A new 3D approach for clinical in- and opposed-phase MRI at 3 T

B. M. Dale[1], and E. M. Merkle[2]

[1]MR R&D, Siemens Medical Solutions, Cary, NC, United States, [2]Radiology, Duke University, Durham, NC, United States

Introduction: The in- and opposed-phase gradient recalled echo (GRE) pulse sequence is a staple of body MRI, and is usually present in any clinical abdominal MRI protocol. In clinical practice it serves several typical purposes [1-3]. First, it is used to detect and characterize adrenal lesions as benign adenomas or as malignant lesions. Second, it is used to visualize fatty infiltration in the liver. Third, it is also used to identify iron storage conditions such as hemosiderosis or hemochromatosis. The first and second uses are possible because the fat and water signals add destructively in the opposed-phase image and constructively for the in- phase image. Therefore, tissues with high fat content, such as adenomas or fatty infiltrated liver, will appear dark on the opposed- phase image and bright on the in-phase image. The third use is possible because tissues with high iron content have a higher T2* and will therefore appear darker relative to normal tissues on the image with the later echo time. In order to avoid confusion between these two effects it is essential that the opposed-phase image be acquired with a shorter echo time than the in-phase image (Method A or C). At 1.5 T this leads to an echo time of 2.2 ms for the first opposed-phase echo and 4.4 ms for the first in-phase echo, which can easily be achieved by modern scanners in the same acquisition. However, at 3 T this requires echo times of 1.2 ms for the first opposed phase echo and 2.4 ms for the first in phase echo. This is more difficult to achieve, and typically one of several compromises is made (Method A or B) which degrade the quality of abdominal imaging at 3 T. It would be preferable to have a pulse sequence where the first in- and opposed-phase echoes could be acquired in a single breath hold.

		First Echo		Second Echo	
Method	2D/3D	Echo	TE	Echo	TE
A	2D	1st out	1.6 ms	2nd in	4.9 ms
B	2D	1st in	2.2 ms	3rd out	5.7 ms
C	3D	1st out	1.2 ms	1st in	2.5 ms

Methods: The standard GRE sequence on a Magnetom Trio a Tim System (Siemens Medical Solutions, Erlangen) was modified in order to have a shorter RF pulse duration and greater readout echo asymmetry. This combination allowed the possibility of a true opposed-phase (1.2 ms) first echo. The readout bandwidth was increased to slightly over 1000 Hz/pixel in order to also acquire the first in phase echo at a TE of 2.4 ms. The decreased RF duration lead to an increased SAR (specific absorption rate), and the increased readout bandwidth lead to a reduced SNR (signal to noise ratio). Since 3D acquisitions require lower tip angles and result in higher SNR than 2D acquisitions [4], both of these effects were alleviated by switching from the standard 2D approach to a 3D acquisition strategy.

Twenty patients were imaged using both standard 2D approaches (Method A and B) and the new 3D approach (Method C). Images were evaluated by a board-certified radiologist with 8 years experience post subspecialty training. Attention was paid to the differences in available diagnostic information, appearance of chemical shift and susceptibility effects, and general image quality.

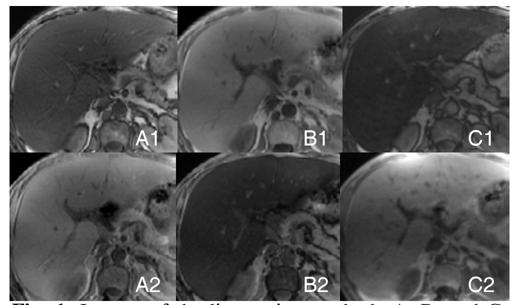

Fig. 1: Images of the liver using methods A, B, and C respectively. The number indicates the echo order (1st or 2nd). Note the reduced signal drop for A and note that the opposed phase image is echo 2 for method B.

Results: In a single breathhold the 3D approach could achieve a higher resolution (0.7 mm x 0.7 mm x 2.0 mm) than the standard 2D approaches (1.4 mm x 1.4 mm x 7.0 mm). Overall, the new 3D approach had lower SNR (~10) than the 2D approaches (~25), but in no case was the SNR or image "grainyness" of Method C considered a limiting factor in making a diagnosis. The Method C was also seen to have somewhat greater sensitivity to pulsation artifacts from the abdominal aorta, though a lower sensitivity to other motion effects such as poor breath-holding or bulk motion relative to Methods A and B. One patient with diffuse fatty infiltration showed a signal drop of 39% with Method A, 70% with Method B, and 78% with Method C (Fig. 1). With Methods A and C this signal drop was uniquely attributed to chemical shift effects, while with Method B the signal drop could have been attributed to either chemical shift or T2* effects. One patient showed the presence of Gamna Gandy bodies (Fig. 2), which are small focal depositions of iron in the spleen in the setting of liver cirrhosis. The Gamna Gandy bodies displayed greater susceptibility artifact size with increasing TE and were visualized on all images except the Method C opposed-phase image acquired with a TE of 1.2 ms. One final result was the observation that bowel loops, the intestinal walls, and intestinal contents were clearly visualized with the Method C (Fig. 3) opposed-phase images acquired with a TE of 1.2 ms whereas the Method A opposed-phase images with a TE of 1.6 ms already showed signal voids in the same locations.

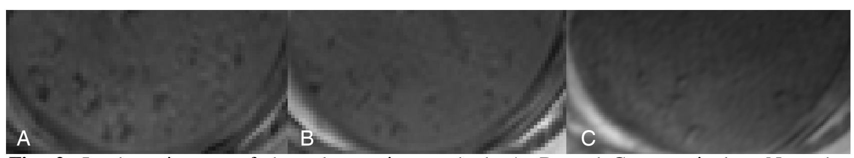

Fig. 2: In-phase images of the spleen using methods A, B, and C respectively. Note the visualization of Gamna Gandi bodies, focal deposits of iron in the spleen, in all three. They show as hypointense spots in these images and they generally appear larger with increasing TE.

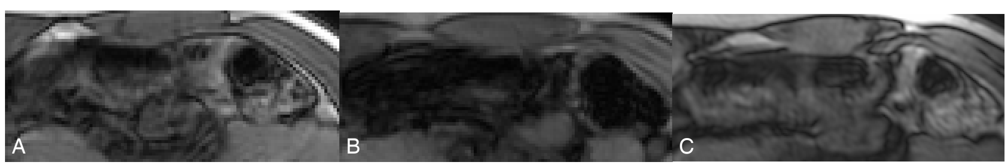

Fig. 3: Opposed-phase images of the bowel using methods A, B, and C respectively. Note the improved visualization of bowel structure and contents and the reduced size of the signal voids with C. The image degradation with the standard techniques is most likely primarily due to the longer echo times and larger voxels

Discussion: The lower SNR of Method C is not surprising considering the higher resolution and higher readout bandwidth, but the 3D approach recovers sufficient SNR to remain diagnostically useful. The improved fatty-liver signal drop in Fig. 1 of Method C relative to Method A is also understandable since the first TE of Method A is somewhat later than a true opposed-phase echo, so the signal cancellation is incomplete in Method A. However, it is somewhat surprising that the signal drop of Method C is also greater of Method B, which had both the chemical shift and T2* effects working to reduce the opposed-phase signal. The reduced susceptibility artifact size for the Method C first echo is a function both of the shorter TE and also the smaller voxel sizes. These two factors combine to make the opposed-phase 3D images essentially free of susceptibility effects, resulting in potential utility in evaluating the bowels as well as the other major abdominal organs. The 3D approach warrants further investigation with a larger patient population to determine its sensitivity and specificity for detecting abdominal pathologies relative to the standard approaches.

References: [1] Tsushima Y, et al. *Radiol.* **1993**;186:705-9. [2] Fujiyoshi F, et al. *AJR* **2003**;180:1649-57. [3] Namimoto T, et al. *Radiol.* **2001**;218:642-6. [4] Haacke EM, et al. *MRI – Phys. Prin. and Seq. Design*. **1999**:914p.