Using Adiabatic Inversion Pulses to Suppress Long-T₂ Species in Ultra-short Echo Time (UTE) Imaging

P. E. Larson¹, J. M. Pauly¹, D. G. Nishimura¹, S. M. Conolly²

¹Electrical Engineering, Stanford University, Stanford, CA, United States, ²Bioengineering, University of California-Berkeley, Berkeley, CA, United States

Introduction:

Ultra-short echo time (UTE) imaging can visualize short-T₂ species that are normally invisible and has possible clinical applications [1-3]. Long-T₂ species will dominate the images unless they are suppressed. RF pulse methods of long-T₂ suppression have been used before [4], but they respond poorly to off-resonance and variations in RF power. We have investigated the use of adiabatic pulses to better suppress long-T₂ species.

Theory and Methods:

When amplitude-modulated pulses have a long duration and low amplitude, short-T₂ species are unaffected by the pulse [4]. Similarly, adiabatic pulses of sufficiently low amplitude and narrow bandwidth will not excite short-T₂ species. To minimize short-T₂ attenuation, a near minimum amplitude should be used. This requires a long duration to maintain adiabaticity for long-T₂ species.

Experiments were performed on a GE Excite 1.5T system. Inverted images were acquired by using an inversion pulse followed immediately by a dephaser and then a half-pulse excitation.

Results:

Figure 1 shows the T₂ profile of two 10 ms adiabatic sech inversion pulses with parameters shown. T₂s of a few hundred µs are not inverted, while T₂s near 100 ms are fully inverted. There is more short-T₂ attenuation during Inversion 2 because it has a wider bandwidth requiring a larger amplitude.

The figure 2 contour plots of MZ show that RF amplitude variations of ±20% are tolerated by both inversion pulses, which is not true for amplitude-modulated pulses [5]. The wider bandwidth of Inversion 2 is shown.

Figure 3 shows phantom images using the Inversion 1 pulse. The short-T₂ phantom (0.35 ms) is unaffected by the pulse, the medium-T₂ phantoms (4 and 6 ms) have been nulled, and the long-T₂ phantoms (50 and 100 ms) are inverted. When the non-inverted and inverted images are combined, the long-T₂ phantoms are suppressed. The inverted image is also separated by phase into short (3d) and long (3e) T₂ images.

Discussion:

There are multiple possible techniques to remove long-T₂ species using adiabatic inverted images. The images can be separated based on their phase to produce short and long T₂ images, as shown in figure 3d,e. Combining an inverted and non-inverted image will suppress long-T₂s, as shown in figure 3c. Inverted water and inverted fat images can be combined for long-T₂ and fat suppression. These combination techniques are SNR efficient because both images have short-T₂ signal. Image subtraction using a later echo only contributes noise to short-T₂s.

Conclusion:

Long adiabatic inversion pulses of low amplitude and bandwidth do not invert short-T₂ species and can be used in UTE imaging to suppress long-T₂ species. They are particularly robust to RF variations and also have reasonable off-resonance bandwidths. They can be used in multiple robust long-T₂ suppression techniques for UTE imaging.

References: