Applications of Dynamic Contrast-Enhanced MRI in Assessment of Spinal Bone Marrow

K. K. Peck1, G. Slater1, X. Wang1, S. Kim1, J. Yamada1, M. Bilsky4, E. Lis2, and S. Karimi2

1Radiology and Medical Physics, Memorial Sloan-Kettering Cancer Center, New York, New York, United States; 2Neuroradiology, Memorial Sloan-Kettering Cancer Center, New York, United States; 3The City University of New York, New York, United States; 4Stony Brook University, New York, United States; 5Radiation Oncology, Memorial Sloan-Kettering Cancer Center, New York, United States; 6Neurosurgery, Memorial Sloan-Kettering Cancer Center, New York, United States

Introduction
The applications and utilities of Dynamic contrast-enhanced MRI (DCE MRI) in the imaging assessment of bone marrow are, unlike in brain imaging, not fully investigated and are not established. Evaluation of the marrow by conventional imaging is routinely done for the initial diagnosis, assessment of treatment response, and follow-up of patients with primary and metastatic tumors (1, 2). Such assessments are limited and rely on presence of non-specific lesions and changes in tumor size, which provide no physiological information such as tumor vascularity and hemodynamics. The effects of treatment, sex, and age on the marrow further complicate the conventional assessment. For example, the current routine MR imaging of the spinal marrow can be markedly limited in differentiating between tumors and non-tumoral processes, hyper and hypovascular tumors, pathological from non-pathological fractures, viable from non-viable tumor, and pathological from treatment related changes of the marrow. An imaging biomarker would facilitate in answering these important clinical questions, and would have an enormous impact on treatment, decision-making, and patient management. Application of DCE MRI to the study of bone marrow between ages, sex subgroups, and among spinal levels has already shown variations in bone marrow time-intensity curves. Since these differences, and other factors described above, influence the appearance of the marrow and its dynamic profile we sought to investigate the utility of DCE MRI in addressing the aforementioned clinical questions. We started our investigation of the bone marrow of the spine using a contrast enhanced dynamic perfusion MRI, and the parameter measured was the bolus wash-in slopes.

Subjects
20 subjects (age range: 45-76, mean=59), who were referred for MRI of the spine, underwent T1 DCE MRI. These patients were divided into three different groups: 5 patients with hyper-vascular tumors, 5 patients with hypo-vascular tumors, and 10 patients without tumor in the spine.

MR Sequences and Data Analysis
MRI studies of the lumbar spine were acquired with a 1.5T GE scanner using an 8 channel Cervical-thoracic-lumbar (CTL) surface spinal coil. The kinetic enhancement of tissue during and after injection of Gd-DTPA was obtained using T1-weighted fast gradient-echo sequence (30 phases, TR=4.5 sec, TE=1-2 sec, Slice Thickness 4-5 mm, FA=30, FOV=34-36 cm) and consisted of 10-15 images in the sagittal plane. Gd-DTPA injection (0.1 mmol/kg body weight) was administered at a rate of 2-3 ml/sec by a power injector. Non-enhanced MRI sequences, including sagittal T1 and T2, axial T1 and T2 were acquired. The automated processing of the dynamic images on a pixel-by-pixel basis was performed using MatLab (Mathworks, MA). The perfusion indices, including the peak enhancement, signal percentage change, and the enhancement slope of the uptake curve were measured pixel-by-pixel. The peak enhancement ([signal\_{max}−signal\_{baseline}]/signal\_{baseline}×100%) and the enhancement slope ([signal\_{max}−signal\_{baseline}]/time\_{rise}) were calculated (signal\_{max}: maximum signal intensity; signal\_{baseline}: baseline value; time\_{rise}: the contrast enhancement rise time). Pixels passing a specific threshold of slope were specified as blue (20<slope<25), green (25≤slope<30), yellow (30≤slope<35), and red (slope≥35). Figure (c) shows an example of noise (baseline) in normal marrow. The signal enhancement curve in a tumor region is shown at figure (d).

Results and Discussion
Figure (b) shows an enhancement map obtained by slope measurement. Figure (a) is a corresponding T1 sagittal image. Statistically, significant differences in the enhancement percentage signal change are found between hypervascular and hypovascular tumor groups (p<0.05). A trend showing statistical differences was found using enhancement slope measurement (p=0.08). The signal in normal marrow was compared to those of tumors. It showed that there are no significant enhancement signals in the marrow in patients without tumors. The results of our DCE perfusion imaging were histologically confirmed from biopsy specimens in a subset of patients. These results support that DCE is a sensitive technique in discriminating between normal marrow and pathologically replaced marrow. Furthermore, the technique accurately characterized lesions as hyper or hypovascular. The bolus washing slopes were significantly different between hypervascular and hypovascular tumors (p<0.05). A trend showing statistical differences was found using enhancement slope measurement (p<0.08). The signal in normal marrow was compared to those of tumors. It showed that there are no significant enhancement signals in the marrow in patients without tumors. The results of our DCE perfusion imaging were histologically confirmed from biopsy specimens in a subset of patients. These results support that DCE is a sensitive technique in discriminating between normal marrow and pathologically replaced marrow.

utility of DCE in clinical work up of patients with spinal compression fractures. A non-invasive technique that could characterize marrow heterogeneity and differentiate between different conditions that affect the marrow would have an enormous impact on patient management. Early detection of treatment failure would allow for change in treatment strategy or adjuvant treatments before significant change in tumor volume becomes evident on conventional imaging thereby potentially improving patient outcome. Additionally larger studies are warranted to further investigate the utility of DCE in evaluating bone marrow.