Free-breathing quantification of liver proton density fat-fraction

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Target audience: Radiologists and scientists who are interested in liver imaging and fat quantification

Purpose: To evaluate the feasibility and the validity of confounder-corrected chemical shift-encoded MRI for quantification of hepatic proton density fat fraction (PDFF) using respiratory-gating methods with either respiratory bellows or navigator echoes.

Methods: Twelve patients (mean age of 57.3 years, M:F 6:6) who were scheduled for routine clinical abdominal MRI were recruited after obtaining IRB approval and informed consent. The subjects consisted of 6 men and 6 women (mean age = 57.3 years). Imaging was performed on a clinical 3T scanner (MR750, GE Healthcare, Waukesha, WI) using a 32-channel phased array body coil. The following 4 acquisitions were performed in all subjects to measure PDFF; (1) breath-hold (**BH**) IDEAL-IQ, a chemical shift encoded water-fat separation method used clinically for measuring PDFF[1], (2) free-breathing IDEAL-IQ with respiratory gating using bellows (**BL**); (3) free-breathing IDEAL-IQ with respiratory gating using navigator echoes (**NV**)[2], (4) single voxel multi-echo T2-corrected STEAM spectroscopy (reference standard).

The entire liver was scanned in the axial plane for all scans. Phase encoding for BL and NV were set as left-to-right to reduce respiratory motion-related artifact in the liver and anterior-to-posterior for BH. Other acquisition parameters included: TE = 1.2, 2.2, 3.2, 4.3, 5.3, 6.3, TR = 8.0 ms, FA = 3°, matrix = 256×144×32, slice thickness = 8 mm, scan time = 16s for BH and ~1:20 min for BL and NV. An on-line reconstruction algorithm was used to perform T2* correction, spectral modeling and eddy current correction to create quantitative PDFF maps over the entire liver.

For STEAM spectroscopy, a 2.0×2.0×2.0 cm^3 voxel was placed in the posterior lobe of the liver. STEAM parameters included: TE = 10, 15, 20, 25, 30 ms (multiple echoes to enable T2 correction), TR = 3500 ms, 1 signal average, 2048 points, and a spectral width of 5kHz, acquired in one breath-hold of 21s. Fat-quantification from STEAM multi-echo data was performed using the AMARES [3)] algorithm under jMRUI [4)], followed by calculation of T2-corrected fat-fraction in Microsoft Excel.

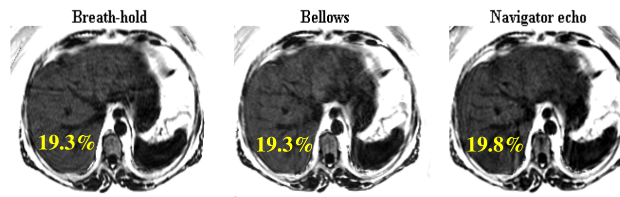

Fig 1. *Visually, equivalent image quality was obtained from the 3 IDEAL-IQ methods; Percentages on the images are fat fractions measured in posterior lobes (STEAM-MRS showed 18.0%).*

Fat fraction measurements were performed from PDFF maps by placing 2 region of interest (ROI) in each anterior, posterior, and lateral lobe. Average values of each lobe were compared among the 3 IDEAL-IQ methods. The mean PDFF values of posterior lobe of the 3 different IDEAL-IQ acquisitions were compared with STEAM spectroscopy serving as the reference standard. Visual assessment of image quality was performed independently by 2 radiologists using a 3-point scale; 3-good, 2-fair, 1-non-diagnostic.

Intra-class correlation coefficient (ICC) with 95% confidence interval was calculated between BH, BL, and NV. Intra-individual difference was calculated for each liver lobe. Two-one-sided test was used with a null hypothesis of "1% difference was assumed between BH, BL, and NV". If the p value of <0.05 was observed for the comparison, we adopted an alternative hypothesis of "no more than 1% difference was assumed". PDFF of STEAM-MRS and 3 IDEAL-IQ were compared using Bland-Altman plots and ICCs were calculated.

Results: Image quality was rated as good in 6 cases (both readers) for BH, 9 (reader 1) and 8 (reader 2) cases for BL, and 8 and 7 cases for NV, respectively. (Fig. 1) No acquisition was assigned as non-diagnostic. The difference between any 2 of 3 IDEAL-IQ PDFF had no more than 1%. (Table 1) The ICCs between PDFF of IDEAL-IQ versus STEAM spectroscopy were shown in Fig. 2.

	BH - BL	**BL - NV**	**NV - BL**
Anterior lobe			
ICC (95%CI)	0.99 (0.97–0.99)	0.98 (0.95–0.99)	0.98 (0.94–0.99)
Difference (SD)	0.1 (0.7)	0.2 (0.9)	0.3 (0.9)
p value*	0.0004	0.0031	0.0061
Posterior lobe			
ICC (95%CI)	0.988 (0.96–0.99)	0.991 (0.97–0.99)	0.981 (0.94–0.99)
Difference (SD)	-0.4 (0.5)	0.3 (0.7)	-0.1 (0.5)
p value*	0.0049	0.0040	0.0084
Lateral lobe			
ICC (95%CI)	0.962 (0.88–0.98)	0.972 (0.91–0.99)	0.914 (0.75–0.97)
Difference (SD)	-0.1 (0.9)	0.1 (1.0)	-0.1 (1.6)
p value*	0.0056	0.0046	0.0430

Table 1. *Excellent intra-class correlation (ICC) and small differences of PDFF measurement between the 3 IDEAL-IQ in each liver lobe was seen. *Note; A p value of <0.05 indicates no more than 1% difference in measurement between the 2 methods.*

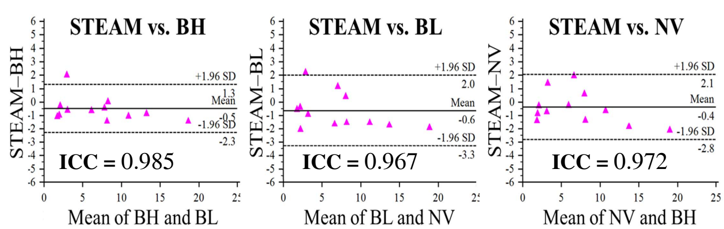

Fig 2. *Bland-Altman plots show very small differences in measurement of proton density fat fraction (PDFF) by 3 IDEAL-IQ methods compared to STEAM-MRS with intra-class correlation coefficient (ICC); breath-hold (BH), respiratory-triggering with bellows (BL) and navigator echo (NV).*

Discussion: In this work we have demonstrated the feasibility of two free-breathing chemical shift-encoded methods to quantify PDFF in the liver. Both methods had high image quality and excellent agreement with MRS and breath-hold MRI methods, indicating that both free-breathing methods may be valid and reliable approaches to quantify liver fat in patients who are unable to hold their breath.

Conclusion: PDFF measurement using respiratory-gating methods with bellows or navigator echo were feasible and valid technique.

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