Double Half RF Pulse for Reduced Sensitivity to Linear Eddy Currents in Ultrashort T2 Imaging

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Introduction

Imaging of short T_2 species generally uses half RF pulse excitation to achieve ultrashort echo times[1-3]. Two excitations with the slice-select gradient of opposite polarity are applied and the MR signals are added to form the desired slice profile. However, the half-sinc excitation pulse is very sensitive to gradient imperfections such as eddy-current distortions[4]. Each half pulse excitation individually is not very selective, and excites signal far from the intended slice location. In the presence of eddy currents, the magnetization from out of the slice does not cancel appropriately. The purpose of this work is to investigate a novel half RF pulse which makes short T_2 imaging and quantitation less sensitive to eddy currents. A full RF pulse is split in time and referred to here as a double half RF pulse.

Method

The proposed pulse, like the half pulse excitation, consists of two excitations with the slice-select gradient polarity inverted, as shown in Figure 1. Each excitation produces a half-sinc weighting in k-space for short T_2, and ideally, a full-sinc weighting for long T_2. In actuality, the pulse amplitude is modulated by T_2 decay. Solving the Bloch equation numerically for short T_2 (1ms) and long T_2 (50ms) provides a simulation of the slice profiles as a function of T_2.

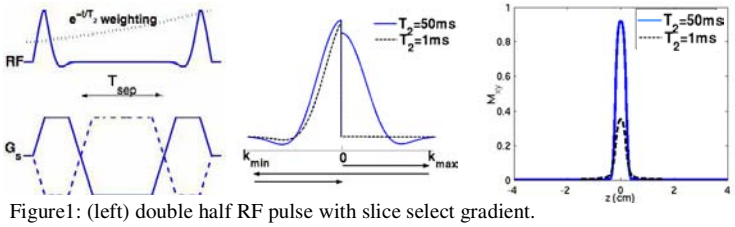

Figure1: (left) double half RF pulse with slice select gradient. (center) weighting in excitation k-space for different T_2s. Arrows show the k-space trajectory. (right) simulated slice profile for combined excitations.

Experiments were performed on a 0.5T GE Signa SP interventional MR scanner. A spherical phantom with a long T_2 was imaged with a radial acquisition (TE =100μs) with both the half pulse and the double half pulse. The slice profile was measured by reading in the slice select direction. The free induction decay(FID) signal was also measured with both pulses. The double half RF PR sequence was used in an *in vivo* canine prostate during cryoablation. R_2* maps were obtained from images at echo times of 0.1, 0.4, 0.7, and 1.0 ms

Results

Short time constant linear eddy currents cause distortion of the applied gradient waveform. Figure 2 demonstrates the effectiveness of the double half pulse in the presence of eddy currents for a T_2 of about 60ms. The half RF pulse has tails that extend far from the desired slice, while the double half RF demonstrates much better selectivity. In the presence of eddy currents, the slice selectivity of the half pulses vary over time, so that the FID demonstrates an oscillating behavior. The FID for the double half RF decays without oscillation.

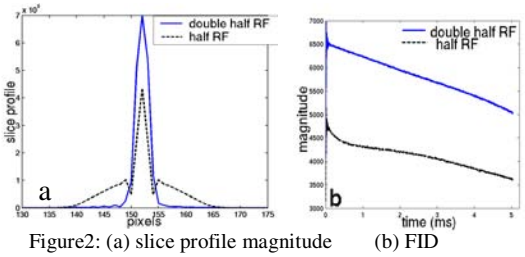

Figure2: (a) slice profile magnitude (b) FID

Figure 3 shows images of a phantom for the half RF and the double half RF pulse. The phantom consists of vials with T_2 values ranging from 0.5ms to 20ms. The long T_2 has greater signal with the double half pulse as it experiences two full-sinc excitations. The short T_2 has slightly lower signal due to incomplete T_1 recovery during T_{sep}. Images from the *in vivo* canine prostate cryoablation are shown in Figure 4. These images were obtained without any linear eddy current compensation. Figure 4a is the coronal image with frozen tissue around the two cryoprobes. Figure 4b is the R_2* map obtained by an exponential fit of the images acquired at different echo times.

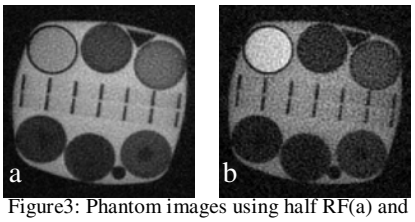

Figure3: Phantom images using half RF(a) and double half RF (b). TE=100μs. T_2 values are- Left to right, top row: 20ms, 0.9ms,1.5ms Bottom row: 0.8ms, 0.5ms,1ms

Discussion

With the double half pulse, the slice profile for the long T_2 components is improved for each excitation, so that imperfect cancelation of signal from out of slice long T_2 components does not contribute to the signal. This is important when R_2* maps may be contaminated by out of slice signal due to eddy current distortions. Off-resonance due to B_0 inhomogeneity and chemical shift causes phase to accumulate during the T_{sep} interval between the two half pulses in a single excitation, and can result in partial cancelation of signal.

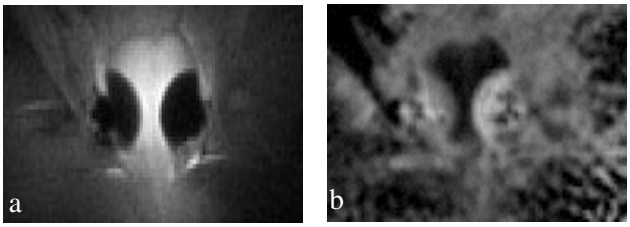

Figure4: (a) *In vivo* canine prostate cryoablation image (TE=100μs). (b) R_2* map demonstrated elevated R2* in the frozen tissue.

References

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