Contrast-Enhanced MRI with Fat Suppression using T_1 Dispersion

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Introduction. Fat suppression techniques are important when using contrast-enhanced MRI to detect bone marrow diseases such as osteomyelitis [1]. Gadolinium contrast agents can enhance the signal of edema in bone marrow, which is a sign of infection. However, a contrast agent that enhances signal by shortening T_1 can result in the enhanced signal blending with the signal from short-T_1 species such as fat. The STIR fat suppression technique is ineffective for contrast-enhanced imaging, as it suppresses all short-T_1 species, including the enhanced signal. Frequency-selective presaturation sequences can be problematic for imaging extremities such as the feet due to inhomogeneity problems. The Dixon chemical shift method has been used for fat suppression with contrast agents, but can suffer from displacement artifacts if there is patient movement [2]. We have developed a new contrast mechanism to provide fat suppression with gadolinium contrast agents using T_1 dispersion.

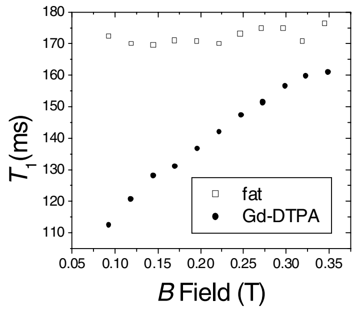

Figure 1. T_1 measurements of 1 mM Magnevist and fat.

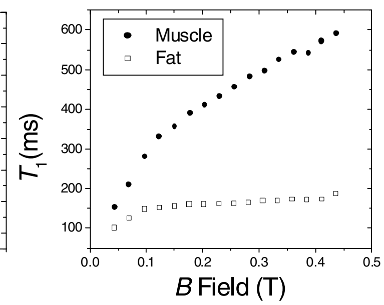

Figure 2. T_1 measurements of muscle tissue and fat.

This technique uses prepolarized MRI, which offers flexibility in the strength and duration of the magnetic field by using two pulsed electromagnets: a strong magnet to polarize the sample and a low-field homogeneous magnet for signal readout [3]. For tissues whose T_1 varies with magnetic field (T_1 dispersion), changing the field strength allows the tissue magnetization to decay with a different value of T_1. The difference between two images taken after allowing the magnetization to evolve at different field strengths yields an image with T_1 dispersion contrast: tissues with flat T_1 dispersion curves are dark and tissues with changing T_1 dispersion curves are bright [4]. In particular, fat has a fairly flat T_1 dispersion curve, whereas the T_1 of a gadolinium contrast agent increases with magnetic field strength [5]. We have created images with fat-suppressed contrast enhancement by exploiting differences in T_1 dispersion between fat and Gd-DTPA. We have also used this technique *in vivo* on the wrist of a normal volunteer without contrast enhancement, demonstrating good fat suppression of the bone marrow. T_1 dispersion fat suppression may be useful for diagnosing and monitoring osteomyelitis in the extremities for patients with bone infections.

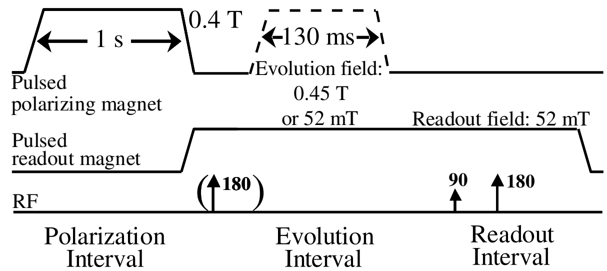

Figure 3. PMRI pulse sequence: initial polarization at 0.4 T, then an evolution interval at either 0.45 T or 0.05 T, and then signal readout.

Methods. Figure 1 shows T_1 dispersion measurements taken with our prepolarized MRI scanner on a solution of 1 mM Gd-DTPA (Magnevist) and a sample of vegetable oil; T_1 dispersion measurements on muscle tissue (from chicken) and fat samples are shown in Fig. 2. Over the field range plotted, the T_1 of the Magnevist changes by about 50 ms (35%), while the T_1 of the fat sample stays virtually constant. We exploit the different slopes of the two T_1 dispersion curves using the pulse sequence shown in Fig. 3. A strong polarizing pulse (0.4 T) is followed by an evolutionary pulse (0.45 T or 0.052 T), and then the RF excitation and readout is performed at the lower field (52 mT). Final images with T_1 dispersion contrast are created by direct subtraction of the high and low field data.

Results. As a preliminary test, we imaged two samples: 1 mM Gd-DTPA (Magnevist) and fat (vegetable oil). Figure 4 (top row) shows two images taken with different evolutionary field strengths: 0.45 T evolution field, and 52 mT evolution field. Figure 4 (bottom) shows the direct subtraction of the two images. In the resulting image, the signal from the fat sample has been almost entirely subtracted out, while the signal from the sample of Gd-DTPA contrast agent is still strong.

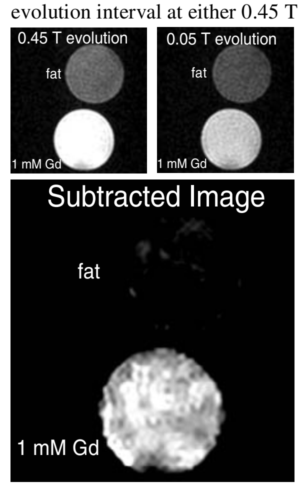

Figure 4. T_1 dispersion image of tubes of oil and 1 mM Magnevist. 6 cm FOV, 64x64, 6:30 scan time.

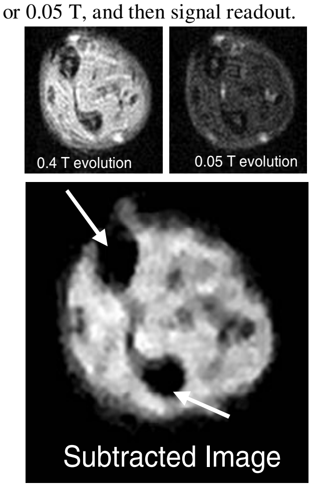

Figure 5. T_1 dispersion wrist image, showing good suppression of bone marrow (arrows). 6cm FOV, 64x64, 7:00 scan time.

We also imaged the arm of a normal volunteer without contrast enhancement. Figure 5 shows images taken at the two different evolutionary field strengths and the T_1 dispersion image generated by subtraction. Regions of fat (flat dispersion curve), such as the bone marrow, are dark in the image with T_1 dispersion contrast, while the signal from the surrounding muscle is still strong. If there were contrast-enhanced fluid inside the bone, it would be clearly visible due to the complete suppression of the fat signal.

Discussion. We have demonstrated a method for T_1 dispersion fat suppression by exploiting the difference between two images taken at different evolutionary field strengths. Our T_1 dispersion images show good fat suppression due to the flat T_1 dispersion curve of fat, while the signal of the gadolinium contrast agent remains bright. This technique may provide a new method of fat suppression for contrast-enhanced imaging of disorders that affect bone marrow, such as osteomyelitis. A PMRI extremity scanner would cost about the same as an ultrasound scanner and could use T_1 dispersion contrast to identify bone marrow edema while also providing conventional T_1 and T_2 contrast.

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