OPTIMIZATION OF A 3D DIXON MR IMAGING TECHNIQUES FOR FAT / WATER QUANTITATION

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Introduction: Reliable estimates of liver fat to water fractions have several important clinical implications [1]. Currently the gold standard for this information is liver biopsy, however non-invasive measurements are gaining clinical acceptance. In this work we evaluate a recently implemented 3D Dixon [2] method using a homogeneous fat-water phantom comprised of various concentrations of a soy oil emulsion. We performed spectroscopic validation of the fat water ratios and relaxation times on four concentrations expected in clinical situation.

Methods: The lipid water phantom was made using serial dilutions of 10, 15, 17.5 and 20% Intralipid (KabiVitrum Inc. Clayton NC) in 50 ml sample tubes suspended in a water phantom at room temperature. Intralipid is a homogenous suspension of soy oil in water formulated for intravenous infusion. Imaging was performed on a 1.5 Tesla Philips Scanner. T1 relaxation measurements were performed using a inversion recovery technique with TI of 24, 50 100, 200 400, 800 1600 and 3200 msec. T2 relaxation measurements were performed at 30, 40, 50, and 70 msec echo times (TR = 3 sec) with a single-voxel double-echo sequence, identical to the acquisition technique used for patient data collection. The 2D imaging was performed using standard SPGRE multi-slice technique in the coronal plane. 32 slices were acquired in a 2 minute scan with 256 by 256 in plane resolution. The 3D acquisition was also acquired with similar resolution, however 3 averages were used to improve signal to noise while keeping similar imaging times to the 2D technique. The use of in-phase and out-phase echoes, allows the generation of fat or water only images.

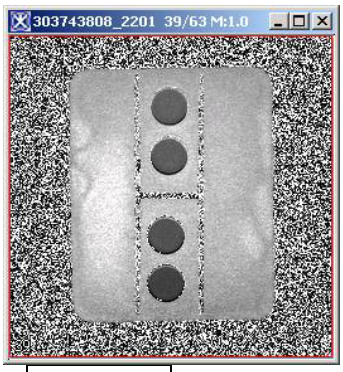

Figure 1a

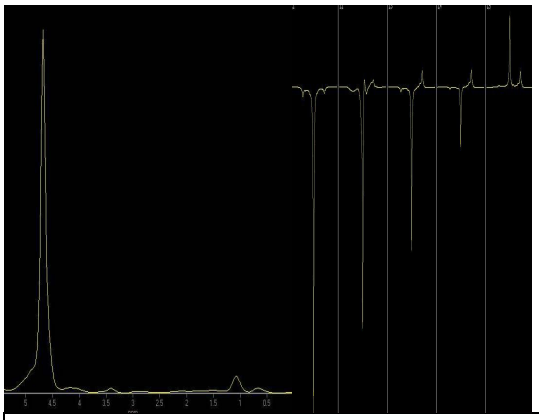
Figure 1b:

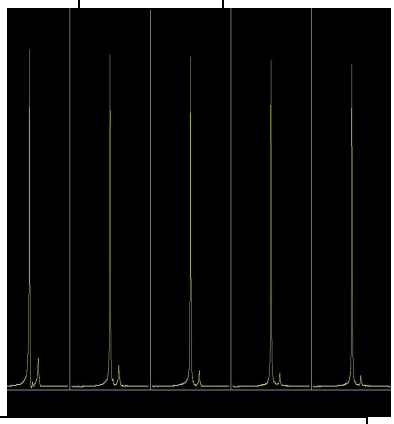
Figure 1c:

Figure 1d

Results and Discussion: Figure 1a shows a coronal T1 map image of the phantom surrounded by distilled water. Figure 1b shows a representative spectrum of the Intralipid solution (20%), the methylene and methyl resonances mimic the in vivo lipid spectrum. Figure 1c is an inversion recovery spectral data set, Figure 1d is a representative T2 measurement dataset. Shorter T1 and T2 for the methylene resonance are observed. The T1 and T2 of the water and methylene peaks were found to be 1273/503 and 139/45.5 ms, respectively. Results of simulation shows that there is a well defined flip angle dependence on the signal intensities from lipid and water based on the measured T1 and T2 relaxation. For the long TR 2D acquisition strategy, saturation effects begin to affect signal difference at a flip angle of 20°. Saturation effects begin to contribute to signal difference at 5° for the low TR, 3D acquisition strategy. Figure 2 shows an example of the flip angle dependence of the simulated signal of liver water and lipid for 50% ratio. The magnitude of the out-of-phase signal (diamond label) changes with flip angle. Using lower flip angles we were able to achieve good correlation to expected lipid-water ratios. At a flip angle of 5 ° the measured vs. expected lipid fraction were: 23, 21, 18, and 10 % for expected ratios of 20, 17, 15, and 10 %. While this phantom did allow validation of the techniques, one limitation is that the range of T1 and T2 values are higher than the in-vivo situation. The results show that in-phase out-phase "magnitude subtraction" technique has good signal to noise ratio and can qualitatively differentiate a range of fat water ratios. However, it suffers from the ambiguity of fat water ratios greater than 0.5 and does have some T1 saturation contribution to the signal difference when clinically relevant TR are shortened to achieve breath-hold scan times. Both effects can be compensated for with suitable correction.

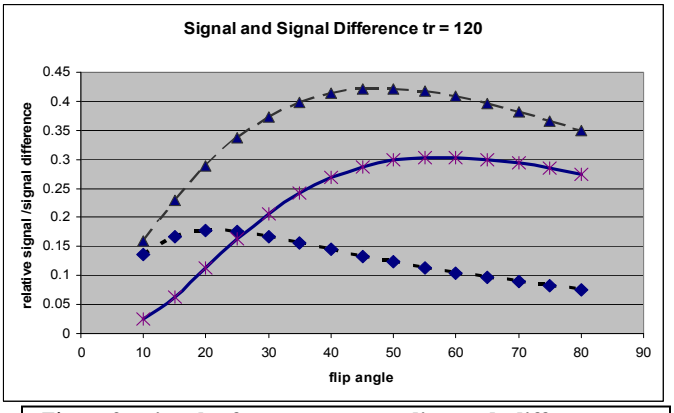

Figure 2: **triangle: fat, cross: water, diamond: difference**

Conclusion: Using a well characterized serial dilution lipid-water phantom we were able to simulate signal intensity results to determine the appropriate range of sequence parameter values over which we could experimentally validate measured lipid-water ratios on existing clinical 2D technique as well as using a recently available 3D Dixon technique.

References: Sebastian T. et al. Effect of Echo Time Pair Selection on Quantitative Analysis for Adrenal Tumor Characterization with In-Phase and Opposed-Phase MR Imaging: Initial Experience, *Radiology: Volume 248: Number 1—July 2008*. 2. Dixon WT. Simple proton spectroscopic imaging. *Radiology 1984; 153:189–194*.