Two-dimensional mapping of triglyceride and creatine content of the human heart

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Introduction

Single voxel proton magnetic resonance spectroscopy has been shown to be a promising tool for assessing triglyceride and creatine content of the human heart [1, 2]. While information from a single voxel is valuable in circumstances where the entire ventricle is affected, two-dimensional information is required to map regional differences. A recent implementation of 2D spectroscopic imaging employing local-look excitation and navigation for respiratory compensation has shown promise for studying triglyceride and creatine content of the heart [3]. The objective of the present work was to assess the utility of 2D local-look Echo-Planar Spectroscopic Imaging (EPSI [4]) in a series of volunteers. As an important component field map data were acquired upon shimming along with measurements of water line widths to investigate reproducibility and robustness of 2D EPSI as part of regular cardiac protocols.

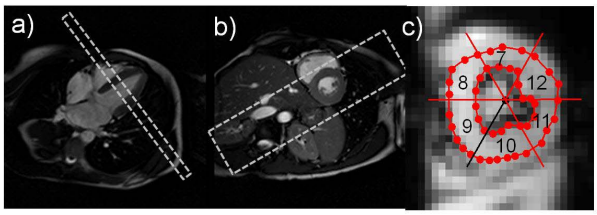

Figure 1: Position of the slice a) and the field-of-excitation (FOX) b) of the EPSI acquisitions. c) Integral of the water peak of a water unsuppressed EPSI scan. The myocardium was segmented according to the AHA segment model for the mid-cavity region.

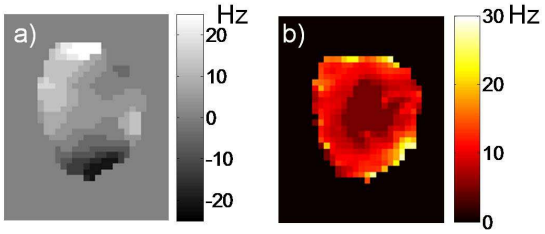

Figure 2: a) B_0 variations estimated from the water peak resonance in the water unsuppressed reference scan. b) Resulting line broadening of the water peak. In the septal region line widths are smaller than 15 Hz. In the anterior wall line widths up to 25Hz are found.

Methods

Local-look navigator gated and cardiac triggered spin echo EPSI was implemented on a 1.5T Philips Achieva system (Philips Healthcare, Best, The Netherlands). Prior to data acquisition automatic first order shimming of the volume-of-interest during a breath hold was performed. A slice of the mid-cavity region in short axis view was acquired (Figure 1). The EPSI sequence had the following parameters: echo time: 12 ms, field of view (FOV): 300x150mm^2, field-of-excitation (FOX): 70 to 85mm depending on heart size, spatial resolution: 3x3mm^2, slice thickness: 15mm, spectral bandwidth: 1064Hz, spectral resolution: 4.2Hz. The repetition time was 1 second on average and dependent on the heart rate. Data acquisitions were ECG triggered to end systole. An Ernst angle excitation was used to optimize the signal to noise ratio per unit time for the creatine resonance at 3.01ppm. Water-suppressed and unsuppressed 2D EPSI data were acquired in 9 healthy volunteers during free breathing in an average scan time of 2:30min per average. Eight signal averages were acquired for the water suppressed scans. Weighted gating was used to minimize respiratory motion with a gating window of 3mm for the central region (30%) and 5mm for the outer region of k-space. A frequency selective excitation pulse placed on the water resonance was used for water suppression just before signal excitation. Reconstruction parameters were estimated from the water unsuppressed data and were used for both water suppressed and unsuppressed scans. For analysis, the myocardial muscle was segmented according to the American Heart Association (AHA) 17-segment model [5] for mid-cavity region, resulting in 6 segments (Figure 1c). Spectra within the segments and from different averages were averaged after individual phase correction to ensure phase coherent signal addition.

Results

Field map values across the heart varied between -25Hz to 25Hz after shimming which led to line broadenings from 5 to 25 Hz within the myocardium (Figure 2). Line width variations across subjects were found to be 10.92Hz ±0.73Hz for the whole myocardium and 8.96Hz ±0.81Hz and 13.22Hz ±0.65Hz for the septal and the anterior region, respectively indicating sufficient reproducibility of the shimming quality for different subjects. Mean intra subject variations were found to be ±3.08Hz for the whole myocardium and ±1.46Hz and ±3.90Hz for the septal and the anterior regions, respectively. Representative spectra of segment 9 and segment 12 from 3 different subjects are shown in Figure 3. The small line width variations in the septal region allows for detection and discrimination of the resonance of trimethylammonium compounds (TMA) at 3.2ppm and creatine at 3.01ppm. However, the increased line width variations in the anterior region led to a degradation of the spectral quality in this region, compromising the separation of TMA and creatine. Furthermore water suppression quality was influenced by B_0-inhomogeneity in this region. Besides the TMA and the creatine resonance the resonances of unsaturated fat at 2.1ppm and the triglyceride resonance at 1.3ppm were detected in all subjects.

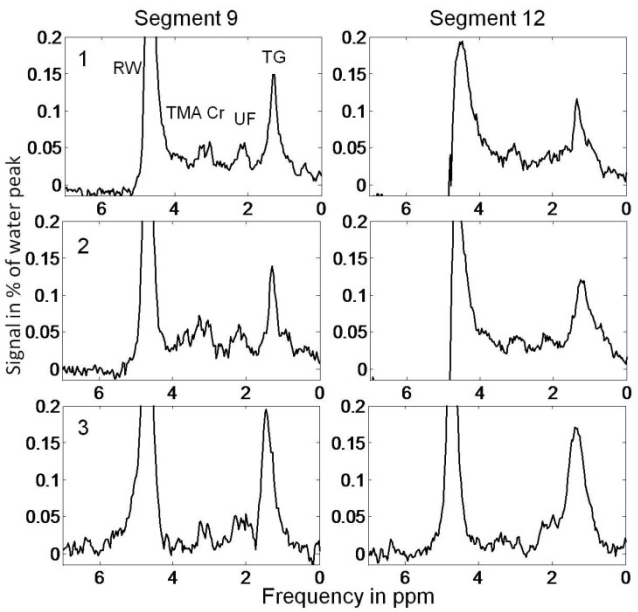

Figure 3: Spectra from 3 healthy volunteers (1, 2, 3) from segment 9 and 12 (see Figure 1). The residual water peak (RW) at 4.7ppm, TMA at 3.2 ppm, creatine (Cr) at 3.01ppm unsaturated fat (UF) at 2.1ppm and triglycerides (TG) at 1.3ppm are labeled. All labeled resonances can be discriminated in segment number 9. However due to line broadening in the anterior wall spectra from segment number 12 do not allow for differentiation of TMA and creatine.

Discussion

This work has demonstrated that triglyceride and creatine content can be assessed by means of 2D local-look EPSI during free breathing acquisitions. However line broadening due to susceptibility artifacts in the region of the anterior wall degrades spectral quality and emphasizes shimming as the limiting factor for spectral quality. For the present study only first order shim capabilities were available and it is speculated that higher order dynamic shimming can partially address the shortcomings faced in this study.

References

[1] Bottomley et al. Lancet 351 (1998), [2] Szczepaniak et al. Magn. Reson. Med. 49 (2003), [3] Weiss et al. Proc. ISMRM 18 (2010)
[4] Mansfield Magn. Reson. Med. 1 (1984), [5] Cerqueira et al. Circulation 105(4) (2002)