Malignant versus benign vertebral collapse: are new imaging techniques useful?

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Abstract

Benign and malignant vertebral collapse is common in the middle-aged and elderly population. Differential diagnosis sometimes remains difficult using radiographs, computed tomography (CT) and magnetic resonance imaging (MRI) if strong edema is present. Established morphological criteria and new methods such as positron emission tomography (PET)-CT and diffusion and perfusion MRI are helpful for the correct diagnosis. Increased fluorodeoxyglucose (FDG) uptake accounts for the neoplastic cause of a fracture. Hyperintensity on diffusion-weighted images and a high plasma flow also are associated with the malignant cause of a fracture. However, the combination of all criteria should be taken into account for differential diagnosis.

Keywords: *Spine; MRI.*

The spine is one of the most commonly organs imaged using magnetic resonance. Differential diagnosis is mostly based on morphological criteria. Typical benign lesions are hemangiomas, edema in degenerative disease, osteoporotic fractures with edema and spondylodiscitis as an inflammatory process. Atypical hemangiomas, hematopoietic islands and excessive edema due to degenerative processes can pose problems in the differential diagnosis of malignancy. The most common malignant diseases are metastases, neoplastic vertebral fractures, myeloma, primary malignant bone tumors, primary or secondary lymphoma and diffuse marrow diseases such as leukemia and myeloproliferative diseases.

Degenerative disease with edema usually presents as band-like edema along the end-plates. Sometimes edema may affect the whole vertebral body, thus raising the question of whether a neoplastic process may be present. Acute osteoporotic fractures usually show band-like edema along the fractured end-plate with residual normal marrow in the remaining vertebral body. However, sometimes edema is excessive and affects the whole vertebral body, again raising question of whether a neoplastic fracture is the underlying cause. Malignant infiltration can be either focal or diffuse. There is no

specific alteration in signal intensities for the different underlying pathologies. They always show up as hypointense on T1-weighted images and hyperintense on T2-weighted and short tau inversion recovery (STIR) images. Both benign disease and neoplastic diseases take up contrast.

New imaging techniques that can help in differential diagnosis are positron emission tomography (PET)-computed tomography (CT) and diffusion and perfusion of the spine. It has been shown that fluorodeoxyglucose (FDG) PET-CT can be used for the differentiation of benign and malignant fractures and in first results for differentiating benign and malignant vertebral collapse. Increased FDG uptake (standardized uptake value (SUV) >3) is usually seen in malignant conditions.

Diffusion-weighted magnetic resonance imaging (DWI) is a well-established magnetic resonance imaging (MRI) technique, in which the MRI signal intensity is influenced by self-diffusion, i.e., microscopic stochastic Brownian motion of water molecules caused by the molecular thermal energy. DWI can provide information about the microscopic structure and organization of biological tissue and, thus, can depict various pathological changes in organs or tissues. Diffusion-weighted imaging

has been especially used for differentiation of benign and neoplastic vertebral collapse^[1]. Different sequences have been explored. Qualitative measurements with diffusion-weighted imaging of benign and malignant vertebral collapse were performed in 1998^[2] with steady state free precession sequences (SSFP; Siemens, Erlangen). A hypointense or isointense signal was associated with benign edema, whereas tumor showed hyperintensity in contrast to normal surrounding marrow^[2]. This is not transferable to other sequences, such as echo planar imaging (EPI), since here the whole spine lacks signal. In addition, strong sclerotic metastases can yield hypointense signal due to the lack of water protons^[3,4]. An alternative to non-quantitative diffusion-weighted SSFP imaging is the acquisition of diffusion-weighted images at two or more *b*-values in order to calculate the apparent diffusion coefficient as a quantitative measure of diffusion. Several studies applied quantitative DWI to normal and pathological vertebral bone marrow. Although the results exhibit a certain variability, there appear to be typical ranges of apparent diffusion coefficient (ADC) associated with normal and pathological vertebral bone marrow in the majority of these studies. Typical ADCs of normal vertebral bone marrow (but also of osteopenic or osteoporotic bone marrow) are relatively low at between 0.2 and $0.6 \times 10^{-3} \text{ mm}^2/\text{s}$. Pathological bone marrow exhibits much higher diffusivities, ranging from about 0.7 to $1.0 \times 10^{-3} \text{ mm}^2/\text{s}$ in metastases as well as malignant fractures. In acute osteoporotic and traumatic fractures, ADCs of 1.0 to $2.0 \times 10^{-3} \text{ mm}^2/\text{s}$ were found. Vertebrae affected by inflammatory disease such as spondylitis or tuberculosis have been reported with ADCs in an intermediate range from 1.0 to $1.5 \times 10^{-3} \text{ mm}^2/\text{s}$. Although a certain overlap of ADC ranges can be seen, ADC measurements can be useful for the differentiation of benign vertebral fractures and metastatic lesions^[5–7].

The general variability of the reported ADCs can be explained by the different pulse sequences and different diffusion weightings used in these studies. The most important difference with respect to the applied pulse sequences is the use of fat saturation, which is required for single-shot echo-planar imaging (due to the large chemical shift-related displacement of fat relative to other tissue) but is optional in combination with spin echo or fast spin echo techniques. Since the ADC of vertebral fat is very close to zero, the calculated diffusion coefficients of normal bone marrow are systematically decreased when fat saturation is not applied. Typical values are in the range of 0.2 to $0.4 \times 10^{-3} \text{ mm}^2/\text{s}$ without fat saturation, in contrast to 0.3 to $0.6 \times 10^{-3} \text{ mm}^2/\text{s}$ with fat saturation^[8]. Smaller differences are seen in lesions, since the relative fat content is much lower there than in normal bone marrow.

The chosen range of *b*-values can also systematically influence the measured ADCs. At very low *b*-values, the diffusion effect is known to be overestimated due to the contribution of perfusion to the signal attenuation, while

the choice of relatively high *b*-values greater than about 600 s/mm^2 may result in an underestimation due to signal intensities comparable with the noise level as discussed above.

The pathophysiological background of the diffusion properties in vertebral bone marrow is not yet fully understood. Currently, the most probable hypothesis is that the molecular diffusion of water is substantially increased in osteoporotic fractures because of bone marrow edema and the disruption of the trabecular structure. In contrast, the diffusion is restricted in malignant vertebral compression fractures due to the high cellularity of tumor tissue. In addition, if DWI without fat suppression is applied, the ratio of the fat and water contributions to the signal, i.e., the presence of red and yellow bone marrow or of tumor tissue, also plays an important role. In general, the lower the fat contribution to the signal, the higher the diffusivity of the composite tissue signal.

Previous studies using dynamic contrast-enhanced MRI (DCE-MRI) on the spine were based on qualitative descriptive signal parameters^[9]. Time intensity curves yielded no significant difference between benign and malignant vertebral collapse. New methods for direct measurement of perfusion and endothelial permeability in bone marrow using high temporal resolution DCE-MRI are now under investigation. With this method the plasma volume, the extraction fraction and the interstitial volume can be determined. In addition the correction for the fat component in vertebral marrow might play an important role since it can significantly influence perfusion parameters. First results seem to be promising.

Conclusion

In conclusion morphologic criteria remain the most important tool for differentiating benign and malignant collapse. However, new techniques such as FDG PET-CT and diffusion-weighted MRI provide additional tools in difficult cases. MRI perfusion is still under investigation.

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