MR Imaging with T_1 Dispersion Contrast

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Introduction. The ability to manipulate soft tissue contrast is one of MRI's greatest strengths. Prepolarized MRI uses two pulsed electromagnets: a strong magnet to polarize the sample and low-field homogeneous magnet for signal readout [1]. This enables flexible pulse sequences in which the duration and strength of the magnetic field are varied. Here we present a technique in which we polarize a sample in a strong field, then allow the magnetization to decay in an "evolutionary" field strength before imaging. For the case of tissues whose T_1 varies with field strength, changing the evolutionary field strength allows the magnetization of the tissue to decay with a different value of T_1. Taking two images at different evolutionary field strengths and then subtracting the images yields an image with contrast between tissues with flat T_1 dispersion curves and tissues with rapidly changing T_1 dispersion curves [2]. In particular, tissues with high protein content, such as muscle tissue or multiple sclerosis plaque, exhibit rapid changes in their T_1 dispersion curves at 50 mT and 65 mT due to cross-relaxation with nitrogen nuclei in the protein backbone [3,4]. We have used our sequence to create images with T_1 dispersion contrast between fat or unbound water, which have roughly constant T_1 over a small field range, and muscle tissue, which has a rapidly varying T_1 near the quadrupole dips.

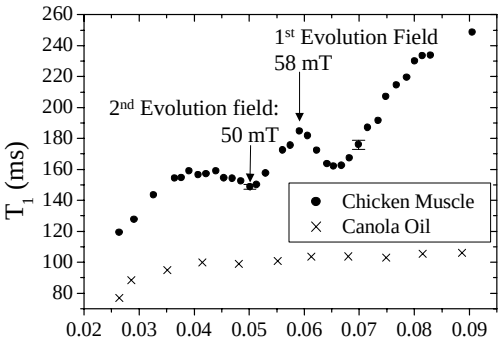

Figure 1.

Methods. Figure 1 shows T_1 measurements taken with our prepolarized scanner on muscle and fat samples [5]. The two evolutionary field strengths we chose are indicated with arrows; between the two evolution fields, the T_1 of the muscle tissue changes by about 35 ms, while the T_1 of the fat sample stays virtually constant. We exploit this difference in the slopes of the two T_1 dispersion curves using the pulse sequence shown in Figure 2. Our pulse sequence uses a strong polarizing pulse (0.35 T) followed by an evolutionary pulse (at 50 mT or 58 mT), and then performs the RF excitation and readout at low field (26 mT).

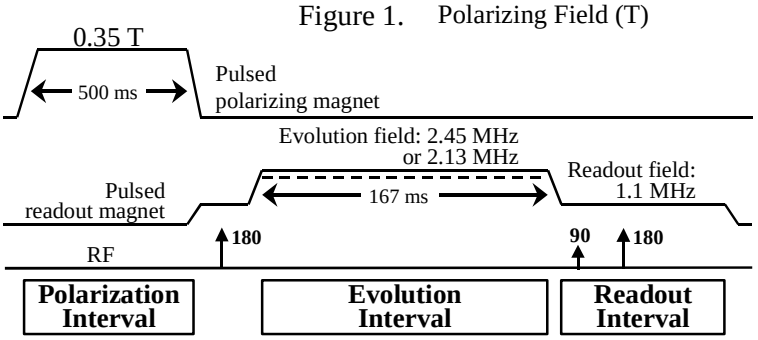

Figure 2.

For pure T_1 dispersion contrast, it is important to eliminate differences in signal strength that are solely due to the change in equilibrium evolution magnetization between images taken at the two evolution fields (and not due to the change in T_1). To eliminate this difference, we take two images at each field strength, one with an initial 180º RF pulse before evolution and one without. Subtracting these two images yields an image whose signal depends only on the initial polarizing field strength and the value of T_1 at the evolution field. We perform this measurement at both evolution field strengths (a total of four measurements, interleaved to eliminate subtraction artifacts from field drift due to magnet heating) and subtract the images from the high and low evolution fields to achieve a final image with T_1 dispersion contrast.

Results. We imaged three samples: muscle tissue and fatty tissue (both from chicken), and water doped with copper sulfate to have a T_1 of 100 ms. Figure 3(a-b) shows two images taken with different evolutionary field strengths: (a) was taken with a 58 mT evolutionary field, and (b) was taken with a 50 mT evolutionary field. Figure 3(c) shows the subtraction of the two images. In the resulting image, the signal from the fat and water samples has been almost entirely subtracted out, while the signal from the muscle sample is still significant.

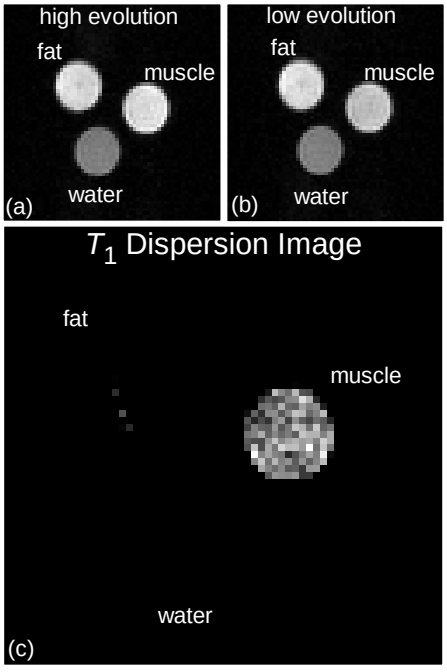

Figure 3. Images are 64×64, 4 cm FOV, 2D projections. Samples are 1 cm diameter vials, 3 cm in depth.

Discussion. We have demonstrated a method for creating T_1 dispersion contrast in images by subtracting two images taken at different evolutionary field strengths. Species whose T_1 does not change between the two evolutionary field strengths are subtracted out, while species whose T_1 varies between the two evolution fields remain. Our test image shows contrast between muscle tissue, which appears bright, and fat and unbound water, which both appear dark. Further improvements in the pulse sequence should allow us to achieve this effect by collecting only two images rather than four.

This technique may provide avenues for pursuing new contrast for other species that exhibit quadrupole dips, such as multiple sclerosis plaques. Any species that has a rapidly changing (large slope) T_1 dispersion curve should be discernible from slowly changing (small slope) T_1 dispersion species.

[1] CARLSON, J.W. *et al*., *Radiology*, **184**:635, 1992.
[2] LURIE, D.J. *et al*., *Proc. Field-Cycl. Relax.*, p. 5, 1998.
[3] KIMMICH, R. *et al*., *Phys Med Biol*, **29**:593, 1984.
[4] RINCK, P.A. *et al*., *Radiology*, **168**:843, 1988.
[5] UNGERSMA, S.E. *et al*., *Proc. ISMRM*, p. 616, 2002.