Feasibility of Simultaneous Evaluation of Coexistant Liver Iron and Fat Content with T2*-IDEAL

J. Wei[1], C. A. McKenzie[1], H. Yu[2], A. Shimakawa[2], I. Pedrosa[1], J. H. Brittain[2], and S. B. Reeder[3]

[1]Radiology, Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, United States, [2]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States, [3]Radiology, University of Wisconsin Medical School, Madison, WI, United States

Introduction: In-and-out-of-phase imaging (IOP) is a routine dual echo technique used in clinical practice for the detection of hepatic fat and iron deposition, with echo times (TEs) chosen to exploit the different chemical shifts of fat and water. With TEs selected so that the fat and water signals are in phase (IP) and 180° out of phase (OP) during the two acquisitions, coexistence of fat and water within an imaging voxel results in summation of signal intensity (SI) in the IP image and the difference of SI (i.e., signal drop) in the OP image. Thus, signal loss on the OP image compared to the IP image indicates the presence of fatty infiltration. Because IOP imaging utilizes two different TEs, the enhanced T2* decay caused by iron deposition can be detected as reduced liver SI in the longer TE image relative to the shorter TE image. At 1.5T the shortest OP and IP TEs are ~2.1 ms and 4.2 ms respectively. Signal loss on the longer TE (IP) image compared to the shorter echo (OP) image is suggestive of iron deposition. The presence of fat or iron deposition can be unambiguously detected when these occur separately in the liver. However, because the assessment of iron and fat deposition both require comparison of the IP image to the OP image, the coexistence of both forms of diffuse liver disease may be masked by the type of deposition which results in the more dominant drop in hepatic SI.

We investigated the feasibility of using a modified IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation) method [1,2] in combination with 3D spoiled gradient recalled echo (SPGR) imaging as an alternative to standard IOP imaging. "T2*-IDEAL-SPGR" [3] collects images at three or more TEs with different relative fat-water phases and generates both a R2* (1/T2*) map as well as separate fat-only and water-only images corrected for R2*. In-phase (sum) and out of phase (difference) images can be calculated from the fat- and water-only images. Thus, in a single acquisition, T2*-IDEAL SPGR provides iron-independent R2* compensated IOP images, fat-only and water-only images, and R2* maps which reflect the iron content of the hepatic tissue.

Methods: We obtained images from five adult patients referred to BIDMC (3 pts) or UWMC (2 pts) for assessment of liver iron deposition using abdominal MRI. The study was approved by the BIDMC and UW Institutional Review Boards. We performed all scans on GE Signa 1.5T MR imaging systems (GE Healthcare, Milwaukee, WI, USA) using 8-element torso array coils for signal reception.

Two sets of images were acquired from each volunteer: standard 2D T1w IOP (TR/TE1,TE2/flip=265-280/2.1,4.3 ms/80°, BW= ±62.5kHz, 256x160, 7mm axial slice, 1 mm slice gap, 36 cm FOV, 0.75 Phase FOV) and 3D T2*-IDEAL-SPGR (TR=13.6ms, TE1-6 = 1.3,3.4,5.5,7.7,9.8,11.9 ms, flip angle = 10°, BW= ± 100kHz, 256x128, 10mm axial slice, no slice gap, 48 cm FOV, 0.55 FOV). Both IOP and T2*-IDEAL were performed in a single 20-25 s breathhold for full liver coverage. The T2*-IDEAL on-line reconstruction produced R2* maps and both uncorrected and R2*-compensated water-only, fat-only, IP, and OP images.

Results: One patient had no apparent iron deposition or fatty infiltration. Significant iron deposition was detected on standard IOP imaging as a visual drop of SI in the longer TE (IP) image when compared to the shorter TE (OP) image in 2/5 patients. However, because the IP image is the reference standard for assessment of fatty infiltration with IOP imaging, it becomes virtually impossible to assess for the presence of mild-moderate steatosis in the presence of significant hepatic susceptibility, as shown in Figure 1 where mild iron deposition was not apparent on the IOP imaging of the only patient that had both iron deposition and fatty infiltration.

Fatty infiltration throughout the liver was detected on conventional IOP imaging as a visual drop of SI in the OP (shorter TE) image when compared with the IP (longer TE) image in 2/5 patients (including the patient in Fig. 1). However, because the shorter TE image is the reference standard for assessment of signal loss due to regional susceptibility on the longer TE image, significant fatty infiltration can impair detection of R2* effect resulting from mildly elevated hepatic iron (Figure 1a).

Using the T2*-IDEAL-SPGR technique, the R2* map (Figure 2a-d) unambiguously illustrates the distribution and magnitude of susceptibility (presumably from iron deposition) throughout the liver. The R2*-compensated fat-separation IDEAL image corrects for the calculated R2* signal loss when determining the contribution of SI from fat protons. Therefore, the presence of iron deposition and fat infiltration can be independently and simultaneously assessed, and the contributory effects of each can be calculated even when they coexist (Figure 1b).

Discussion: T2*-IDEAL-SPGR has great potential for imaging of chronic liver disease through direct and simultaneous evaluation for fatty infiltration and iron deposition. In addition to providing calculated IOP images which are routine in liver imaging, R2*-compensated water-only and fat-only images allow for quantification of water and fat contribution to SI even in the presence of diffuse susceptibility. The R2* map allows assessment of regional susceptibility (as seen with iron deposition) or focal susceptibility differences (especially if ferumoxide contrast agents are administered). These capabilities in a single breathhold sequence could simplify liver imaging protocols while reducing ambiguity of interpretation when hepatic steatosis and iron deposition states coexist.

Conclusion: We have demonstrated advantages of T2*-IDEAL-SPGR over more traditional IOP techniques for imaging of chronic liver disease. By measuring R2* and compensating for its effects, the presence of fat or iron deposition within the liver can be easily evaluated even when these two states coexist.

References: 1. Reeder et al, MRM, 2004, 51:35-45. 2. Reeder et al, ISMRM, 2005, pg 105. 3. Yu et al, ISMRM. 2006; pg. 624.

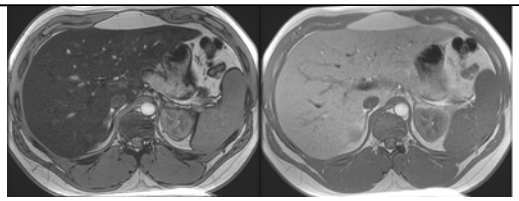

Figure 1a: Conventional out-of-phase (left) and in-phase (right) images of the liver, with identical window settings, show unequivocal drop of hepatic signal intensity in the out-of-phase image (SI=182) compared with the in-phase image (SI=627). This signifies fatty infiltration of the liver, and based on these images, iron deposition is not detected within the liver.

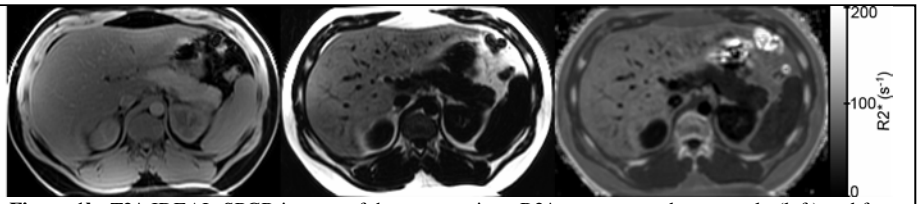

Figure 1b: T2*-IDEAL-SPGR images of the same patient: R2*-compensated water-only (left) and fat-only (middle) images, as well as R2* map (right) through the same portion of the liver. As predicted by the in- and out-of-phase images, there is elevated fat signal throughout the liver in the R2*-compensated fat-only image. In addition, the R2* map shows greater susceptibility within the liver than the remainder of the abdominal viscera. R2* measurement of the liver was 70 s^{-1} (T2* = 14 ms), suggesting mild concurrent iron deposition in addition to the expected fatty infiltration.

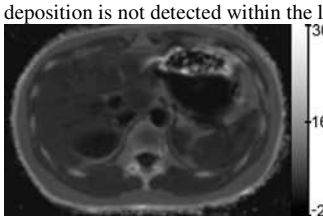

Figure 2a: R2* map in a healthy volunteer. T2* (1/R2*) of liver/spleen/muscle ~ 30/32/28 ms.

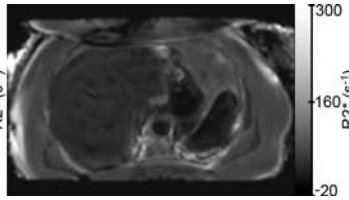

Figure 2b: Patient with hemochromatosis, regular phlebotomy. T2* of liver/spleen/muscle ~ 31/76/25 ms.

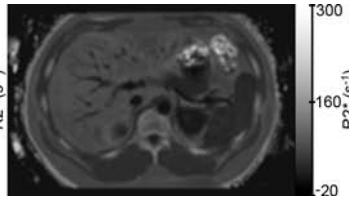

Figure 2c: Patient with elevated ferretin, fatty liver. T2* of liver/spleen/muscle ~ 14/32/30 ms.

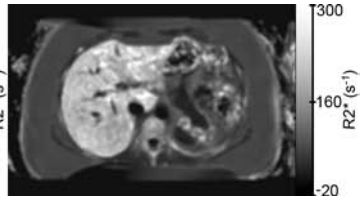

Figure 2d: Patient with congenital hemolytic anemia, splenectomy. T2* of liver/muscle = 4/29 ms.