

Validation of Chemical Shift Based Fat-Fraction Imaging with MR Spectroscopy

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Introduction: Nonalcoholic fatty liver disease (NAFLD) affects up to 30% of the US population and 75% of obese individuals (1). Liver biopsy is the gold standard for the detection and grading of steatosis but its clinical utility is limited because it is risky, expensive and suffers from high sampling variability related to the heterogeneous nature of intracellular fatty accumulation. Other noninvasive imaging techniques (CT, US) have a limited role in accurate grading of steatosis due to limited sensitivity and the use of ionizing radiation (CT). ¹H-MRS is regarded by many as the non-invasive gold standard for quantification of hepatic steatosis, but it is limited due to poor spatial coverage with a single voxel. The purpose of our study is to compare a chemical shift based fat-fraction imaging method (IDEAL) with ¹H-MRS for quantification of hepatic steatosis.

Methods: Our study protocol was approved by the Institutional Review Board and was HIPPA compliant. Informed written consent was obtained prior to all studies. Seventeen patients (age=24-71, 10 male and 7 female) referred for MRI of the liver (all indications) were imaged consecutively and prospectively. All studies were performed on a 1.5T Signa HDx scanner (GE Healthcare, Waukesha, WI) using an 8-channel phased array cardiac coil. An investigational version of a chemical shift based fat-fraction imaging method known as IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least squares estimation) combined with a 3D multi-echo spoiled gradient echo sequence (SPGR) (2) with T2* correction (3) was utilized. Acquisition parameters included: 6 echoes/TR, TR=13.7ms, TE_{min}=1.3ms, ΔTE=2.0ms, full readout, BW=±125kHz, FOV=35x35cm, slice=10mm, 256x128 matrix, 24 slices, and a total scan time of 21sec. A 2D parallel imaging acceleration method (ARC) (4) was used to reduce scan with an effective acceleration of 2.2. A 5° flip angle was utilized to minimize T1 bias between water and fat (5, 6) and a magnitude discrimination method was used to avoid noise related bias (5). In addition, accurate spectral modeling with a self-calibrated multiplet reconstruction was used to account for multiple fat peaks (7). Images were reconstructed with an on-line reconstruction algorithm. In order to investigate the effects of T2* correction and accurate spectral modeling (multiplet), fat-fraction images were reconstructed in four ways: with and without T2* correction and with and without multiplet reconstruction. Fat-fraction measurements were made for the four reconstructions from a region of interest that matched the location of the MRS voxel.

For comparison, single breath-hold MRS was performed by using single voxel STEAM (Stimulated Echo Acquisition Mode) without water suppression. A 2.5x2.5x2.5cm³ voxel was placed in the posterior segment of the right hepatic lobe free from large vessels. Acquisition parameters included: 2048 readout points, 1 signal average, TR=3500, and TE=10, 20, 30, 40, 50ms, all acquired in the same 21s breath-hold. All spectroscopy data were post-processed at a separate institution, blinded to the MRI results, using AMARES algorithm included in JMRUI to calculate fat-fraction by estimating the area under the water and total area under the fat peaks at 5.3 ppm, 4.3 ppm, 2.1 ppm, 1.3 ppm and 0.9 ppm peaks, including correction for relative differences in T2 decay between water and fat peaks (8).

Results: Figure 1 shows a calculated fat-fraction image with corresponding STEAM spectrum in a patient with steatosis. Figure 2 plots IDEAL fat-fraction against the MRS fat-fraction without T2* correction, for both single peak and multiplet reconstructions. Finally, figure 3 plots IDEAL fat-fraction against the MRS fat-fraction with T2* correction, for both single peak and multiplet reconstructions. Overall, excellent correlation was seen for all methods, however, the best agreement with MRS occurred when T2* correction and accurate spectral modeling was used ($r^2=0.96$, slope=1.01, intercept=2.0%). Multiplet reconstruction improved the slope such that there was a one-one correspondence with MRS, by including all spectral peaks of fat in the fat measurement. The major impact of T2* correction occurred at lower fat-fractions where a 4.6% bias occurred without T2* correction. This matches expected bias caused by T2* decay at low fat-fractions as recently predicted (9). Correction for T2* decay, reduced this bias to 2.0%. These results (with/without T2* correction and with/without accurate spectral modeling) agree with results from a similar method that used a magnitude fat quantification method with T2* correction and accurate spectral modeling (8). The T2* correction method also provides estimates of T2* in addition to fat-fraction. For the multiplet reconstruction with T2* correction, the average T2* measured over all 17 patients was 28.4 +/- 8.3 (range =14.5-42.9).

Discussion: This study demonstrates excellent correlation between a chemical shift based fat quantification method (IDEAL) and MR spectroscopy. Incorporation of T2* correction and spectral modeling of fat to the chemical shift based imaging method improves the correlation and one-one agreement.

References: 1. Browning JD et al. Hepatology 2004; 40:1387-1395, 2. Reeder et al. MRM 2005; 54: 636-644, 3. Yu H et al. JMRI 2007; 26:1153-1161, 4. Beatty et al ISMRM, 2007 pg 1749, 5. Liu CY et al. MRM 2007; 58:354-364, 6. Bydder M et al. Magn Reson Imaging. 2008; 26:347-359, 7. Yu H. et al. MRM 2008; 60:1122-1134, 8. Yokoo T et al. Radiology, 2008 *in press*, 9. Chebrolu VV et al. ISMRM, 2008 pg 1585.

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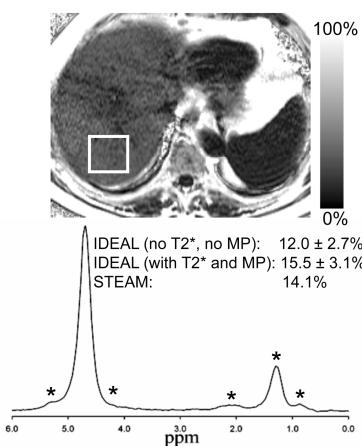


Figure 1: Fat-fraction measured in a patient with steatosis demonstrates excellent correlation between STEAM and IDEAL when multiplet reconstruction and T2* correction is used. The STEAM voxel (square) was acquired from the posterior segment of the right hepatic lobe. Note the multiple fat peaks in the spectra (*).

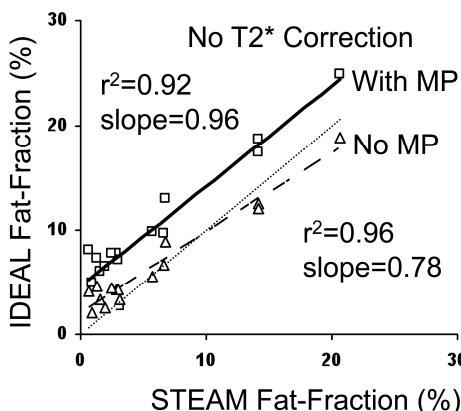


Figure 2: IDEAL vs. STEAM fat-fraction in 17 patients without T2* correction and with and without multiplet reconstruction methods shows excellent correlation, but with a large bias of 4.6%. The fine dashed line represents the line of unity.

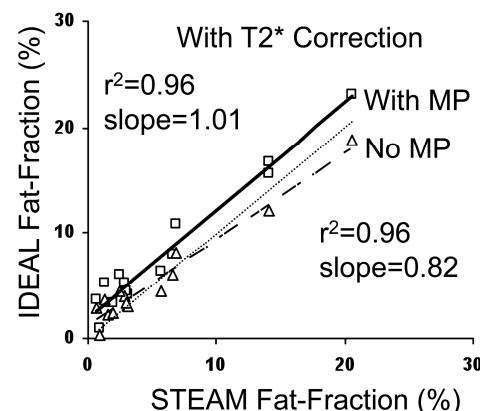


Figure 3: IDEAL vs. STEAM fat-fraction in 17 patients with T2* correction and with and without multiplet reconstruction demonstrates excellent correlation. Fat-fraction images reconstructed with accurate spectral modeling and T2* correction show excellent correlation with a slope of 1.01. The fine dashed line represents the line of unity.