Same Day 1.5T vs 3T Reproducibility of Liver Proton Density Fat Fractions in Obese Patients

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Target Audience: Researchers and clinicians interested in liver fat quantification.

Purpose: Non-alcoholic fatty liver disease (NAFLD) is the most common cause of chronic liver disease and can affect up to 75% of the obese population.[1] If left untreated, it can progress to complications such as liver failure, portal hypertension, and hepatocellular carcinoma.[2] Definitive diagnosis of NAFLD currently requires biopsy, which is limited by expense, risk, and sampling variability.[3] In recent years, a number of quantitative MR methods have shown great promise as a non-invasive biomarker of hepatic steatosis, with validation studies performed in phantoms, animal models, and patients.[4-9] The purpose of this work is to examine the reproducibility of these MR techniques by evaluating hepatic proton density fat fraction (PDFF) measurements across magnetic field strengths, specifically 1.5T and 3T, in an obese population at high risk for NAFLD.

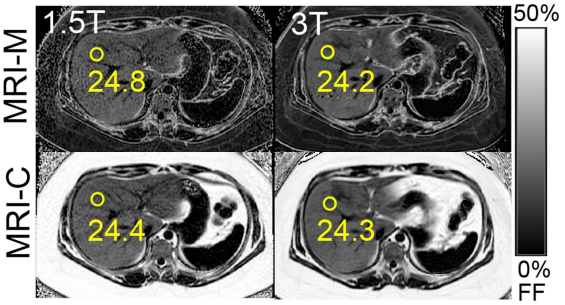

Figure 1: Very good agreement was observed in proton density fat fraction measurements between 1.5T and 3T for MRI-M and MRI-C as demonstrated for this subject with high fat content in the liver. MRS measurements in the right lobe were also very similar (22.2 % at 1.5T; 23.9% at 3T).

Methods: This study was IRB approved and informed consent was obtained from all 22 subjects (age: 47±13 yrs; weight: 115±14 kg; BMI: 45±4 kg/m^2). Obese patients approved for weight-loss surgery were scanned on the same day at both 1.5T and 3T (Signa HDx and Discovery 750 respectively, GE Healthcare, Waukesha, WI) within a one hour period. At each field strength, data for three distinct liver fat quantification techniques were acquired.

First, a previously described ***3D complex-based (MRI-C) gradient echo method***[4] was performed at 3T: 6 total echoes in two shots, TR=8.6ms, ETL=3, TE$_{min}$=1.2ms, ΔTE=1.0ms, flip=3° full readout, BW=±125kHz, FOV=44cm, slice=8mm, 256x128 matrix, 32 slices, ARC parallel imaging acceleration = 2x2, and a total scan time of 20sec (single breath-hold). Parameters at 1.5T were similar except for the following: TR=13.4ms, ETL=6 in one shot, 256x160 matrix, flip=5°, ΔTE=2.0ms. The second MRI method was a previously described ***2D magnitude-based (MRI-M) gradient echo method***[3]: 6 echoes/TR, TR=150 ms, TEmin=1.1ms, ΔTE=1.15ms, flip=10°, full readout, BW=±125KHz, FOV=44cm, slice=8mm, 224x160 matrix, 28 slices, ASSET factor=2, for a total scan time of 26 sec (split into two breath-holds). Parameters were adjusted at 1.5T as follows: TR = 170, TEmin=2.3ms, ΔTE=2.3ms, BW=±83kHz, matrix=256x160, total scan of 42 sec (split into three breath-holds). Fat-fraction images for both MRI-C and MRI-M were reconstructed using two separate on-line reconstruction algorithms. Both algorithms use spectral modeling of fat[10,11] and T2* correction[12], while MRI-C also corrects for eddy currents and noise-related bias.[13,14] Finally, a single breath-hold ***MRS was performed by using single voxel STEAM***[6] (Stimulated Echo Acquisition Mode) without water suppression. A 2x2x2cm^3 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 at 5TEs, all acquired in the same 21s breath-hold.

MRI-M and MRI-C fat-fractions (FF) were averaged across nine ROI's placed in each of the 9 Couinaud liver segments and were co-localized between 1.5T and 3T. MRS fat fractions were determined as previously described.[6] To compare MRI-M and MRI-C with MRS, additional ROI's were co-localized with the MRS voxel coordinates. Regression analysis was used for all comparisons.

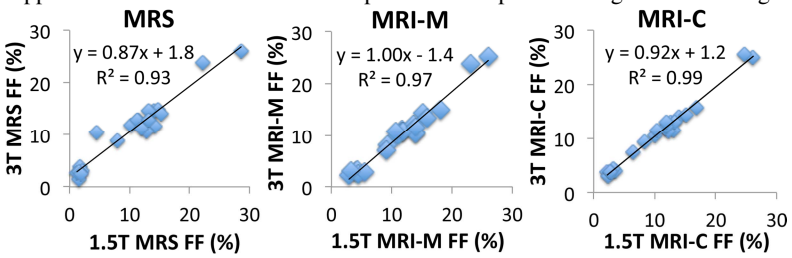

Figure 2: Although perfect agreement (slope=1 and intercept=0) was not observed for any of the techniques, excellent correlation was observed for all three.

Results and Discussion: Figure 1 shows MRI-M and MRI-C PDFF maps at 1.5T and 3T for a subject with high fat content in the liver. Excellent agreement was observed between field strengths for MRI-M and MRI-C and very good agreement was observed for single voxel MRS (22.2 % at 1.5T; 23.9% at 3T). Regression analysis for all 22 subjects (Fig 2) yielded the following: MRS: slope=0.87 (CI 0.77, 0.98), intercept=1.8 (CI 0.5, 3.1)%, r^2=0.93; MRI-M: slope=1.00 (CI 0.91, 1.08), intercept=-1.4 (CI -2.5, -0.3)%, r^2=0.97; MRI-C: slope=0.92 (CI 0.87, 0.97), intercept=1.2 (CI 0.6, 1.8)%, r^2=0.99. Table 1 shows regression results for MRI-M and MRI-C vs MRS at both field strengths. Excellent correlation was observed.

Comparison	r^2	Slope (95% CI)	Intercept (95% CI)
1.5T MRI-M vs MRS	0.95	0.97 (0.88, 1.07)	3.2 (2.0, 4.4)
3T MRI-M vs MRS	0.98	1.01 (-0.95, 1.08)	-0.4 (-1.2, 0.5)
1.5T MRI-C vs MRS	0.96	1.10 (1.00, 1.20)	0.9 (-0.4, 2.1)
3T MRI-C vs MRS	0.96	1.02 (0.93, 1.11)	1.2 (0.1, 2.3)

Table 1: Excellent correlation of MRI vs MRS was observed at 1.5T and 3T.

None of the three FF techniques achieved perfect agreement (slope=1 and intercept=0) between field strengths, but each demonstrated excellent correlation with slopes near 1 and intercepts near 0. While results are similar, MRS demonstrated the lowest correlation, and the largest divergence from a unitary slope and zero intercept. This is likely due to variations in voxel placement which is an inherent drawback of MRS when performing repeated studies. Future work will investigate the source of the small remaining biases observed with each technique.

Conclusion: MRS, MRI-M, and MRI-C demonstrated excellent correlation with MRS, and very good agreement between same day 1.5T and 3T liver PDFF measurements in obese patients. Although further validation is necessary assessing the accuracy of PDFF measurements with tissue reference standards in the patient population, this study in obese patients indicates that PDFF quantification is reproducible across field strengths.

References: [1] Browning, Hepatology 2007. [2] Ekstedt, Hepatology 2006. [3] Ratziu, Gastroenter 2005. [4] Reeder, MRM 2004. [5] Hines, Radiology 2010. [6] Hamilton, NMR Biomed 2011. [7] Yokoo, Radiology 2009. [8] Yokoo, Radiology 2011. [9] Meisamy, Radiology 2011. [10] Bydder, MRI 2008. [11] Yu, MRM 2008. [12] Yu, JMRI 2007. [13] Yu, MRM 2011. [14] Liu, MRM 2007.

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