Image-based weighted B0 shimming using a fast multi-echo DIXON technique: feasibility for abdominal imaging

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Introduction: One of the main challenges for abdominal MRI is robustness. A key element to always achieve diagnostic image quality is to obtain clinically acceptable fat suppression over the full FOV. This is particularly challenging given the large FOVs used in abdominal examinations, and even more at high field strength (e.g. 3.0T). Good B0 homogeneity plays an important role in achieving complete fat suppression, but standard spectral-based B0 shimming approaches may not always provide optimal results. As a result more sophisticated shimming techniques such as image-based weighted approaches have been recently proposed[1]. Image-based shimming methods typically use B0 maps acquired upfront. In this work, we describe an image-based weighted B0 shimming technique (IBwS) using a recently introduced fast multi-echo DIXON-based sequence (mDIXON)[2]. mDIXON allows to generate 3D B0 maps as well as water and fat images and have been used to tailor the cost function method employed in our IBwS approach. Our new shimming technique was validated on volunteers for abdominal imaging using 1st order IBwS and 2nd order IBwS and compared with a conventional 1st order spectral-based shimming approach (SBS).

Methods: Abdominal imaging was performed on 10 volunteers on a Philips Achieva 3T MR system using the torso-XL coil for signal reception. The mDIXON scan was performed within one breath hold of 5 seconds on a 400x400x210mm FOV with 6x6x6mm resolution. The reconstructed water (W) and fat (F) images were segmented using thresholding and the resulting 2 compartments fed to the IBwS tool together with the 3D-B0 field map. Our IBwS cost function was expressed as the sum of pixels in a given compartment whose F0 (F0pix) met the following criteria with respect to the mean compartment F0 (F0mean): i) For the fat compartment: F0pix < F0mean-75Hz or F0pix > F0mean +50Hz; ii) For the water compartment: F0pix < F0mean-50Hz or F0pix > F0mean +75Hz. A nonlinear minimization algorithm (MATLAB, MathWorks, Natick, Massachusetts, USA) was then performed with the above cost function to estimate the 1st order (x, y, z) and 2nd order (x, y, z, z^2, zx, zy, x^2-y^2 and 2xy) shim terms. Subsequent B0 maps were acquired with 1st order IBwS, 2nd order IBwS and SBS. Standard Fat suppressed T1-FFE and DWI scans were performed with IBwS and SBS for visual comparison. All scans were performed in breath-hold. For each volunteer a quantitative comparison was also performed using a quality measure (Q) retrieved from the IBwS and SBS B0 maps. Q was defined as the percentage of pixels whose F0 value falls outside a frequency range of 190Hz centered on the mean F0 of the water+fat compartments. A lower Q value represents better fat suppression performance.

Results: Fig.1 a) and b) and c) show respectively the mDIXON Water and Fat images and the result of the W/F segmentation (blue= water, red=fat) for volunteer 7. Fig.1 d) and e) show respectively the corresponding mDIXON-B0 maps with SBS and 2nd order IBwS. Note for this case the markedly improved B0 homogeneity when IBwS is used. Fig.1 f) to i) show respectively fat suppressed T1-FFE with SBS and IBwS, and DWI images with SBS and IBwS. Again here, fat suppression is dramatically improved when IBwS is used. The visual data inspection showed that IBwS was as good as or better than SBS on all 10 volunteers. The Q value analysis is reported in Fig. 2 for each volunteer and for the 3 shimming strategies. The graph shows that the Q values obtained with IBwS are lower than with SBS and more consistent across volunteers.

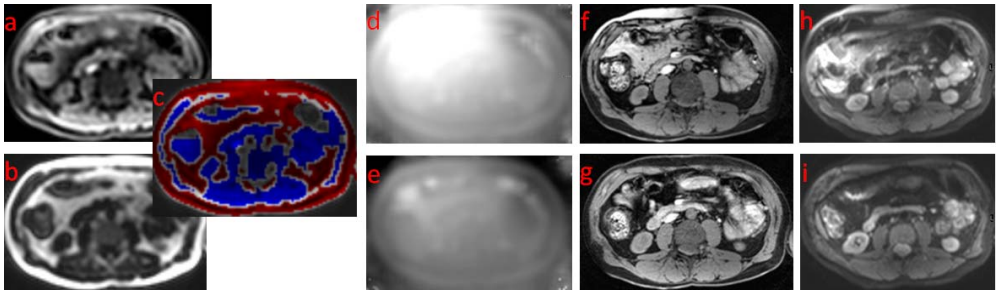

Fig 1: Water, Fat, B0, DWI and fat suppressed FFE images obtained on volunteer 7 (cf: Fig. 2)

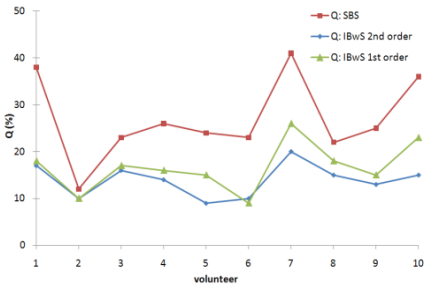

Fig 2: Q values for the shimming strategies.

Discussion / conclusion: Results showed that our novel IBwS approach resulted in visually improved fat suppression as compared to a conventional spectral-based shimming method. The quantitative analysis confirmed that IBwS also provided better and more consistent B0 homogeneity across volunteers. The study also showed that the image based weighted approach was the main contributor to B0 improvements compared to going from 1st order to higher order shims. Our approach using a fast DIXON-based technique was successfully applied to abdominal imaging on volunteers with no impact on examination workflow and duration thanks to a fully automated approach allowed by the intrinsic water/fat segmentation provided by mDIXON.

References: [1]: Siero JCW. et al. ISMRM 2010, #2589 [2]: Eggers H. et al. Proc. Intl. Soc. Mag. Reson. Med., 17:2705 (2009)