

Feasibility of water-fat separation with diffusion weighted EPI

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Introduction: Dixon water-fat separation techniques can provide consistent fat suppression in a variety of pulse sequences and imaging applications [1]. For EPI-based DWI, spatial spectral pulses are most commonly used for fat suppression [2]. However, image shading and fat suppression failure are routinely observed in areas of inhomogeneity. STIR prepared EPI can provide more uniform suppression, albeit at the expense of substantially reduced SNR and increased scan time. While Dixon techniques have been applied to FSE-based DWI sequences [3], EPI-based DWI is an exception because fat signals are significantly shifted along the phase encode direction relative to water signals. In this study we demonstrate the feasibility of using a water-fat separation algorithm [4] with a single-shot EPI sequence under the condition that the spatial shift is small compared to the variation in magnetic field. We further propose corrections to enable water-fat separation with diffusion weighted data.

Methods: Acquisition: A single shot DW-EPI sequence was modified to allow shifting of the echo time away from the true spin echo time. For any given slice, the sequence was run with two echo times per diffusion weighting, with one of the echoes shifted 2.3 ms from the spin echo to produce an out-of-phase image. A conventional 90 degree excitation pulse was applied in place of the typical spatial spectral excitation to excite both fat and water spins. Abdomen and pelvis images were acquired of a volunteer on a 1.5T scanner (GE Healthcare, Waukesha, WI). Other sequence parameters were: TR = 5000 ms, TE = 58 and 60 ms, matrix = 128x192, FOV = 380 x 285 mm, slice thick = 6 mm, number of slices = 13, diffusion weighting $b = 0$ and 500 (slice select direction), total acquisition time = 25 sec. Parallel imaging (ASSET) and ramp sampling was applied to maximize the effective bandwidth in the phase encode direction, and fractional NEX was applied in the phase encode direction to minimize TE. **Reconstruction and image processing:** Reconstruction of complex images, with coil combination and EPI phase correction, was performed online. Separation of the water and fat signals on the complex images was performed offline using MATLAB (The Mathworks, Natick, MA). The two echoes acquired with $b=0$ were processed with no modifications to the water-fat separation algorithm [4], which applies phase correction to the phase difference between the echo times. Spatial phase variations in the diffusion weighted images were handled separately as follows. First, the diffusion weighted out-of-phase image was demodulated by the receiver coil phase estimated from the $b=0$ in-phase image, and by the inhomogeneity-induced phase error map generated by the water-fat algorithm as applied to the $b=0$ images. All low-order phase was also removed from the diffusion weighted in-phase image. After these initial corrections, the diffusion weighted images were processed by the water-fat separation algorithm. Water images were evaluated for artifacts and consistency of fat separation.

Results: Pelvic and abdominal images are shown in the figure to the right. Water-fat separation was successful on images acquired without diffusion weighting. For diffusion weighted images, occasional water-fat swaps were observed in motion prone areas that were often away from areas of clinical interest (e.g. stomach, subcutaneous regions).

Discussion: We demonstrated the feasibility of using Dixon water-fat separation on data acquired with echo shifted EPI. Since complex combination of the echoes was performed by the water-fat separation algorithm, SNR efficiency is potentially gained compared to conventional magnitude averaging of single shot EPI data. This method may benefit further from the use of high resolution reduced FOV techniques [5,6], which reduce distortion as well as the spatial shift of fat relative to water.

References: 1. Bley TA, JMRI 2010. 2. Schick F, JMRI 1998. 3. Hwang KP, ISMRM 2008. 4. Ma J, MRM 2004. 5. Saritas EU, MRM 2008. 6. Wheeler-Kingshott CA, MRM 2002.

Out-of-phase base images acquired by the echo shifted EPI sequence and resulting water-separated images. In-vivo pelvis (top) and abdomen (bottom) are shown, with (left) and without (right) diffusion weighting.

