Fast 3D Quantification of Fat Liver Tissue Using Sequentially Shifted echo times and a singular value decomposition matrix pencil method

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INTRODUCTION: An accurate quantification of the fat liver fraction is of increased clinical value, as for the follow-up of patients suffering from non-alcoholic fatty liver disease (NAFLD) having a high prevalence in the western world [1]. MR spectroscopy is currently the gold-standard for non-invasive quantification of liver fat, but requires a complicated setup and does not offer whole organ coverage. As a result, alternative MR imaging techniques, such as common 2-point or 3-point Dixon techniques [2, 3], or other multi-echo imaging techniques [4, 5] were developed for quantification of liver fat. Here, we present an new 3D multi-contrast gradient echo (GRE) technique using a singular value decomposition (SVD) matrix pencil method for calculation of in vivo water-fat fractions and the T2* maps of the liver within a single breath-hold [6].

METHODS: Multi-contrast in vivo 3D GRE images of the liver were acquired in a single breath-hold. Experiments were performed at 3T on a clinical scanner on healthy volunteers and on a patient with fatty liver. Twelve echoes were acquired with a modified 3D GRE sequence using sequentially shifted echo times (ΔTE) to allow a fast sampling of the signal time course. Scan parameters were: α = 11°, TE_1 = 1.36ms, $TE_n = TE_{n-1}+\Delta TE$, ΔTE = 1.15ms, TR = 20ms, 2×2×4mm^3 resolution (8 slices), bandwidth/pixel = 947 Hz, total scan time ~ 20 sec). For comparison, a common 2-point Dixon analysis was performed using a standard 3D GRE approach.

The signal time course of each voxel was analyzed based on a spectroscopic approach, proposed by Lin et al. [6]. This allowed an extraction of the water and fat components, as well as of the corresponding T2* relaxation times using an SVD analysis of the magnitude signal, while the phase images were used for proper water fat identification.

RESULTS: In Fig. 1, the signal time course of a region of interest (ROI, see Fig. 2) attributed either with water or fat is shown. For the fat signal, a prominent oscillation in the phase can be observed, as expected, whereas the water shows only a pronounced phase drift.

Exemplary, water and fat images with corresponding T2* relaxation maps derived from singular value decomposition are shown for normal appearing liver tissue in Fig. 2 and 3. Overall, a lower fat fraction was observed using the SVD approach (2.4 ± 0.9%), as compared to the 2-point Dixon technique (6.7 ± 1.2%).

Water and fat images of a NAFLD patient are shown in Fig.4. In agreement with literature [4], liver fat maps in volunteers revealed a fat percentage below 5% while for the patient, a fat percentage above 10% can be expected.

DISCUSSION/ CONCLUSION: The proposed multi-echo GRE with sequentially shifted TE offers short echo spacings and allows whole liver coverage within a single breath-hold. As compared to common Dixon techniques, the SVD analysis offers a spectroscopic imaging approach that yields additional tissue information, such as T2* relaxation times or chemical shifts. Moreover, SVD provides a robust way for fast and reliable analysis of water and fat signals.

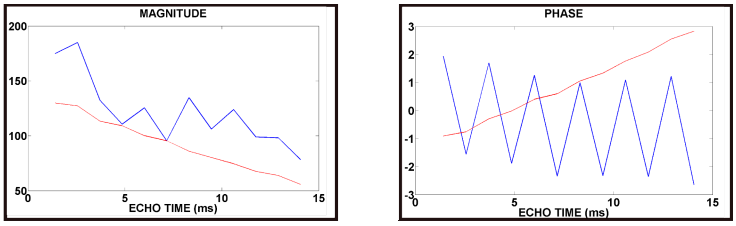

Figure 1: Signal time course (magnitude and phase) of adipose tissue (blue) and for liver tissue (red) in a region of interest (for ROI definition, see Fig.2).

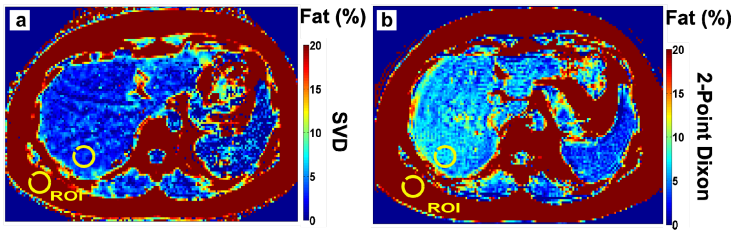

Figure 2: Normal appearing liver fat fraction derived from (a) SVD decomposition (liver: *2.4* ± 0.9 %, subcutaneous tissue: *95.8* ± 3.9%), and (b) 2-point-Dixon (liver: *6.7* ± *1.2* %, subcutaneous tissue: *84.4* ± *1.5%*).

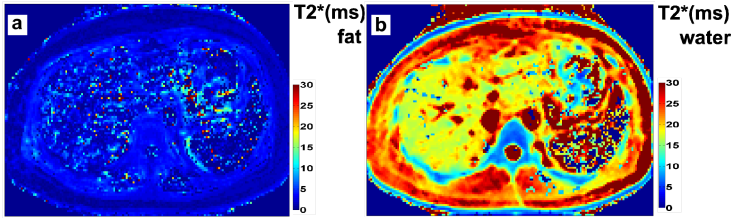

Figure 3: Normal appearing liver T2* derived from SVD decomposition: (a) fat T2* map (liver: *4.5* ± *1.7* ms), and (b) water T2* map (*17.2* ± *0.3* ms).

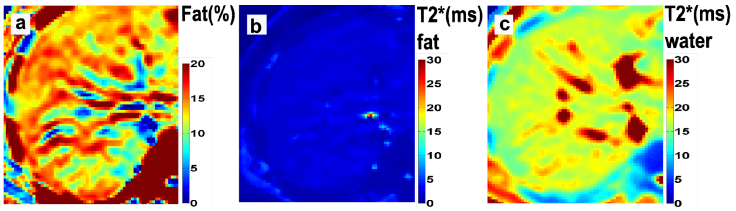

Figure 4: Liver sample images of a NAFLD patient: (a) fat fraction map (*10.8* ± *1.3* %), (b) fat T2* map *(2.6* ± *0.1* ms), and (c) water T2* maps (*18.3* ± *1.*0ms)

REFERENCES: 1. Browning et al., Hepatology 2004, 2. Raptis, Fischer, Graft el, gut, 2011, 3.Guiu et al. Journal of Magnetic Resonance 33:119-127 (2011) , 4. O' Regan et al. Radiology: Volume 247: Number 2- May, 2008, 5. Machman et al. 275 ESMRMB2011, 6. Lin et al. Journal of Magnetic Resonance 128, 30-41 (1997)