Quantification of Hepatic Steatosis with IDEAL-SPGR: Correlation with PRESS Spectroscopy and Biopsy

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Introduction: Accurate non-invasive quantification of fatty infiltration of the liver (hepatic steatosis) is a critical unmet need in the diagnosis and management of chronic liver disease, particularly non-alcoholic fatty liver disease (NAFLD). Biopsy, the current gold standard, is very limited for accurate quantification of steatosis: biopsy has high sampling variability due to the heterogeneous behavior of fatty infiltration, it is expensive and it has non-trivial risks of serious complications including death [1]. In this work, we describe the use of IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation) combined with a 3D multi-echo SPGR sequence for quantification of hepatic steatosis [2,3]. Direct comparison of IDEAL is made with point-resolved spectroscopy (PRESS) and/or biopsy in patients with known or suspected steatosis.

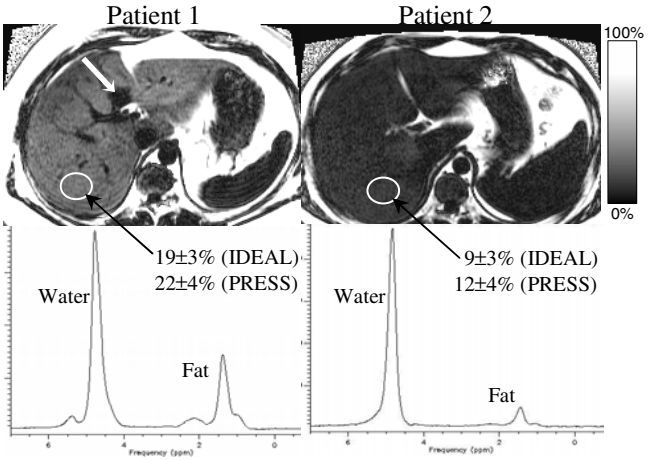

Fig 1: IDEAL fat-fraction images from 2 patients, and the corresponding PRESS spectra. Good agreement between IDEAL and PRESS was seen in all patients. Note the focal fatty sparing in patient 1, near the gall-bladder fossa (white arrow) in the medial lobe of the liver.

Methods: After obtaining IRB approval and informed consent, 6 patients with known or suspected hepatic steatosis were imaged with IDEAL. Imaging was performed on a 1.5T GE Signa "XMR" System (v12.0, GEHC, Waukesha, WI) with an adjacent fluoroscopy suite accessible to the MR scanner via sliding doors. All imaging was performed with an 8-channel phased array cardiac coil positioned over the liver. IDEAL imaging was performed using a 3D multi-echo spoiled gradient echo (SPGR) pulse sequence modified to ensure that echo times match those that optimize SNR performance of the water-fat decomposition [3,4]. IDEAL reconstruction was performed on-line using a region-growing algorithm to prevent water-fat swapping [5]. Acquisition parameters included: 3 echoes/TR, TR=7.4ms, TE=2.0/3.6/5.2ms, BW=±143kHz, FOV=35cm, slice=8-10mm, 224-256x160-192 matrix, 18-22 slices, total scan time = 18-22s. A 5° flip angle was used to minimize bias from T_1 differences between water and fat. Fat fraction images were calculated off-line using Matlab (Natick, MA) from separated water and fat images.

In 5/6 patients, breath-held spectroscopic acquisitions were performed in one or more locations using the point-resolved spectroscopic (PRESS) method [6], without water suppression. A cubic 2.0x2.0x2.0cm^3 volume was selected in a region of the liver free from large vessels. Acquisition parameters included: TR/TE=3000/25ms, BW=±2500Hz, 4 avgs, readout points=2048, total scan time=20s. Raw data were post-processed (blinded to IDEAL results), using SAGE analysis software (GEHC, Waukesha, WI) to estimate areas under the water and fat peaks, and calculate fat fraction.

In 2/6 patients who were referred clinically for non-targeted ultrasound guided biopsy, images were acquired immediately prior to and immediately after biopsy. This localized the biopsy site in the fat-fraction images. Biopsy specimens were analyzed with a subjective four-point scale based on the percentage of cells containing fat vacuoles (0: <5%, 1: 5-33%, 2:34-66%, 3: >66%)[7].

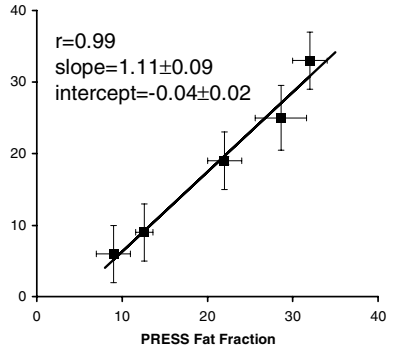

Fig 2: Fat fraction measured with IDEAL and PRESS from the same location in the liver in 5 patients. Excellent correlation (r=0.99) with a slope near one (1.11±0.09) was noted. A small bias in the intercept (-0.04±0.02) was noted.

Results: Fig. 1 shows the IDEAL fat fraction images and corresponding PRESS spectra acquired in two patients, one with moderate to severe steatosis, and a second with mild steatosis. Fig. 2 plots fat fraction measurements made with IDEAL in comparison to PRESS measurements, demonstrating excellent correlation (r=0.99) between the two methods with a slope near one (1.11±0.08) and an intercept slightly below zero (-0.04±0.02). This small bias from zero may have resulted from uncorrected T2 weighting of the PRESS data, and the source of this small bias will be further investigated in future studies. Finally, Fig. 3 shows a fat fraction image from a patient with severe steatosis and the corresponding biopsy specimen, also demonstrating severe steatosis. In this patient, fat fraction from IDEAL at the biopsy site was approximately 56%, corresponding to grade 3 steatosis by histologic grading (>66% of cells with steatosis). In the 2nd biopsy patient (not shown), IDEAL measured 9±3% fat, PRESS measured 12±4% fat, and biopsy demonstrated grade 1 steatosis.

Conclusions: Results from this preliminary clinical study demonstrate excellent correlation between IDEAL and PRESS for the measurement of fat-fraction. In two patients, good qualitative agreement between steatosis measured with MRI and biopsy was also demonstrated. IDEAL is a promising non-invasive method for quantification of hepatic steatosis, offering potentially improved accuracy and safety compared to biopsy.

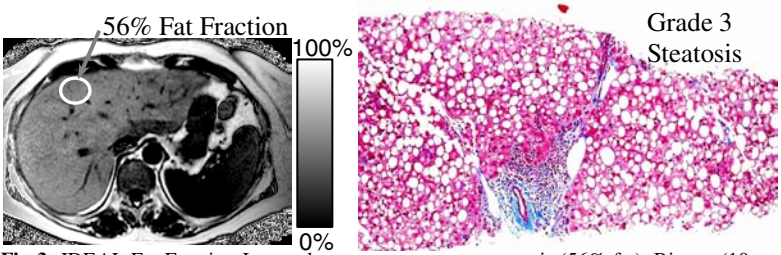

Fig 3: IDEAL Fat Fraction Image demonstrates severe steatosis (56% fat). Biopsy (10x Trichrome stain) from the right lobe of the liver grade 3 steatosis (white vacuoles).

References: **1.** Ratzui et al, Gastroenterol 2005 128(7): 1898-1906, **2.** Reeder et al, MRM 2005 54(3): 636-44, **3.** Reeder et al, ISMRM 2006, pg 2444, **4.** Pineda et al, MRM, 2005 54(3): 625-35, **5.** Yu etl el, MRM, 2005 54(4): 1032-9, **6.** Bottomley et al Ann NY Acad Sci, 1987 508: 333-48, **7.** Brunt et al, AJG 1999: 94(9): 2467-74.