Optimization of In-phase and Opposed phase Imaging at 3T for Abdominal MRI

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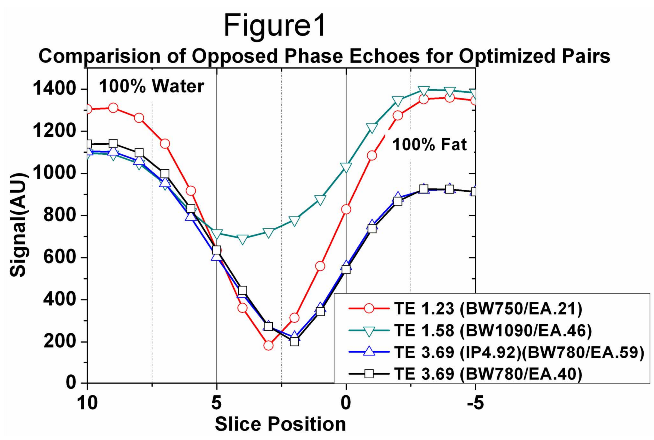
Introduction

Dual gradient echo In-Phase(IP) and Opposed-Phase(OP) imaging (or Dixon's technique) is used routinely in body imaging for a broad range of clinical diagnoses, including hepatic steatosis, adenomas and renal angiomyolipomas[1,2]. This sequence can also be used to quantify the fat content of pathology[3]. IP/OP imaging is based upon periodic addition (IP) or cancellation (OP) of fat and water signals due to their chemical shift. The difference of frequencies is $\Delta\omega$=223Hz at 1.5T which results in n echo times of (2.24 + n 4.47) ms for OP, and (4.47 + n 4.47) ms for IP acquisition. At 3.0T, the difference is twice as large $\Delta\omega$=447Hz, resulting in shorter echo times of (1.12 + n 2.24) ms for OP and (2.24 + n 2.24) ms for IP acquisition. The shorter echo spacing causes the sequence to use the technical limits of the gradient and RF-power system of the scanner at 3T. The purpose of this study was to optimize a IP/OP gradient echo protocol by varying bandwidth (BW) and echo asymmetry (EA) in order to achieve desired echo times and to assess the effects on T1-weighted image contrast and fat quantification potential.

Methods

Table #1					
TE[1] (ms)	**TE[2] (ms)**	**BW[1] (Hz/px)**	**BW [2] (Hx/px)**	**EA[1]**	**EA[2]**
2.46(I)	3.69(O)	750	780	.60	.40
1.23(O)	4.92(I)	750	750	.21	.50
3.69(O)	4.92(I)	780	780	.59	.40
1.58(O)	2.93(I)	1090	930	.46	.50

A phantom filled with vegetable oil (fat) and distilled water was imaged using a spoiled gradient echo sequence (FLASH) with FOV 300x225 mm, matrix=154x256, TR 182 ms, iPAT = 2 and flip angle 90°. Based on the signal intensity equation for FLASH, the largest contrast C= SI_{diff} / $SI_{average}$ of a variety of tissues with published T1 values[4] at 3T is given by a flip angle of 90°. The phantom cross section was imaged with a single 5mm coronal slice in 1 mm increments to yield voxels with varying amounts of fat and water. Based on system defined phase conditions, echo pairs listed in Table 1 were acquired with minimum BW and EA chosen to maximize SNR and reduce artifacts. Echo pair 1.23 (OP)/2.46 (IP) could not be achieved with the conventional sequence implementation due to time constraints imposed by the RF pulse and spatial encoding gradients. Hence, the closest approximation 1.58(OP)/2.93(IP) was acquired. 6 subjects (2 with fatty liver) were scanned with the same dual gradient echo protocol. For phantom and human studies, comparison of the echo pairs were quantified using a signal intensity (SI) index = (S_{IP} – S_{OP})/S_{IP} and optimal contrast.



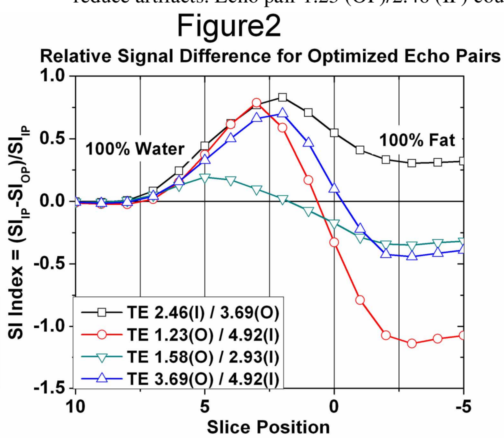


Table #2 In Vivo Results		In-phase Contrast	
Protocols	**Mean SI Index for Fatty Liver Cases (n=2)**	**Liver/Spleen Contrast (n=6)**	**Spleen/Pancreas Contrast (n=6)**
2.46(I) / 3.69(O)	**.67**	**.053**	**.134**
1.23(O) / 4.92(I)	.55	-.061	.085
3.69(O) / 4.92(I)	.53	-.064	.058
1.58(O) / 2.93(I)	.34	-.088	.074

Results

Phantom results show the greatest range of signal and cancellation with TE 1.23(O) (Fig 1). As expected, exact OP times result in greater cancellation of signal compared to partial opposed phase, TE 1.58(O) (Fig 1). Of the optimal TEs compared, the echo pair 2.46ms (I) / 3.69ms (O) shows slightly higher relative signal difference compared to other optimal pairs (Fig 2). Comparison of IP conditions show highest liver/spleen contrast and spleen/pancreas contrast for TE=2.46ms (Table2). Contrast is reduced or inverted at later echoes due T2* decay of tissues of interest.

Discussion

To achieve optimal signal difference it is essential that exact in-phase and opposed-phase times are acquired. Conventionally, the OP echo is acquired before the IP to ensure that signal loss in the OP image is caused by intravoxel fat and water instead of T2* decay. Acquiring the IP echo before the OP, at 2.46 ms (I) / 3.69 ms (O), could be a viable option as long as the minimum difference between the echoes is maintained. Our results suggest that this pair can also enhance the identification of fatty liver. In the future, modified sequences that allow the acquisition of 1.23(I) / 2.46(O) echo pair should be explored.

References

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