Orientation dependence of grey/white matter contrast in ultra high fields

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Introduction:

Recently, it has been shown that high resolution T2*-weighted images acquired at ultra high field show much more T2* heterogeneity in white matter [1] than at lower field [2], which alters with the orientation of fibre bundles with respect to the static field [3]. Phase images produced by using high resolution spoiled gradient echo sequences show high contrast between different compartments [4]. Since phase images reflect susceptibility variations more strongly than magnitude data, we have used phase images at 7 Tesla to address the orientation dependence of GM/WM contrast. Furthermore, we compare measurements with simulations based on applying a field calculation [4] to the HUGO body model (Medical VR Studio GmbH, Lörrach).

Methods:

Phase images were acquired with a whole body 7T scanner (MAGNETOM, Siemens Medical Solutions, Erlangen, Germany) using a T/R head coil. The subject was firstly positioned supine in the magnet, and 18 axial slices were acquired using a 2D fully flow compensated spoiled gradient echo sequence (TR/TE=500/20 ms, bw=130 Hz/pixel; voxel=1x1x1mm³). The subject then was asked to tilt the head backward (hyper-extended), which results in an angle of about 27 degrees compared to the first position. The image acquisition was then repeated using the same scanning parameters with the slices repositioned to cover the same area of the head.

Field perturbations due to a susceptibility distribution, $\chi(\mathbf{r})$ in a magnetic field B_0 applied in the z-direction were evaluated by inverse 3D Fourier transformation (FT) of $B_0 X(\mathbf{k})(1/3-\cos^2\beta)$ where $X(\mathbf{k})$ is the 3DFT of $\chi(\mathbf{r})$ and β is the angle between $\mathbf{k}$ and the k_z-axis [5]. This approach has the advantage of naturally including the effect of the sphere of Lorentz so that multiplication of the calculated field offset by the magnetogyric ratio γ, yields the NMR frequency offset [5]. Field changes due to object rotation may also be simply evaluated. Simulations were carried out with 3D matrix sizes of 512^3 based on structures taken from the HUGO body model with 1mm isotropic resolution.

Both the measured phase data and simulated field-shifts were high-pass filtered to remove phase variations occurring on a large length scale. This was accomplished by dividing the original complex data by a low-pass filtered version of the data, formed via Gaussian Fourier filtering (8 pixel FWHM).

Results and discussion:

Figure 1 shows modulus (b,d,h,j) and phase T2*-weighted images (c,e,i,k). All images show a dependence on the orientation of the head with respect to the main magnetic field, with a greater change in GM/WM contrast noticeable in the phase images. GM/WM boundaries also appear sharper in the phase images acquired with the orientation where slices are perpendicular to the main magnetic field (arrow). The same orientation effect appears in the simulated field-shift data (f,l). Thus, orientation dependent contrast changes in T2*-weighted data appear to be an effect of the non-local dipolar field.

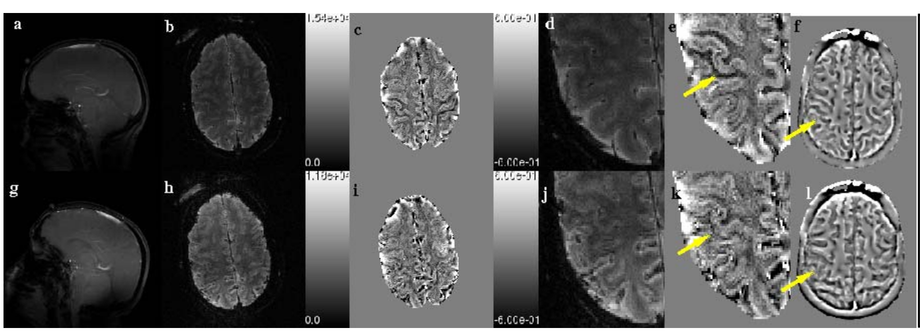

Figure1: The modulus (b,d) and phase image (c,e) acquired at the supine position (a) and the modulus (h,j) and phase image (i,k) at the hyper-extended position (g). The calculated field shift of the HUGO model with the same orientations to the main magnetic field as the measured data (f,l).

References:

[1] Li *et al*. NeuroImage 32:1032-1040 (2006) ; [2] Henkelmann *et al*. MRM 32:592-601 (1994) ; [3] Wiggins *et al*. Proc ISMRM 16:237 (2008); [4] Duyn *et al*. PNAS 104 (26):11796-11801 (2007) ; [5] Marques *et al*. Conc. MR 25B: 65-78, (2005)