Fat/Water Separation using a Divided Inversion Recovery Technique (DIRT)

J. W. Goldfarb[1], N. Reichek[1]

[1]Department of Research and Education, Saint Francis Hospital, Roslyn, NY, United States

Introduction: In the Dixon Method, fat/water separation is accomplished using phase detection. There is a phase difference between lipid and water signals due to different resonant frequencies. We present a phase-based technique that uses T_1 recovery to alter the phase of short T_1 lipid signals. After an inversion pulse, one can introduce a phase shift by using a recovery time such that short T_1 species have passed through the null point (M_z=0) while longer T_1 species have not (M_z<0). Image reconstruction is identical to the Dixon phase based technique, but the quality of the separation will not be dependent on resonant frequencies and therefore is not affected by main magnetic field inhomogeneities.

Lipid rich tissues have relatively short T_1 times, on the order of 200ms. After an inversion pulse and SSFP acquisition, they recover their magnetization quickly (M_z>0). Tissues with longer T_1 times remain inverted (M_z<0) and the longitudinal magnetization would now be out-of-phase. If the magnetization is subjected to another inversion pulse and a second SSFP acquisition, longer T_1 tissues will be out of phase relative to long T_1 species in the first acquisition and lipid signals in the both acquisitions. This is illustrated in Figure 1. The Divided Inversion Recovery Technique (DIRT) utilizes a 180 degree preparatory rf pulse with a gradient refocused readout to produce an image divided into two parts (see Fig. 2). Contribution to each part of the image is dependent on the individual T_1 times.

Methods: All imaging experiments were performed on a 1.5T whole body MRI system (Magnetom Siemens Sonata, Erlangen,Germany). Nine subjects participated in this study. Imaging was performed using an inversion recovery TrueFISP sequence (TR/TE/FA=2.4/1.2/50; Matrix=256x512; Voxel size=2x1.8x8mm; 128 phase encoding lines per segment; interleaved segments; 1 dummy heartbeat; BW=1180 Hz/pixel with linear filling of k-space). Region-of-interest signal intensity measurements were made in fatty regions of the heart and chest in both the water and lipid images. The ratio was calculated to determine the effectiveness of the method and signal measurements were compared using a paired student's t-test.

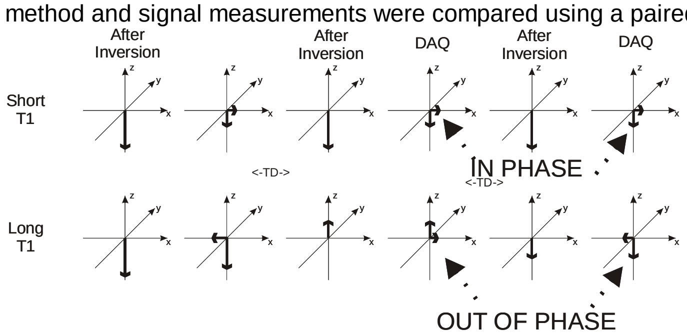

Figure 1: Diagram shows the evolution of magnetization in the DIRT sequence. During two data acquisition (DAQ) periods, Short T_1 species remain in phase while Long T_1 species are out-of-phase. Which species are out-of phase is determined by the longitudinal magnetization recovery during the delay time (TD) between data acquisition and inversion.

Results: Fig. 2 shows axial images through the aortic root/pulmonary artery and the heart, respectively and a para-sagittal image through the aorta. Water/lipid separation is effective even in regions with main magnetic field inhomogeneities (note the black SSFP lines in the lipid images). Fat signal intensity was suppressed by a factor of 48±29 with a min of 18 and a max of 108. The signal measured in the divided images was significantly different ($p \ll 0.01$).

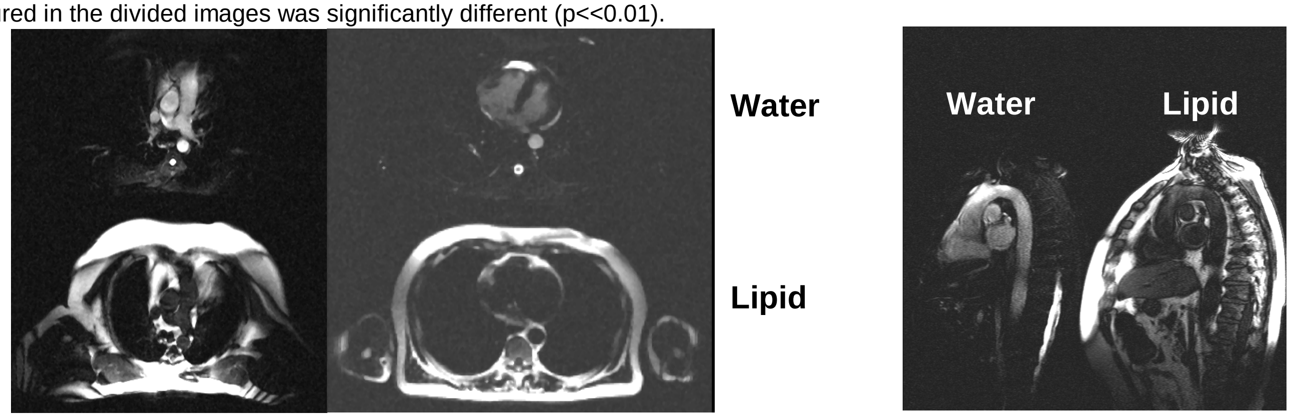

Figure 2: Examples of Water/Lipid Separation using the Divided Inversion Recovery Technique (DIRT): Each set of images was acquired in three heartbeats. Water images retain signal from blood and fluid. Lipid images have signal from body fat.

Conclusions: Fat saturation using a chemically selective rf pulse is difficult in SSFP imaging due to the continuous pulsing required to maintain a steady-state. The DIRT technique utilizes the short T_1 of lipid tissues as is commonly used in STIR (Short TI Inversion Recovery) to provide fat/water separation using an inversion pulse and SSFP acquisition. SSFP images are typically acquired such that water and fat signals are 180 degrees out of phase (TE=TR/2). Pixels having signal contributions from both water and fat molecules will have signal cancellation and produce black line artifacts. The DIRT technique removed the black line artifact resulting from this out of phase signal cancellation. DIRT may find use as a fat saturation alternative for MR Angiography and for the identification of lipid pathology such as lipomas and fatty infiltration of the right ventricle.