

# Magnetic Resonance Evaluation of Multiple Myeloma at 3.0 Tesla: How Do Bone Marrow Plasma Cell Percentage and Selection of Protocols Affect Lesion Conspicuity?

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## Target audience: Diagnostic radiologists

**Purpose:** 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 survival<sup>1</sup>. However, focal lesions can be difficult to detect on MRI because signal intensity of background bone marrow (BM) is sometimes similar to that of focal lesions (FL). Therefore, the optimal MRI sequence for detecting focal bone lesions has yet 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, resulting in robust fat suppression<sup>2</sup>. 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 BM plasma cell percentage (BMPC%) obtained from biopsy specimen.

**Methods:** Spinal MRI was performed in 45 patients with multiple myeloma. We estimated the proportion of BMPC% in BM biopsy specimens obtained from the iliac crest. Imaging was performed using a 3.0-T MRI unit (Signa HDxt 3T; GE Healthcare) with sagittal T1 FSE; FS-T2 FSE (with the CHESST 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; bandwidth, 83.3 kHz; ETL, 16; acquisition time, 6 min 17 s). Co-registered water and fat images were generated using IDEAL software. Mean signal intensity and standard deviation were calculated by placing operator-determined regions of interest within the focal myeloma lesions and in the BM of the L1–L3 vertebral bodies. 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 FL (n=45) were measured using the following equations:

$$\text{Percent contrast} = (S_a - S_b) / (S_a + S_b)$$

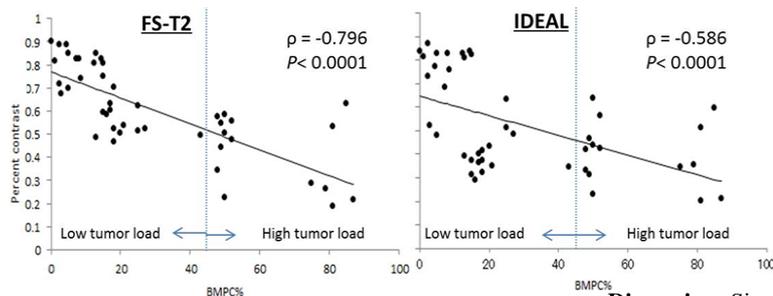
$$\text{CNR} = |S_a - S_b| / ((S_{\text{asd}}^2 + S_{\text{bsd}}^2) / 2)^{1/2}$$

where  $S_a$  and  $S_b$  are mean intensities and  $S_{\text{asd}}$  and  $S_{\text{bsd}}$  are the standard deviations of intensities for the investigated lesion or normal tissues. Spearman rank correlation coefficients ( $\rho$ ) were calculated to investigate possible correlations between CNR, and percent contrast and BMPC% for the four sequences (i.e., FS-T2 FSE, water image of IDEAL, fast STIR, and T1 FSE). One-way analysis of variance with Scheffé's post hoc test was used to compare CNR and percent contrast among the different sequences for all patients.

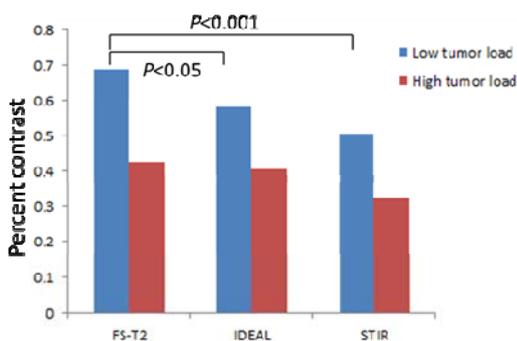
**Table 1.** Results of Spearman rank correlation for percent contrast and CNR with BMPC%

Sequence	Percent contrast		CNR	
	$\rho$	$P$	$\rho$	$P$
Water image of IDEAL	-0.580	<0.0001	-0.664	<0.0001
Fat-suppressed T2 FSE	-0.796	<0.0001	-0.709	<0.0001
Fast STIR	-0.494	<0.001	0.500	<0.001
T1 FSE	-0.086	0.57	-0.100	0.48

**Figure 1.** Graph of BMPC% versus percent contrast for FS-T2 FSE and water image of IDEAL. Linear regression curve was plotted. Vertical line corresponds to a BMPC% of 45%.



**Figure 2.** Percent contrast comparison among the three different sequences.



**Results:** Table 1 and Figure 1 show a significant negative correlation between percent contrast and CNR with BMPC%, except in T1-FSE. Correlations with BMPC% were highest in FS-T2 FSE among the three fat-suppression techniques ( $\rho = -0.796$  for percent contrast,  $\rho = -0.709$  for CNR).

Next, we categorized patients into the following two groups: a high tumor load BM group (n=15), with BMPC%  $\geq 50\%$ ; and a low tumor load BM group (n=30), with BMPC%  $< 50\%$ . Figure 2 shows the results of percent contrast comparison among the three fat-suppression sequences. In the low tumor load BM group, BM-focal lesion percent contrast was significantly greater for FS-T2 FSE than for the water image of IDEAL ( $P < 0.05$ ) and STIR ( $P < 0.001$ ). However, no significant difference was found in the high tumor load BM among the three fat-suppression methods. CNR comparisons found no significant difference among the three fat-suppression technique in both tumor load groups.

**Discussion:** Since the Durie-Salmon PLUS staging system does not mention the diffuse infiltration pattern of tumor cells in BM, focal myeloma lesions must be detected regardless of diffuse abnormality in background BM. In this study, BM-focal lesion percent contrasts and BMPC% showed significant negative correlations in the three fat-suppression techniques. This means that the higher the BMPC% within BM, the less conspicuous the focal lesion will be on fat-suppressed MRI. We attributed the lower percent contrast on fat-suppressed images with higher BMPC% to increased signal intensity of background BM, mainly caused by  $T_2$  prolongation by diffusely infiltrated myeloma cells, which can reduce signal intensity contrast between focal lesion and background BM.

The present study showed that BM-focal lesion percent contrast for FS-T2 FSE was significantly greater than that of water images of IDEAL in the low tumor load group. The exact cause is unclear, but may be related either to differences in SNRs or to variability in the spatial distribution of myeloma cells. BM-focal lesion percent contrast for FS-T2 FSE also showed significantly higher percent contrast than STIR. This finding can be explained by improvement of the saturation pulse of CHESST technique in 3-T MRI.

**Conclusion:** The higher the BMPC% obtained from biopsy, the less conspicuous the focal lesion on fat-suppressed MRI. This dependence of lesion detectability on the diffuse infiltration of tumor cells has not been described previously, and could have clinical implications for staging and treatment planning in cases of multiple myeloma. The most effective protocol for detecting focal lesions was FS-T2 FSE.

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