Efficient fat suppression by slice-selection gradient reversal in stimulated echo diffusion weighted liver imaging

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TARGET AUDIENCE: Researchers and clinicians interested in fat suppression methods on liver imaging

PURPOSE: Single-shot echo planar imaging (EPI) has become a widely used acquisition method for diffusion imaging in clinical application for its fast acquisition and motion insensitivity [1]. However, it is extremely sensitive to chemical-shift artifacts due to the low bandwidth in the phase-encoding direction, making fat suppression particularly challenging for the liver imaging on 3T. Traditional fat suppression methods usually prolong the acquisition time or increase the specific absorption rate (SAR). Moreover, they may not suppress the fat signal efficiently due to the improved magnetic field inhomogeneity at 3T [2]. On the contrary, the slice-selection gradient reversal (SSGR) method [3] uses slice-selection gradients with opposing polarity for two RF pulses and proves rather effective in spin echo imaging [1]. This work aims to introduce the SSGR method into a stimulated echo (STE) diffusion weighted imaging (DWI) method which can be used for fat suppression in the liver and for studying the diffusion time effect on liver diffusion measurements [4] at 3 T.

METHODS: STE DWI combined with SSGR: To suppress the fat signals in STE DWI by using the SSGR technique, the 2nd and 3rd slice-selection gradients (green) were reversed compared with the 1st gradient (black) (Fig. 1), where only on-resonance water signal experienced both excitation and refocusing pulses. For multi-slice acquisition mode, the slice gap and slice thickness should satisfy two basic conditions: 1) the chemical shift distance of fat should be equal or less than half of the slice thickness [3]; 2) the bandwidth of slice-selective RF excitation or refocusing pulse should be equal or less than the frequency offset between water and fat resonance [5]. Only in this way can it separate the fat and water signal in slice direction or suppress the fat signal of every slice successfully. The stimulated echo was weighted by the diffusion gradients (1st and 3rd purple gradients in 3 directions) and the residual transvers magnetization was spoiled by the crusher gradient (2nd purple gradient) during the mixing time (TM) duration.

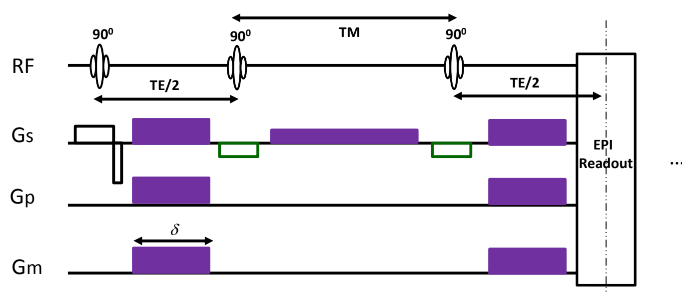

Fig. 1 Pulse sequence diagram for STE single-shot EPI DWI.

MR Imaging: A STE DWI sequence combined with SSGR technique with single-shot EPI acquisition was implemented on a Philips 3T clinical scanner (Philips, Best, The Netherlands). Liver images were acquired from 15 healthy volunteers using a 32-channel SENSE Torso/Cardiac coil. These subjects underwent STE single-shot EPI DWI with 5 different b values: 0, 200, 300, 400 and 600s/mm^2. For comparison, three fat suppression methods (Spectral Inversion-Recovery - SPIR, spectrally selective Attenuated Inversion Recovery - SPAIR, and the proposed SSGR method) were used with identical in-plane resolution of 3mm and repetition time of 1600ms. Other imaging parameters were TE=57ms, respiratory trigger delay =500ms, gradient duration δ=10.25ms, diffusion time=60ms, SENSE factor=2, NSA=2, three slices with slice thickness=5mm, slice gap=9mm. All subjects provided written informed consent.

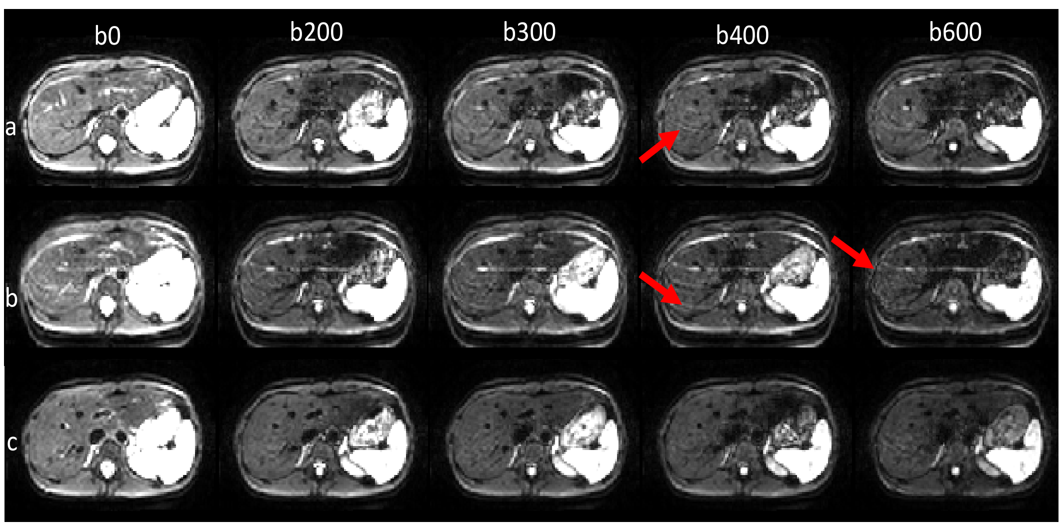

Fig. 2 Comparison of three types fat suppression methods. From top to bottom, the fat suppression methods are: SPIR (a), SPAIR (b), SSGR (c) respectively.

RESULTS: Fig. 2 displays the representative results of the same slice using three different types of fat suppression techniques from one subject. The images with different b values (horizontal rows) and fat suppression techniques (vertical columns) are shown in the same windowing level. There were obvious chemical shift artifacts in the first two rows (indicated by the red arrows), which were acquired using SPIR and SPAIR. In comparison, the proposed SSGR approach eliminated the fat signals and its related artifacts completely.

DISCUSSIONS AND CONCLUSIONS: This study, for the first time, introduced the SSGR method into STE DWI liver imaging for fat suppression. Comparing with the traditional fat suppression methods, this SSGR method of fat suppression can be readily incorporated into the STE DWI without increasing acquisition time and SAR. More importantly, diffusion scans are often long with high-duty gradient cycle, which can lead to drifts of the center frequency during scan [6]. There are stronger field in homogeneities at 3T. However, the SSGR method is rather insensitive to these problems in EPI DWI at 3T since it relies on the strong chemical shift effect along the slice direction for separation of water and fat while traditional methods are based on the in plane spectral effect and less effective. In summary, the in vivo experimental results here demonstrate that the combining SSGR with STE DWI sequence can suppress fat signals much more effectively than the traditional fat saturation methods. Furthermore, this SSGR method can be readily combined with any other fat suppression techniques.

REFERENCES: [1] Zoltan N, et al. MRM, 2008, 60:1256. [2] Caserta J, et al. JMR, 2004, 169:187. [3] Gomori JM, et al. Radiology, 1988, 168:493. [4] Zhou IY, et al. MRM. 2014, 72(5):1389. [5] Tang HY, et al. JMRI, 2007, 26:1064. [5] Foerster BU, et al. MRM, 2005, 54:1261.