Spectrally-Selective IR Diffusion-Weighted Imaging with SSFP of Bone Marrow at 3T

Y. Mazaheri[1], J. Grimm[2], E. Bayram[3], D. M. Panicek[2], J. A. Koutcher[1], and H. Hricak[2]

[1]Medical Physics, Memorial Sloan Kettering Cancer Center, New York, NY, United States, [2]Radiology, Memorial Sloan Kettering Cancer Center, New York, NY, United States, [3]GE Healthcare, Wakesau, WI, United States

Introduction

The use of diffusion-weighted (DW) imaging with steady-state free precession (SSFP) for the diagnosis of bone marrow has been reported (1-2). One notable limitation of this approach is the contribution of fat (lipid) signal intensity within bone marrow to the DW signal (3, 4). Healthy bone marrow contains substantial amounts of lipids (20-70%). The lipid component is reduced in pathological conditions such as malignant tumor infiltration, but lipid signal still significantly contributes to the overall DW signal. In this study we developed a novel technique for fat-suppressed DW-SSFP imaging technique based on the spectrally selective inversion pulse to null the in-plane lipid signal before data acquisition. The sequence was evaluated in terms of the degree of fat supression in phantom and healthy volunteer studies.

Methods

All studies were performed on a 3.0-T unit (Signa; GE Healthcare, Milwaukee, WI). To implement diffusion weighting, the SSFP (FIESTA) sequence was modified to contain a gradient pulse in the slice selection direction. Fat suppression was achieved by applying spectrally selective inversion pulses to null the fat spins in the imaging volume. Experiments were performed in phantoms and *in vivo* to demonstrate the effectiveness of DW measurements in the presence of fat. A phantom was created using three 60-ml plastic vials of 1) doped water, 2) light cream, and 3) fat (olive oil). The spine of a healthy volunteer was also imaged. Sequence parameters were: flip angle $\alpha = 45°$ degrees and slice thickness = 3 mm (6 mm for in vivo data), TR = 5.6 ms, TI = 250 ms, gradient duration $\delta = 2$ ms, gradient amplitude G = 4 G/cm, and interval between RF and read-out gradient (ΔT) = 3.2 ms.

Results

Results of the phantom experiments are shown in Fig. 1. Compared to the signal from the fat vial in the DW-FIESTA sequence (Fig. 1B), the signal from the fat vial in the IR DW-FIESTA sequence (Fig. 1C) is heavily attenuated (about 50%), whereas the water signal is not greatly reduced. The signal from the light cream vial containing light cream is attenuated by the diffusion gradients and the fat suppresion. Fig. 2 shows *in vivo* DW images of the spine from a healthy volunteer with good fat suppression.

Discussion

We developed a DW-SSFP sequence with fat suppression. Compared to DW-EPI, the DW-SSFP sequence does not suffer from sensitivity to susceptibility artifacts. The addition of the spectrally selective inversion pulse explicitly nulls the fat signal while avoiding pertubation of the SSFP steady state. Due to the evolution of phase over multiple RF pulses, a DW-SSFP imaging sequence with monopolar gradients is highly sensitive to flow and diffusion. However, the signal model for this sequence is complicated (5), making quantitative analysis difficult. It has been suggested that the relaxation times among vertebrae do not vary significantly within an individual and that the fat fraction provides the underlying reason for the changes in the bulk T_1 relaxation times (6). Hence, although measurement of *D* would require additional measurement of relaxation times, using the proposed fat suppression method differences in diffusion attenuation among vertebrae within an individual could be estimated to identify regions with significant changes in *D*. The spectrally selective inversion pulse is an effective tool for suppressing fat signal in DW-SSFP.

References: [1] *Baur A, et al.* Radiology 1998; 207:349-356. [2] *Le Bihan DJ*. Radiology 1998; 207:305-30. [3] *Mulkern RV, Schwartz RB*. AJNR 2003; 24:1489-1490. [4] *Dietrich O, et al*. In: ISMRM, 2005; [5] *Buxton RB*. MRM 1993; 29:235-243. [6] *Rosen BR, et al*. Radiology 1988; 169:799-804.

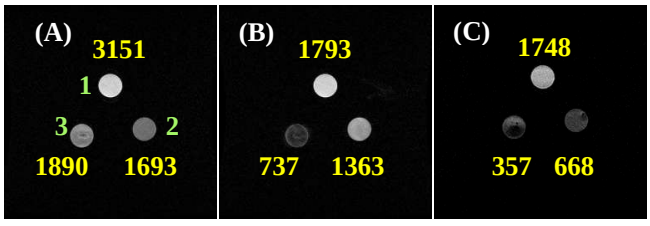

Fig. 1: *Phantom experiments.* A) FIESTA, B) DW-FIESTA, and C) IR DW-FIESTA sequences. The labeled vials are: 1) doped water, 2) light cream, and 3) fat.Mean signal from ROIs placed on each vial are shown.

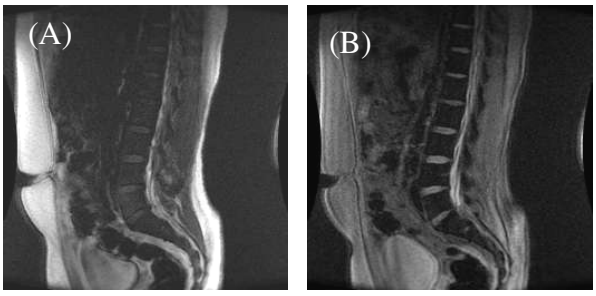

Fig. 2: *In vivo experiments.* A) DW-FIESTA, and B) IR DW-FIESTA sequences.