MR Evaluation of Multiple Myeloma at 3.0 Tesla: How do bone marrow signal intensity and selection of protocols affect lesion conspicuity?

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Target audience: Diagnostic radiologists.

Introduction: The Durie-Salmon PLUS staging system for multiple myeloma takes into account the number of lesions detected by MRI because the number of lesions correlates with overall survival1. However, counting focal lesions can be somewhat confusing, because variegated or diffuse patterns of tumor cell infiltration are present in 57% of T1-weighted images2, which can confound detection of focal lesions. The optimal MRI sequence for detection of focal bone lesions thus remains to be determined. The iterative decomposition of water and fat with echo asymmetry and least-squares estimation (IDEAL) can be used to separate fat and water with very high SNR efficiency, thereby resulting in robust fat suppression3. The present study compared T1-weighted, fat-suppressed T2-weighted FSE (FS-T2 FSE), STIR, and T2-weighted FSE. IDEAL sequences in terms of CNR and percent contrast and assessed the dependence of lesion conspicuity on background bone marrow (BM) signal intensity in multiple myeloma.

Methods: Spinal MRI was performed in 54 patients with multiple myeloma. Imaging was performed using a 3.0-T MRI unit (Signa HDxt 3T; GE Healthcare) with sagittal T1 fast spin-echo-weighted imaging (T1 FSE); FS-T2 FSE (with the CHESS technique); fast STIR imaging; and IDEAL T2 fast spin-echo-weighted sequence (TR/TE, 4000/112.4 ms; averages, 6; matrix size, 448×288; FOV, 300 mm; slice thickness, 4 mm; band width, 83.3 kHz; ETL, 16; acquisition time, 6 min 17 s). Co-registered water and fat images were generated by the IDEAL software. Mean signal intensity and standard deviation were calculated by placing operator-determined regions of interest (ROIs) within the focal myeloma lesions (FL), in the BM of the L1-L3 vertebral bodies and the spinal cord (SC). BM Signal intensity was calculated as the mean value obtained from the three vertebral bodies. For each MRI examination, CNR and the percent contrast between BM and SC (n=54) and between BM and FL (n=20) were measured using the following equations:

\[
\text{CNR} = \frac{|S_b - S_n|}{\sqrt{\text{std}_b^2 + \text{std}_n^2}}
\]

where \(S_b\) and \(S_n\) are mean intensity and \(\text{std}_b\) and \(\text{std}_n\) are the standard deviation of intensities for the investigated lesion or normal tissues.

Fat-signal fraction from IDEAL images was calculated from the ratio of the signal intensity in the fat image divided by the signal intensity of the corresponding ROI in the in-phase image. Spearman rank correlation coefficients (\(\rho\)) were calculated to investigate possible correlations between percent contrast and the fat signal fraction. One-way analysis of variance with Scheffe’s post hoc test was used to compare CNR and percent contrast among the four different groups (i.e., T1 FSE, FS-T2 FSE, fast STIR, and water image of IDEAL) for all patients.

Table 1. Results of Spearman rank correlation for percent contrast with fat signal fraction.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>(r)</th>
<th>(p)</th>
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<tbody>
<tr>
<td>Water image of IDEAL</td>
<td>0.753</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fat-suppressed T2 FSE</td>
<td>0.850</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fast STIR</td>
<td>0.572</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>T1 FSE</td>
<td>-0.160</td>
<td>0.25</td>
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</tbody>
</table>

Results: Table 1 and Figure 1 show a significant correlation between percent contrast and fat signal fraction, except for in the T1-FSE. Therefore, we categorized patients into one of two groups: a T1-dark marrow group (n=15), with fat signal fraction <50%; and a T1-bright marrow group (n=39), with fat signal fraction ≥50%. BM-SC CNR was significantly greater for the water image of IDEAL and FS-T2 FSE than for the STIR. BM-FL CNR was significantly higher for the FS-T2 FSE than for the STIR in T1-bright marrow (p<0.05), but no significant difference was found in the T1-dark marrow among the three fat-suppression methods. Figure 2 shows that the BM - SC percent contrast was significantly higher for FS-T2 FSE than for the STIR.

Conclusions: Consistency of focal myeloma lesion in the spinal bone marrow was dependent on the fat signal fraction in fat-suppressed MRI. The fat-suppressed FSE showed higher percent contrast than other sequences. No significant difference in lesion conspicuity was found among different fat-suppression techniques in T1-dark marrow, suggesting the need for an inclusive, multimodality imaging approach including CT or PET to evaluate focal lesions in multiple myeloma.