Water-fat Separation Based on T1 Relaxation Times using Inversion Recovery bSSFP MR Imaging

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Introduction: MR imaging tissue separation techniques provide multiple images of the same imaging plane with pixels separated by an intrinsic tissue parameter. Water-fat separation is the best known and typically provides two images with pixels comprised primarily of lipids displayed in the fat image and the other pixels composed primarily of water are displayed in the second image. Fat-water separation is most commonly performed using the parameter of resonant frequency.

Image separation can also be performed using other parameters such as T_1 relaxation times or T_1-weighted imaging pixel intensity. In spoiled gradient echo images, fat usually has the brightest signal and water-fat separation can be performed using a simple image intensity threshold. Recently, an artifact was identified during delayed hyperenhanced (DHE) myocardial infarct imaging using an inversion recovery balanced steady-state free precession (IR-bSSFP) technique [Magn Reson Med, 2005; 54(2): 481-485]. This artifact is a displacement of tissues and was shown to be due to a phase change of the magnetization resulting from incomplete magnetization recovery. This newly recognized artifact in IR-bSSFP imaging is a direct result of the gradient refocusing and the reuse of magnetization. The phase change causes a displacement of signals from long T_1 species (cerebrospinal fluid and cysts). With specific imaging parameters (which are commonly used in DHE infarct imaging) long T_1 species are displaced by half of the field-of-view. The change in magnetization phase using this type of sequence is illustrated in Figure 1.

The purpose of this study was to further develop and evaluate an IR-bSSFP pulse sequence which exploits the change in phase of magnetization after inversion due to incomplete T_1 recovery and apply the technique to fat-water separation of the heart. Such a sequence could provide robust tissue separation based on T_1 magnetization recovery differences.

Materials and Methods: All imaging experiments were performed on a 1.5T whole body MRI system (Magnetom Siemens Sonata, Erlangen, Germany). Six subjects participated in this study (Age: 65.7±7.0 years). Multi-slice short-axis cardiac 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 the LV bloodpool, epicardial fat, pericardial fluid or CSF and outside of the body in the same locations in both water and fat images. Signal intensities were compared using a paired student's t-test to evaluate the quality of the technique's water-fat separation.

Results: Images from a representative subject are shown in Figure 3. In the study group water-fat separation provided statistically significant ($p<0.05$) fat and water suppression. Signal suppression was on the order of the background noise (see Figure 2).

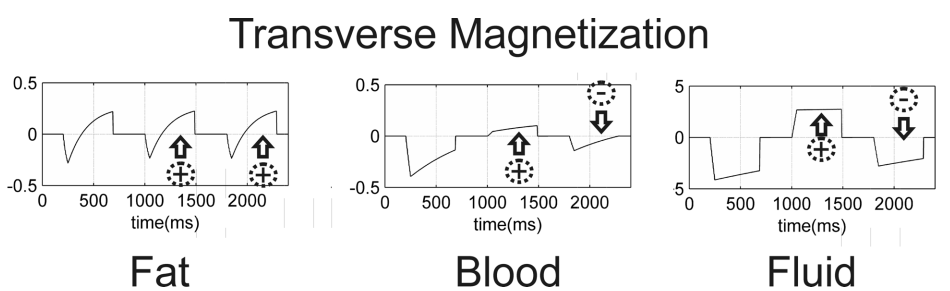

Figure 1: Bloch simulation shows the magnetization for fat, blood and fluid during the pulse sequence. Data acquisition is performed in two segments (arrows) preceded by a single identical preparation segment. Due to their longer T_1s, the magntization of both blood and fluid has a change in polarity, having positive and then negative magnetization. Fat on the otherhand remains positive. This change in phase allows efficient tissue separation similar to the DIXON method.

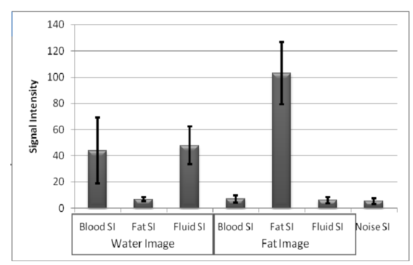

Figure 2: Region of interest measurements show that the fat signal is on the order of the noise in the water image and the fluid and blood signals are on the order of the background noise in the fat image ($p<0.05$).

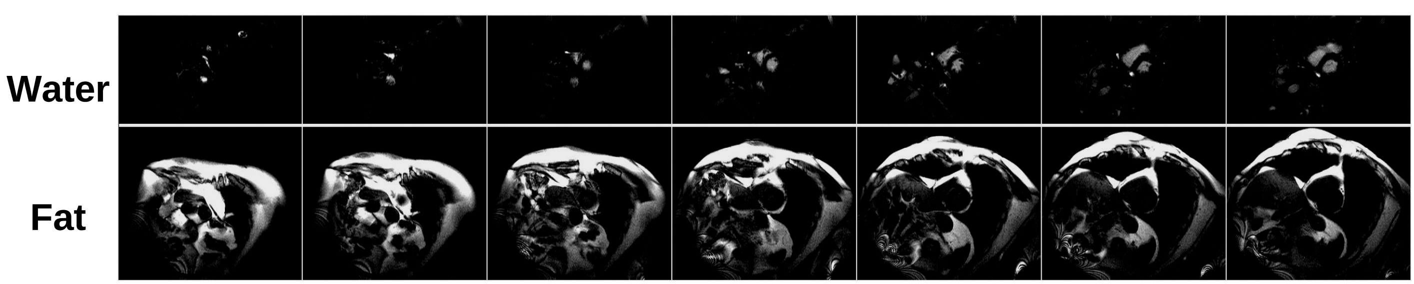

Figure 3: Short axis water-fat separation images. Each slice location was acquired in five heartbeats. Water-fat separation is achieved based on T_1 differences rather than resonant frequency differences and is therefore insensitive to magnetic field inhomogeneities.

Conclusions: Water-fat separation based on T_1 relaxation times can be effectively performed using an IR-bSSFP acquisition. The technique provides suppression on the order of the background noise and is insensitive to magnetic field inhomogeneities.