WATER-FAT SEPARATION IN DIFFUSION-WEIGHTED MRI USING AN EPI-IDEAL APPROACH

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Introduction:
Frequency-selective fat suppression (SPIR, SPAIR) in EPI-based Diffusion Weighted Magnetic Resonance Imaging (DW-MRI) outside the brain is often a challenge due to significant magnetic field inhomogeneities. Although fat suppression may be improved by using other methods such as short tau inversion recovery (STIR) [2], this can increase significantly the acquisition time.
Recently Dixon/IDEAL methods for fat-water separation have found utility in non EPI sequences [3-5]. A 2-point Dixon method with a region growth reconstruction has been applied to DW-EPI by Hwang and Ma [6], and IDEAL has been used by Boernert et al. [7] in combination with spiral imaging. In this abstract we present a 3-point single-shot diffusion-weighted EPI-IDEAL technique which uses signal averages in diffusion-weighted imaging to encode fat-water chemical shift for IDEAL reconstruction, allowing water-only diffusion weighted imaging with little or no increase in scan time.

Methods:
A scheme for a 3-point IDEAL acquisition and reconstruction, as shown in figure 1, was implemented on a 1.5T Achieva scanner (Philips, Best, The Netherlands). This consisted of acquiring 3 images with different acquisition delays to shift the centre of k-space with respect to the spin echo within a single-shot diffusion-weighted spin echo EPI sequence. This was used to acquire images with a range of b-values on a phantom containing water, oil and sugar solution (20% and 50%), and in healthy volunteers, with a 32-channel cardiac coil using parallel imaging. The acquired data were reconstructed offline using an IDEAL reconstruction implemented in Matlab (MathWorks, Natwick, MA, USA).

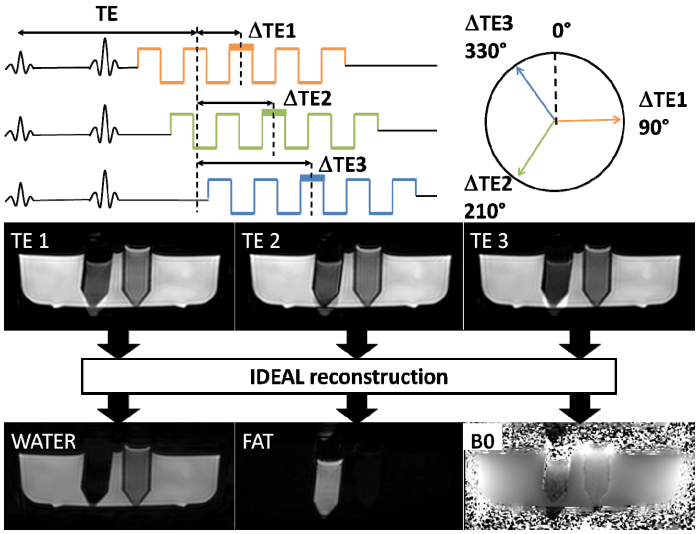

Fig. 1. 3-point EPI Dixon/IDEAL acquisition and reconstruction. Echo trains are shifted by a fixed time interval with respect to the spin echo, so that water-fat phase shift space is filled symmetrically, with one acquisition having a water-fat phase difference of 90° or 270°. Three images are produced and used to reconstruct water and fat images alongside a B0 map.

Results and discussion:
At different b-values, reconstructed phantom images (figure 2) showed good fat-water separation, as did *in vivo* scans of the pelvis (figure 3). Some water-fat swaps were observed at higher b-values. To reduce this, B0 maps calculated at lower b-values were used to demodulate the pre-reconstruction images before the IDEAL reconstruction was performed.
ADC maps were calculated in the phantom and compared with ADC calculated using standard single-shot EPI sequence with 3 signal averages. The ADC of the 20% sugar solution with EPI-IDEAL was measured to be 918±181mm^2/s, compared with 874±124mm^2/s from the standard EPI acquisition. Similarly 50% sugar solution ADCs were 1514±74 mm^2/s and 1452±45 mm^2/s in EPI-IDEAL and standard EPI acquisitions respectively, showing good agreement.
In summary, diffusion-weighted EPI Dixon is a promising, easy to implement method allowing reliable fat-water separation in fast diffusion-weighted imaging with little or no increase in scan time - depending on the required number of signal averages. The method produces diffusion weighted MRI for water and fat separately which can provide additional information, and allows to calculate reliable ADC maps.

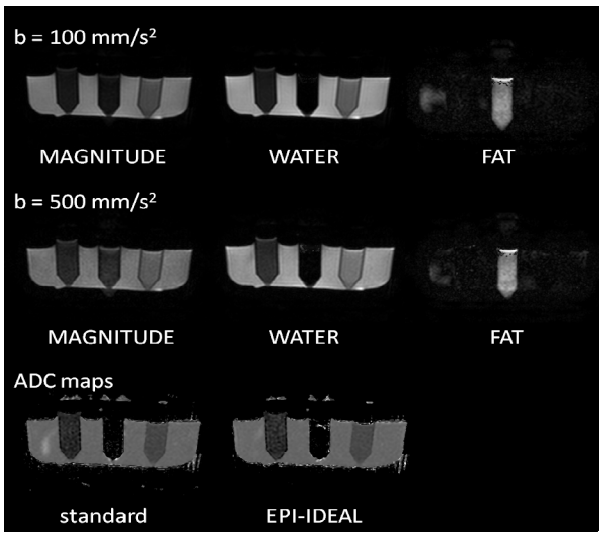

Fig.2. Phantom containing sugar solution (20%, left, and 50%, right) and oil (middle). Images acquired at different b-values show good water-fat separation, although at the edges of phantom some water-fat swaps occur due to large B0 inhomogeneities. ADC map calculated with a standard single-shot EPI acquisition is similar to that calculated with EPI-IDEAL.

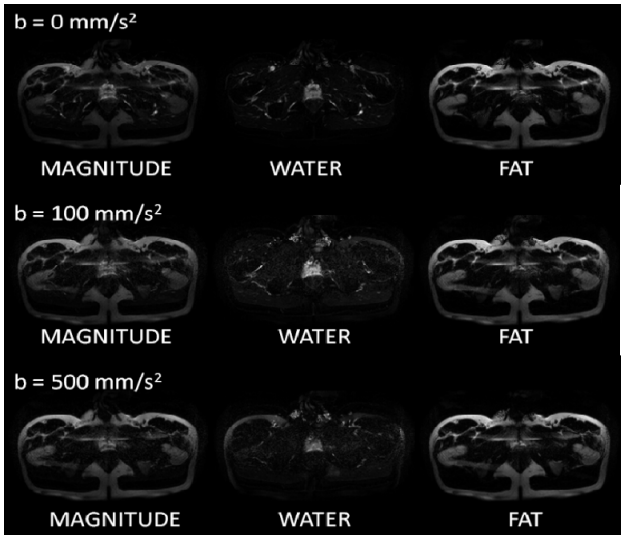

Fig.3. Pelvis scans of the prostate region show good water-fat separation, although at higher b-values some water-fat swapping occurs in the subcutaneous fat.

References: [1] Padhani et al., *Neoplasia* 2009:11 (102-25) [2] Bley et al., *JMRI* 2010:31 (4-18) [3] Glover, *JMRI* 1991:1 (521-530) [4] Reeder et al., *MRM* 2004:51 (35-45) [5] Reeder et al., *MRM* 2005:54 (636-644) [6] Hwang and Ma, ISMRM Annual Meeting 2011, Montreal [7] Boernert et al., *JMRI* 2010:32 (1262-1267)