Diffusion-weighted MRI of the bone marrow: ADC values of multiple myeloma patterns

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Aims and objectives

MRI patterns of involvement based on T1-weighted images have been described in multiple myeloma (MM) and the prognostic significance of a diffuse MRI pattern has been demonstrated. Diffuse MRI pattern of marrow involvement correlates with poor prognosis in MM patients both in the conventional chemotherapy and novel agent era. Sometimes the differentiation of diffuse from normal MRI marrow involvement in MM patients is difficult, particularly in cases of anemia and of low plasma cell marrow infiltration. Diffusion-Weighted Imaging (DWI) is an MRI technique which is based on differences in the diffusivity of water molecules in the tissue under study. Quantitative analysis of DWI can be achieved by calculating the Apparent Diffusion Coefficient (ADC) values from images with two or more different diffusion weightings. Our objective was to calculate and compare ADC values in newly diagnosed patients with MM, to identify possible differences among diffuse, focal, and normal MM MRI patterns and to establish, if possible, a threshold value which might distinguish diffuse from normal MRI patterns.
Methods and materials

We evaluated 44 patients (18M/26F, median age 66 years; range: 37-89 years) with newly diagnosed, untreated, MM and 16 healthy, gender and age-matched controls, with MRI of the lumbosacral spine, using a 1.5 Tesla unit. Conventional MR images were obtained according to bone marrow MRI protocols; MRI patterns of involvement were normal in 22, focal in 11 and diffuse in 11 patients (Figure 1). DWI was obtained with an Echo Planar Imaging sequence using 5 b-values (0, 150, 250, 500, 750 sec/mm²). In MM patients with a normal or a diffuse pattern, as well as in healthy controls, region of interest (ROI) measurements were obtained from each of the five lumbar vertebral bodies avoiding the region of the basivertebral vessels and any focal non-myelomatous lesion and the mean ADC value was calculated. In MM patients with a focal pattern, ROIs were placed on several focal lesions and the highest ADC value was recorded; in these patients an additional ROI was placed on a normal-appearing vertebra in order to record the ADC value of apparently normal marrow.
Fig. 1: MRI patterns of involvement in multiple myeloma. Sagittal T1-weighted images of the lumbosacral spine in three different multiple myeloma patients show (from left to right): normal, focal and diffuse patterns of bone marrow involvement.

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Results

Mean ADC values (±SD, x10^{-3} mm²/sec) were: 0.346±0.107 (range: 0.186-0.544) for the normal MM pattern, 1.188±0.359 (range: 0.715-2.015) for the focal MM pattern and 0.821±0.149 (range: 0.642-1.017) for the diffuse MM pattern (Figures 2,3,4). Mean ADC value of apparently normal marrow in patients with a focal pattern was 0.403±0.142 (range: 0.113-0.589), while that of healthy controls was 0.325±0.135 (range: 0.152-0.542). One way analysis of variance (ANOVA) showed a significant difference in ADC values within the groups of the study (p<0.0001). Further analysis using t-test revealed significant differences of ADC values between diffuse and focal MM pattern (p=0.003), diffuse and normal MM pattern (p<0.0001), focal and normal MM pattern (p<0.0001), diffuse MM pattern and healthy volunteers (p<0.0001), focal MM pattern and healthy volunteers (p<0.0001), diffuse MM pattern and apparently normal marrow in focal MM pattern (p<0.0001) and finally between focal MM pattern and apparently normal marrow in focal MM pattern (p<0.0001)(Figure 5). No significant differences were found between normal MM pattern and healthy volunteers (p=0.442), normal MM pattern and apparently normal marrow in focal MM pattern (p= 0.141), and between apparently normal marrow in focal MM pattern and healthy volunteers (p= 0.175) . The 95% confidence intervals of the ADC values for each group were calculated and a receiver operating characteristic (ROC) analysis was performed to determine the cut-off value with the highest accuracy to distinguish a diffuse myelomatous infiltration of the bone marrow with a sensitivity and specificity of 100%.
Fig. 1: MRI patterns of involvement in multiple myeloma. Sagittal T1-weighted images of the lumbosacral spine in three different multiple myeloma patients show (from left to right): normal, focal and diffuse patterns of bone marrow involvement.

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Fig. 2: Sagittal T1-weighted image (a) and ADC map (b) of the lumbosacral spine of a 41 year-old male with multiple myeloma and 25% bone marrow plasmacytosis. T1-weighted image demonstrates normal pattern of bone marrow involvement. Mean ADC value of the five lumbar vertebrae was 0.322 x 10-3 mm2/sec.

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Fig. 3: Sagittal T1-weighted image (a) and ADC map (b) of the lumbosacral spine of a 55-year-old woman with multiple myeloma and 42% bone marrow plasmacytosis. T1-weighted image demonstrates focal pattern of bone marrow involvement. ADC value of the focal lesion of L2 was $0.778 \times 10^{-3}$ mm$^2$/sec.

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Fig. 4: Sagittal T1-weighted image (a) and ADC map (b) of the lumbosacral spine of a 54-year-old man with multiple myeloma and 44% bone marrow plasmacytosis. T1-weighted image demonstrates diffuse pattern of bone marrow involvement. Mean ADC value of the five lumbar vertebrae was 0.803 x 10^{-3} mm²/sec.
Fig. 5

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Conclusion

We conclude that normal, focal and diffuse MRI patterns of marrow involvement in patients with multiple myeloma have distinct ranges of ADC values on DWI. An ADC value above $0.593 \times 10^{-3}$ mm$^2$/sec is diagnostic of diffuse myelomatous infiltration of the bone marrow with extremely high accuracy and can be used in cases where a diffuse pattern cannot be differentiated from a normal pattern on conventional MRI.
References


