to the L2 and L4 without involvement of the intervertebral disc. T2-weighted images and the STIR sequence show increased signal in the affected area - a typical finding in lytic metastasis.

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**Fig. 3:** Multiple myeloma. T1- and T2-weighted sagittal images of the lumbar spine. There are multiple hypointense to isointense foci, most of them with a rounded or oval shaped appearance on the T1-weighted images corresponding to hyperintense to isointense lesions in T2-weighted images.

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Fig. 4: Plasmocytoma. T1-, T2- weighted and STIR sagittal images of the lumbar spine. Hypointense replacement of L3 bone marrow on T1- weighted image corresponding to a mixed hypo- and isointense appearance on T2-weighted image and slightly hyperintensity on the STIR image without involvement of the intervertebral disc.

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Fig. 5: Enostosis or "bone island". Sagittal T1-weighted image of thoracic spine. There is a small focal hypointensity in the T11 vertebral body. The lesion is oval shaped, oriented along the long axis of the vertebral body and shows rather trabeculated than smooth margins.

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Fig. 6: Multiple myeloma - diffuse bone marrow infiltration. T1- and T2-weighted sagittal images of the cervical and part of the thoracic spine. Diffuse hypointense replacement of normal bone marrow signal on both imaging sequences.

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Fig. 7: Bone marrow hyperplasia in patient with anemia. T1- and T2-weighted images of thoracic spine. Diffuse hypointense replacement of bone marrow on both T1- and T2-weighted images.

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Fig. 8: Benign hyperintense lesions: A) Fatty infiltrations. T1-weighted image of the lumbar spine. There are central round shaped hyperintense foci in each vertebral body - a typical finding in benign fatty infiltration in the adult spine. A) Hemangioma. T1-weighted image of the lumbar spine. Solitary rounded hyperintense lesion in the posterior aspect of the T5 vertebral body corresponding to a vertebral hemangioma.

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Fig. 9: Spondyloiscitis L2/L3. T1- T2-weighted and STIR sagittal images of the lumbar spine. Hypointensity of the paradiscal bone marrow un T1-weighted image. Note the deformation of the intervertebral disc and its high signal intensity on T2- weighted image and the STIR sequence.

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**Fig. 10:** Degenerative changes Modic Type 1 L4/L5. T1- and T2-weighted sagittal images of the lumbar spine. Band like hypointensities on T1- and hyperintensities on T2-weighted images with deformation and low signal of the intervertebral disc.

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**Fig. 11:** Degenerative changes Modic Type 2 L4/L5. T1- and T2-weighted sagittal images of the lumbar spine. Band like hyperintensities on T1- and hyperintensities on T2-weighted images with deformation and low signal of the intervertebral disc corresponding to fatty infiltration of the bone marrow near the endplates.

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Fig. 12: Malignant fracture T11 due to metastatic disease. Sagittal T1- and T2-weighted images of thoracic spine show complete replacement of the vertebral body T11.

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Fig. 13: Benign fracture L4. T1- T2- weighted and STIR images of the lumbar spine. Band-like hypointensities along the fracture line combined with high intensity on STIR images - a typical finding in bone marrow edema due to recent trauma.

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**Fig. 14:** Multiple benign compression fractures in osteoporotic patient. Sagittal T1- and T2-weighted images of thoracic spine. There are no bone marrow intensity changes.

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**Fig. 15:** Old osteoporotic compression fracture. Sagittal T1- and T2- weighted images of lumbar and lower thoracic spine. There is a severe loss of height of the T11 vertebral body without hypointensities, suggestive of benign older fracture.

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Conclusion

Bone marrow abnormalities of the spine can be of benign or malignant origin and differentiation can be challenging. Systematic analysis of additional findings such as fractures and intervertebral disc involvement is essential in order to come to the right diagnosis.
References


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