Fat-water separated imaging at 7T: initial results for cardiac applications

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Introduction

Fat-water separated imaging [1] is an important tool used in characterizing tissue, quantitative measurement of fat fraction, and in suppression of bright fat signal that may otherwise obscure the water signal of interest. In the heart, fat-water separated imaging [2] provides a sensitive means of detecting intramyocardial fat, characterizing fibrofatty infiltration, characterizing fatty tumors, and delineating epicardial and/or pericardial fat. At higher field strengths such as 7T, conventional chemical shift fat suppression is problematic due to variations in B0-field, B1 transmit variation, and the increased SAR associated with adiabatic inversion or saturation pulses. Multi-echo "Dixon" like approaches which jointly solve for the water, fat, and frequency map have potential to provide a high degree of water and fat separation at higher fields. Initial results for fat-water separated imaging at 7T are provided for application to cardiac imaging.

Methods

Imaging was performed using a Siemens (Erlangen, Germany) 7T whole body MRI system with a custom 16 element TX/RX coil array. A multi-echo GRE sequence with monopolar readout using gradient flyback was used to a mid-diastolic phase image in a cardiac gated, segmented manner. Cardiac gating was implemented using a MR stethoscope [3] to overcome interference associated with conventional ECG monitoring at high field. A multi-shot approach was used to reduce the effective echo spacing. Two protocols were evaluated: 4 echoes using 4 shots, and 8 echoes using 4 shots with interleaving. Typical parameters were: 256x144 matrix, 4 mm slice thickness (to reduce T2* losses), 1028 Hz/pixel bandwidth. For the 4 echo protocol, echo spacing was 0.24 ms, 1 echo per shot (TR=5.7 ms), 8-10 PE lines per heartbeat (32-40 shots), 175-220 ms imaging duration per heart beat, 16-19 heart beats total acquisition including 1 discarded beat. For the 8 echo protocol, echo spacing was 2.18 ms, 2 echoes per shot (TR=7.8 ms), 6 PE lines per heartbeat (24 shots), 188 ms imaging duration per heart beat, 25 heart beats total acquisition. For these echo spacings, the effective number of averages was very close to optimum. Shimming was optimized in a rectangular region encompassing the heart. Water-fat separated image reconstruction used a multi-echo Dixon like technique based on the VARPRO formulation with graphcut optimization [4] to jointly estimate the water, fat, fieldmap, and T2*. A pre-calibrated multipeak fat model with 6 peaks was used. Images were reconstructed in SNR units based on prescan noise measurement [5]. Measurements on normal volunteers included SNR, fat water separation, and field map variation.

Results

Fat and water were correctly classified (Fig 1) and good separation was achieved across the full field of view (N=6 subjects). Fat suppression was estimated in water regions to be greater than 30:1 across the FOV. The fieldmap variation (Fig 2a) was typically 150 Hz across the heart. SNR (Fig 2b) of the LV myocardium was in the range 100-200 (for case of 8 echo acquisition).

Discussion

Fat-water separated imaging at 7T has been demonstrated using a multi-echo Dixon like approach for cardiac application providing excellent fat water separation. Fat water separated imaging at 7T has unique challenges due to the increased fieldmap variation, T2* dephasing, and larger chemical shift. A multishot approach was used to achieve shorter echo spacing, and decreased slice thickness was used to reduce T2* losses. Improvements to the B1 uniformity are expected to improve the SNR and uniformity of contrast between blood and myocardium. Fat suppression is believed to be limited by eddy currents and is being investigated. In the current results, precalibrated spectra were based on measurement at lower field strength; calibration at 7T is planned. A limitation of the current implementation was the inability to achieve a dark blood preparation using double inversion recovery. Initial results are encouraging, and performance is expected to improve.

References

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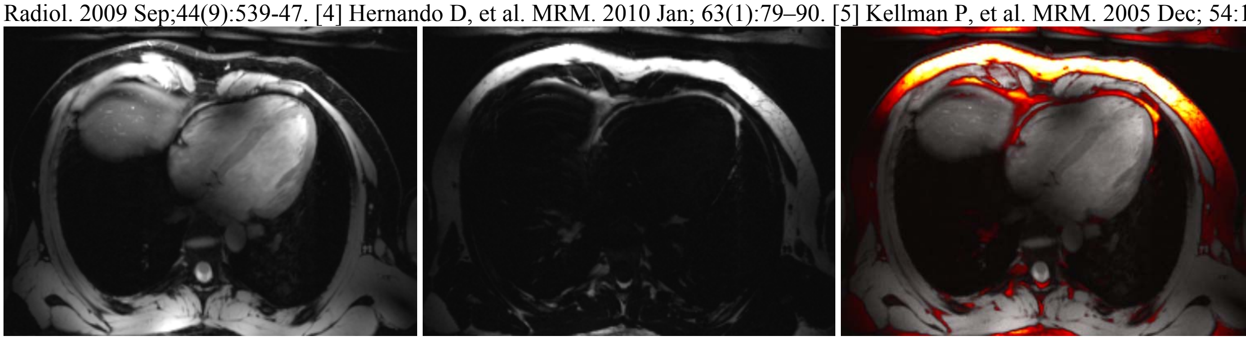

Figure 1. Water (left), fat (center), and combined fat (red) plus water (right) images for normal volunteer acquired at 7T.

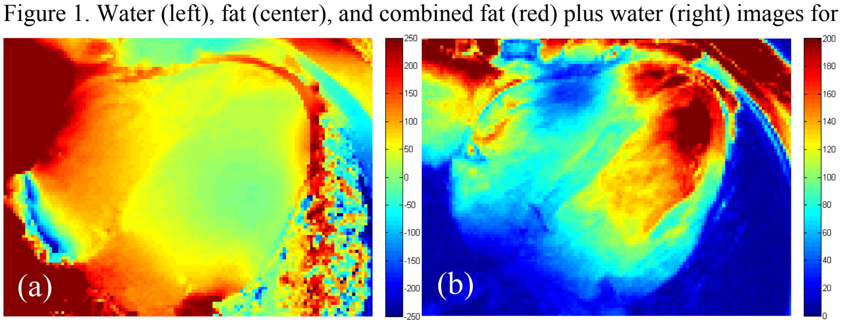

Figure 2. (a) Fieldmap in heart region (left) after local shim with residual variation of approx 150 Hz; (b) SNR map in heart region with LV myocardial SNR in range 100-200.