Comparison of In and Out of Phase Imaging and IDEAL Fat-Water Separation for Liver Imaging at 3.0 T

C. A. McKenzie[1,2], D. Sacchetti[1], S. Fredericks[1], M. Schuster[1], M. Smith[1], H. Yu[3], A. Brau[3], A. Shimakawa[3], J. H. Brittain[3], S. B. Reeder[4], I. Pedrosa[1,2], N. M. Rofsky[1,2]

[1]Radiology, Beth Israel Deaconess Medical Center, Boston, MA, United States, [2]Radiology, Harvard Medical School, Boston, MA, United States, [3]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States, [4]Radiology and Biomedical Engineering, University of Wisconsin Medical School, Madison, WI, United States

Introduction: In and out of phase imaging (IOP) is particularly useful for detecting hepatic fat and iron with MR imaging. Fat detection with IOP exploits the resonant frequency difference between fat and water which results from their different chemical shifts**.** Two images are acquired with different echo times (TEs) selected so that the fat and water signals are 180° out of phase (OP) and in phase (IP). Hepatic fat is detected based on the reduced signal intensity (SI) in the OP image relative to the IP image. Hepatic iron deposition is detected based on reduced liver SI in the long TE image due to the enhanced T2* decay in the presence of iron.

At 1.5T the shortest OP and IP TEs are ~2.1 ms and 4.2 ms respectively so signal loss due to fat can be unambiguously distinguished from signal loss due to iron. However, at 3T the shortest OP and IP TEs are ~1.1 and 2.1 ms. The short 1 ms spacing between the two TE times makes it very difficult to acquire the shortest IP and OP TEs after a single RF pulse with current MR hardware. Therefore, at 3T, IOP images use the first (2.1 ms) IP TE and the third (5.3 ms) OP TE. In this case the OP TE is now longer than the IP TE and signal loss in the OP image can no longer be unambiguously assigned to the presence of iron or fat in the liver.

We investigated the use of T1-weighted (T1w) Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation (IDEAL) (1,2) spoiled gradient recalled echo (SPGR) imaging as an alternative to standard IOP imaging. IDEAL-SPGR collects images at three TEs with relative fat-water phases of $(-\pi/6, \pi/2, 7\pi/6)+\pi k$ (k=any integer) and processes them to separate the fat and water signals into fat-only and water-only images. The separate water and fat images are perfectly registered and can be recombined into calculated in-phase of out of phase images. Thus IDEAL SPGR provides images very similar to standard IOP imaging, as well as fat-only images that allow unambiguous detection of hepatic fat and water-only images in which any signal loss can be unambiguously assigned to iron deposition.

Methods: We obtained images from 41 consecutive adult patients (20 M, 21 F, mean age 51+/- 12 y) referred to BIDMC for abdominal MRI. The study was approved by our Institutional Review Board and written consent was obtained from all volunteers. We performed all scans on GE Signa 3.0T TwinSpeed MR imaging systems (GE Healthcare, Milwaukee, WI, USA) using an 8-element torso array coil for signal reception.

Two sets of images were acquired from each volunteer: standard 2D T1w IOP (TR = 290ms, TE1,2 = 2.5,5.8 ms, flip angle = 70°, BW= ±50kHz, 256x160, 6mm axial slice, 1 mm slice gap, 30-40cm FOV, 0.75 Phase FOV, ASSET R=2, 20-25 s breath hold) and 3D T1w IDEAL-SPGR (TR=6.2ms, TE1,2,3 = 2.2, 3.0, 3.8 ms, flip angle = 18°, BW= ± 83kHz, 256x160, 6mm axial slice (interpolated to 3 mm), no slice gap, 30-40cm FOV, 0.75 Phase FOV, ASSET R=2, 20-25 s breath hold). Both IOP and IDEAL-SPGR required two breath holds for full liver coverage. The IDEAL source images were processed to produce water-only, fat-only, IP and OP images.

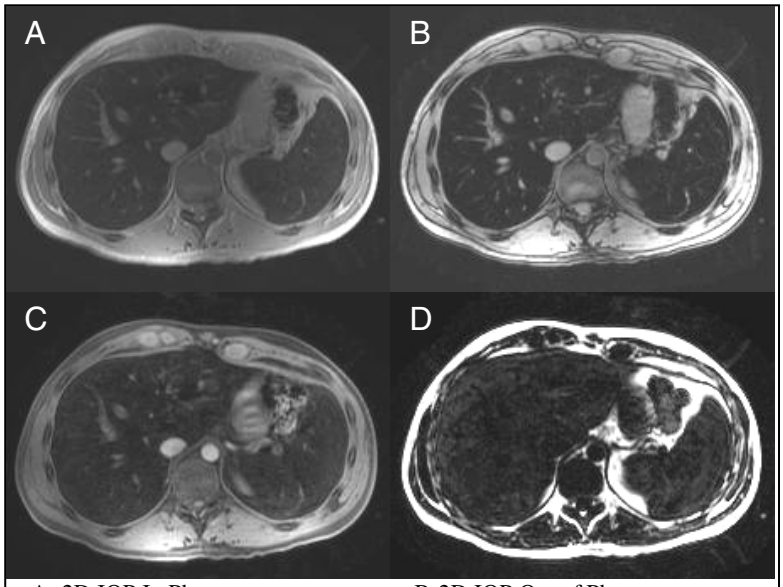
Evaluation of the images for a subset of 10 of the 41 patients was performed by three radiologists in a random and blinded fashion. Readers rated overall image quality and their confidence in the diagnosis of hepatic fat and iron on semi-quantitative scales. Overall image quality was rated as 1=non-diagnostic, 2=poor, 3=acceptable, 4=good, 5=excellent, while confidence in the presence or absence of hepatic fat and hepatic iron was rated as: 1=no confidence, 2=low confidence, 3=marginal confidence, 4=high confidence, 5=complete confidence.

Results: Table 1 shows the results of the readers image analysis. IDEAL received slightly lower scores for overall image quality than IOP. However, the confidence in the diagnosis of iron was slightly higher for IDEAL and the confidence in the diagnosis of fat was clearly higher for IDEAL.

Table 1: Summary of image analysis

	IOP	IDEAL
Confidence Hepatic Fat	3.9	5.0
Confidence Hepatic Iron	4.6	4.8
Overall Image Quality	3.0	2.8

Figure 1 shows images from an IDEAL-SPGR and IOP acquisitions in a patient who had both hepatic fat and iron deposition. There is a clear reduction in SI in the OP image (B) relative to the IP image (A), but because the TE of the OP image is longer than the IP image it is difficult to tell if the signal loss is due to fat or iron in the liver. In the IDEAL water-only (C) image the liver has reduced SI similar to the spleen SI. Since this is a water-only image, fat deposition cannot be causing the SI reduction, so hepatic iron is unambiguously indicated. In the IDEAL fat-only image (D) there is clearly non-zero SI in the liver, unambiguously indicating the presence of fat in the liver. This set of images is an excellent demonstration of the advantages of IDEAL over IOP: this double diagnosis of fat and iron in the liver would be extremely difficult to make with IOP but is straightforward with the IDEAL fat and water images.



A- 2D IOP In Phase B-2D IOP Out of Phase
C-3D IDEAL Water D- 3D IDEAL Fat

Discussion: IDEAL has significant advantages for liver imaging at 3.0T. The water-only and fat-only images increase diagnostic confidence. In addition the contrast of the water-only image is identical to a fat-suppressed T1w SPGR image and could potentially be used for dynamic contrast enhanced imaging as well as a substitute IOP image. This would allow simplification of liver imaging protocols through consolidation of IOP and dynamic imaging into one acquisition.

Conclusion: We have demonstrated the advantages of IDEAL-SPGR over more traditional IOP techniques for imaging the liver at 3.0 T. In particular, by removing ambiguities in the source of signal loss in the OP image for standard IOP, IDEAL allows greater confidence in the detection of fat and/or iron in the liver at 3.0T.

References: 1. Reeder et al, MRM, 2004, 51:35-45. 2. Reeder et al, ISMRM, 2005, pg 105