High SNR improves the repeatability of proton density fat fraction measurements in the liver

Utaroh Motosugi[1,2], Diego Hernando[1], Peter Bannas[1,3], and Scott B. Reeder[1,4]

[1]*Radiology, University of Wisconsin, Madison, wisconsin, United States,* [2]*Radiology, University of Yamanashi, Yamanashi, Japan,* [3]*Radiology, University Hospital Hamburg-Eppendorf, Hamburg, Germany,* [4]*Medical Physics, University of Wisconsin, Madison, wisconsin, United States*

Target audience: Scientists and clinicians who are interested in imaging of diffuse liver disease

Background and Purpose: In general, good signal-to-noise ratio (SNR) performance is necessary to achieve robust quantitative measurement of proton density fat-fraction (PDFF) using chemical-shift encoded MRI (CSE-MRI). CSE-MRI is a well-validated technique for non-invasive liver fat quantification to monitor patients with fatty liver disease[1]. However, high precision (repeatability) is required for both diagnosis and longitudinal treatment monitoring, since clinically significant PDFF is ~5%[2]. The purpose of this study was to improve test-retest repeatability by increasing SNR through tradeoffs in spatial resolution.

Methods: All imaging was performed on a clinical 1.5T scanner (SignaHDxt or OptimaMR450w, GE Healthcare, Waukesha, WI). A ***phantom study*** was performed with eleven phantoms with increasing fat fractions. Three different SNR protocols were set by varying voxel size (4, 14, and 38mm^3) and bandwidth (167, 91, and 63kHz) were used. TE (1.2ms for minimum TE) with 6 echoes spaced by 1.9ms were identical for the 3 protocols. The same TR (21ms) and flip angle (5°) were used to avoid T1 bias. Each protocol was repeated to simulate 4 and 16 signal averages. These scans were then repeated to evaluate for test-retest repeatability.

An ***in vivo study*** included 20 volunteers and 7 patients who were scheduled for liver imaging at our institution. To evaluate test-retest repeatability, two protocols with different SNRs (standard SNR protocol [CSE_{std}], and high SNR protocol [CSE_{high}]) were each performed twice. After scanning the 2 protocols, the subjects were asked to sit-up on the scanner table and repositioned to simulate two separate examinations. MR parameters for in vivo study included: CSE_{std}, 1.6×2.6×8mm, 125Hz; CSE_{high}, 3.3×3.5×10mm, 50Hz. Other parameters were: TR= 14.4, TE=1.2, 3.2, 5.3, 7.3, 9.4, 11.4 ms for CSE_{std}; TR=12.1, TE=1.1, 3.0, 4.9, 6.7, 8.6, 10.5 ms for CSE_{high}; FA = 5°, scan time = 21s for both protocols. An off-line reconstruction algorithm was used to perform T2* correction, and spectral modeling to create quantitative PDFF maps[3]. Relative SNR was calculated with following equation in which T1 value of the liver[4] was assumed to be 500ms:

$$Relative\ SNR = k \cdot V \cdot \sqrt{\frac{N_{PE} \cdot N_z \cdot NEX}{BW}} \cdot sin\theta \cdot \frac{(1-e^{-TR/500})}{1-cos\theta \cdot e^{-TR/500}}$$

where, V is voxel volume, N_{PE} and N_z are phase encoding steps in y and z direction, θ is flip angle, and k is a constant depending on main magnetic field strength. PDFF measurements were performed by placing a region of interest (ROI) in posterior segment of the right lobe of the liver. The difference of two measurements were defined as Δ: $\Delta = PDFF_{Test} - PDFF_{Retest}$. The variance of Δ and the mean value of absolute Δ (|Δ|) were used as indicators of repeatability, and compared between CSE_{std} and CSE_{high} using F test and paired t-test, respectively.

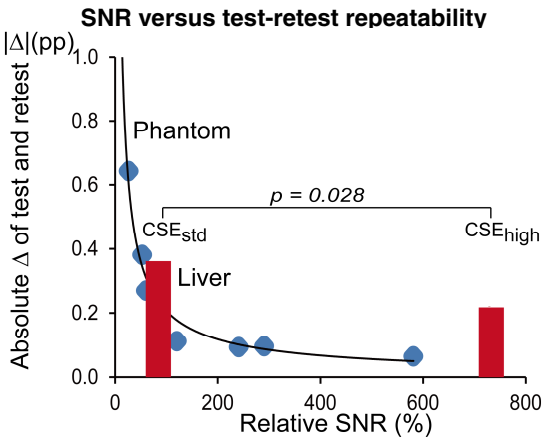

Fig 1*. Higher SNR had better test-retest repeatability in either phantom (blue dots) or volunteer/patients (red bar). Clinical standard protocol (CSE_{std}) was set as 100% of relative SNR.*

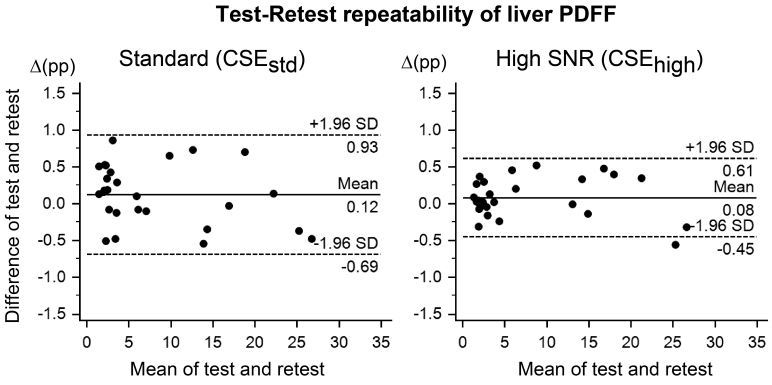

Fig 2*. High SNR protocol showed improved precision (lower variance) comparing PDFF measurements between test and retest scan, relative standard SNR protocol. (p= 0.038, F-test)*

Results: Phantom study revealed that higher SNR provide higher repeatability (=lower |Δ|). (Fig.1) In vivo study, CSE_{high} showed lower (p=0.028, Fig.1 and Table 1) and lower variance (p=0.038, Fig.2 and Table 1) compared with CSE_{std}.

Conclusion: High SNR protocol for CSE PDFF measurements provides higher test-retest repeatability compared to standard protocol. Small decreases in spatial resolution can improve the repeatability (precision) of PDFF quantification using CSE-MRI.

Table 1 Comparison of SNR performance and Variability for In Vivo Repeatability Study

	CSE_{std}	CSE_{high}	p value
Relative SNR	100%	729%	
Variance of Δ	0.17	0.07	0.038
Mean (SD) of |Δ|	0.36 (0.23)	0.22 (0.18)	0.028

References; 1) Meisamy S, et a. Radiology 2011; 258: 767-775. 2) Szczepaniak LS, et al. Am J Physiol Endocrinol Metab 2005;288:E462-468. 3) Yu H, et al. MRM 2008; 60: 1122-34. 4) de Bazelaire CM, et al. Radiology 2004; 230: 652-9

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