Inverted Double Half RF Pulses: Improved Selective Excitation of Short T2 Components in 3T Joint Imaging

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Introduction: Ultra short TE (UTE) imaging with half pulse excitation and center out trajectories reduces the minimum echo time to ~200us dramatically improving visualization of short T2 species(1). However, with half pulse excitation signal from short T2 components is often obscured by strong signal from fat and long T2 tissues. Fat saturation preparation pulses such as ChemSat pulse and double inversion recovery pulse can be used to suppress fat signal and enhance short T2 species contrast. These magnetization preparation methods are time consuming and worthy of further investigation. Inverted double half RF pulse (IDHRF) as described by Sonal J et al, selectively excites short T2 and improves out-of-slice cancelation results from eddy current errors (2). Sonal showed promising result with phantom study at low field strength (0.5T) for interventional application. In this work, we redesigned this pulse to provide fat suppression without using fat saturation preparation pulses. We investigated the use of this method at high field strength (3T) and demonstrate the capabilities of this pulse in musculoskeletal imaging of patella, tendon and ligament.

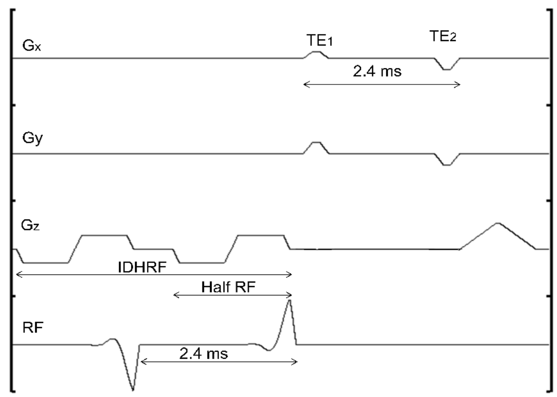

Figure1. IDHRF pulse sequence

Methods: A 2D UTE sequence was implemented on a 3T Signa MR750 (GE Systems, Waukesha, WI) with the pulse sequence diagram shown in Figure 1. A pair of half sinc pulses with opposite polarity are played during each excitation followed by center-out radial data acquisition. In this work, the separation time between the two half pulses is designed so that the lipid spins will be in phase by the end of each excitation, so the second half pulse will tip the lipid spins back to longitudinal axis. For better short T2 contrast, a second image is acquired at later echo time and subtracted from first image. The time between the two echoes is also chosen so that lipid spins are in phase by end of the second echo for more fat suppression. For each pair of RF pulses, a precompensating negative gradient lobe was added before the slice-select gradient for better eddy current cancelation as suggested in (2).

Experiments were performed on a phantom and a healthy volunteer to demonstrate the potential of this method at 3T. The phantom consists of four vials: one filled with vegetable oil (representing fat) and three filled with distilled water doped with different concentrations of Copper Sulfate ($CuSo_4$) leading to transverse relaxation times of 100ms(water vial), 2ms and 0.5ms. Imaging parameters for the phantom study included: TE_1 = 0.2ms,TE_2=2.4ms, BW =+/-125 kHz, TR = 30ms and 15 flip angle. Volunteer study parameters included: TE_1 = 0.2ms, TE_2 =2.6ms, TR =400ms (actual imaging time is 10ms), flip =22, BW = +/_125kHz and FOV = 15cm. scan time was 4min per slice.

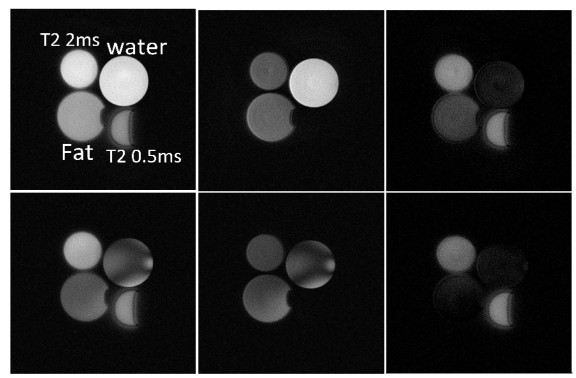

Figure 2. Short TE (0.2ms) and long TE (2.4ms) and difference images of half RF (Top) and IDHRF (bottom). IDHRF suppress water in short TE excitation and most of fat signal. Fat is highly suppressed in IDHRF difference image.

Results: No eddy current correction was used in any acquisition. Figure2 illustrates the short echo (0.2ms), late echo (2.4ms) and subtracted images for half pulse and IDHRF UTE sequences. Both sequences showed signals from short T2 vials. In short echo images, fat signal is reduced by 50% in IDHRF image compared to half RF UTE. Subtracting short and long echo time images with half-pulse UTE results in reduced fat signal but the signal is substantially higher than with the IDHRF method with two echo subtraction. Difference images of later echo (2.4ms) subtracted from early echo (0.2ms) for IDHRF and half RF pulses are shown in figure 3. The contrast of the origin of PCL (big arrow) and deep layer cartilage (small arrow) is improved in the IDHRF image compared to the half RF image as a result of increased fat suppression in bones. Suppression of fat in the fat pad behind the patella in the IDHRF image is also improved. Patellar tendon is highlighted in both images with better contrast in IDHRF image. In this work, one slice acquired only per TR. In future work, up to 40 of interleaved slices per TR could be acquired.

Figure 3. Difference images of half RF (left) and IDHRF (right) pulse sequence are shown. The contrast of origin of PCL (thick arrow) and deep-layer cartilage (thin arrow) is improved in IDHRF image compared to half RF, as well as quadriceps tendon (large arrow head)and periosteum (small arrow head)

Conclusion: The Inverted double half pulse with time delay between the two half pulses selected for fat saturation, improves fat suppression and increase the dynamic range for short T2 components at no additional cost in imaging time.

References: [1] Pauly JM et al. SMRM 1989:p28. [2] Sonal J et al.MRM 2009:61:1083-1089.

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