SPIO: Positive contrast by adiabatic IRON using repetitve inversion pulses

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Introduction

Superparamagnetic iron oxide particles (SPIO) have been shown to accumulate in lymph nodes and macrophages, e.g. within atherosclerotic plaque. [1-2] Susceptibility weighted imaging is the most sensitive means to detect the particles, however the lack of signal caused by the magnetic dipole field perturbations is ambiguous, as numerous other sources of signal loss exist. To overcome this problem, so called "bright-iron" or "off-resonance imaging" techniques have been proposed. [3-5] Here we describe a further development of the IRON method [5].

Materials and Methods

The original IRON implementation uses broadband non-selective inversion pulses for fat suppression and a resonant saturation pulse with low spectral bandwidth for eliminating resonant water protons. As an alternative, frequency selective adiabatic inversion pulses with low spectral bandwidth may be used to invert resonant water and fat protons [personal communication M. Stuber]. Adiabatic inversion pulses are less sensitive to B1 inhomogeneities and produce uniform preparation in the whole sample. Because fat and water T_1 relaxation times differ, a common zero-crossing of their magnetization can be achieved. (figure 1) A drawback is that the suppression is only perfect for certain T_1 values. To achieve a uniform background suppression in-vivo, we implemented a sequence with repetitive inversion pulses that prepares a steady-state of longitudinal magnetization (figure 2).

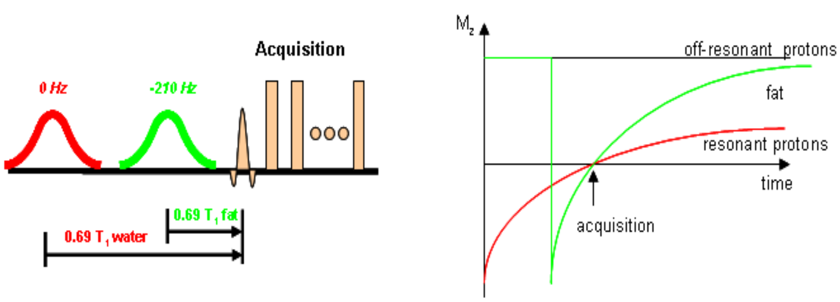


Figure 1: Adiabatic IRON at 1.5 T using adiabatic inversions to suppress fat and resonant water.

By careful adjustment of the delay times between the inversion pulses and the acquisition, suppression is improved over a wide range of tissue T_1 values. The acquisition is interleaved with the inversion and does not perturb the steady state of fat and resonant water protons. Interleaved multi-slice acquisition in combination with the short TR of the inversion pulses (200 ms) speed up the acquisition considerably. The method was tested in an agarose phantom containing iron loaded microbubbles. The repetition time was 200 ms between the 100 Hz broad inversion pulses, a slice selective TSE readout with a turbo factor of 7 was used.

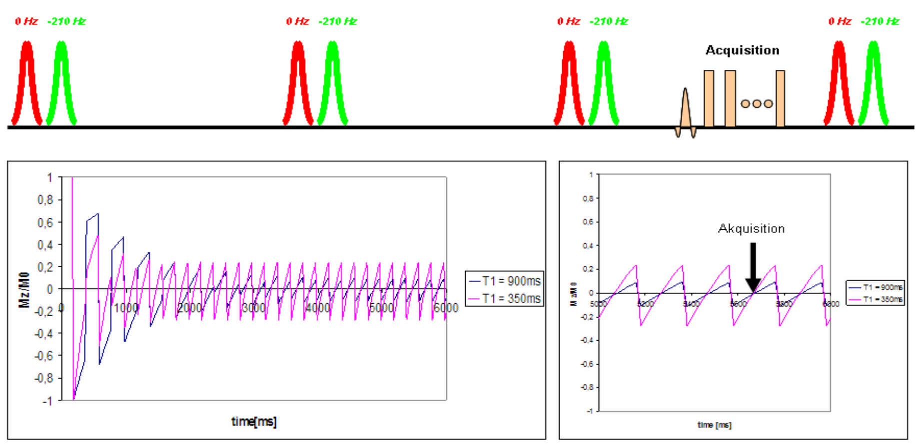
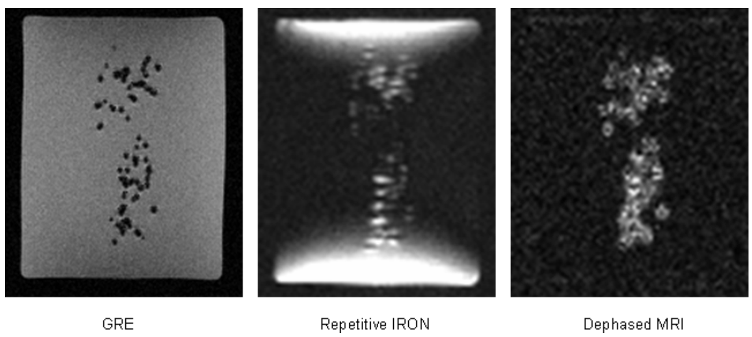


Figure 2: adiabatic IRON with repetitive inversion pulses (top: sequence scheme, bottom: time course of longitudinal magnetization).

Results and Discussion

Figure 3 shows the results of the phantom measurements. For comparison another bright iron image is shown (Dephased MRI [6]). Repetitive IRON is much faster than other off-resonance imaging techniques. However, careful shimming has to be performed in the target region. The air-agarose interfaces at the top and bottom of the phantom induce a frequency shift of about 50 Hz, which is enough to let the preparation fail. Dephased MRI, which is sensitive to the local field gradient only, is more robust. Because the method proposed here is so fast, it is feasible to acquire images with different frequency offsets for the inversion pulses to do a kind of saturation spectroscopy and compensate for a bad shim.



In conclusion, our method is fast and suppresses resonant water protons over a wide range of T_1 relaxation times.

Figure 3: Agarose phantom with embedded iron-loaded microbubbles.

References

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