The relationship between susceptibility weighted phase and white matter fiber orientation.

E. Hernández[1], A. MacKay[2], and A. Rauscher[3]

[1]Instituto de Física, Universidad de Guanajuato, León, Guanajuato, Mexico, [2]Physics and Astronomy, University of British Columbia, Vancouver, British Columbia, Canada, [3]UBC MRI Research Centre, University of British Columbia, Vancouver, British Columbia, Canada

Introduction: The origin of contrast in susceptibility weighted phase imaging (1) is not yet fully understood. Both grey and white matter show considerable heterogeneity on phase images (2) and white matter T2* was also found to be heterogeneous (3).

Subjects and Method: Data from 2 healthy volunteers (1 female, 1 male, ages 29 and 31) were acquired on a Philips Achieva 3.0T system. SWI data were acquired with a flow-compensated 3D gradient echo method [4] (TR/TE/alpha=40/20/19, acquisition matrix = 480 x 231 x 32, reconstruction matrix 560 x 560 x 64). Phase images [7] were unwrapped [8,9] and high pass filtered. DTI data were acquired axial orientation with the following parameters: SE EPI, Voxel size = 2.2 x 2.2 2.2, FOV = 212 x 212 x 132, SENSE-factor = 2.4, TR = 7.4 s, TE = 75 ms, δ = 13.2ms, Δ = 27.4 ms, b = 0 & 1000s/mm^2, 16 directions, 2 averages.

Magnitude and phase images were reconstructed for the SWI. Phase wraps were removed from the phase images by homodyne filtering in 2D with a Hanning window of 140 x 140 pixels. This filter also removes phase variations with low spatial frequencies The DTI data were corrected for eddy currents using FSL (6). The phase images were coregistered to the DTI data using FSL's FLIRT tool by coregistering the magnitude and applying the parameters to the phase images. DTI analysis was performed with FSL's FDT diffusion The phase was compared to the orientation between the fibers and the main magnetic field obtained from the DTI data. To exclude noise, CSF and grey matter, only pixels with fractional anisotropy above 0.25 were evaluated. The phase of all pixels for a given fiber orientation was averaged and plotted against the fiber orientation for the range between 0 to 90 degrees.

Results:

A map of fiber orientation is shown in Fig 1. Blue corresponds to fibers parallel to the main magnetic field and red to fibers perpendicular to the magnetic field. The corresponding phase is shown in Fig 2. The realtionship between fiber orientation and phase was similar for both subjects, except for a constant offset. Phase was negative for fibers parallel and perpendicular to Bo and positive for fibres at intermediate angles

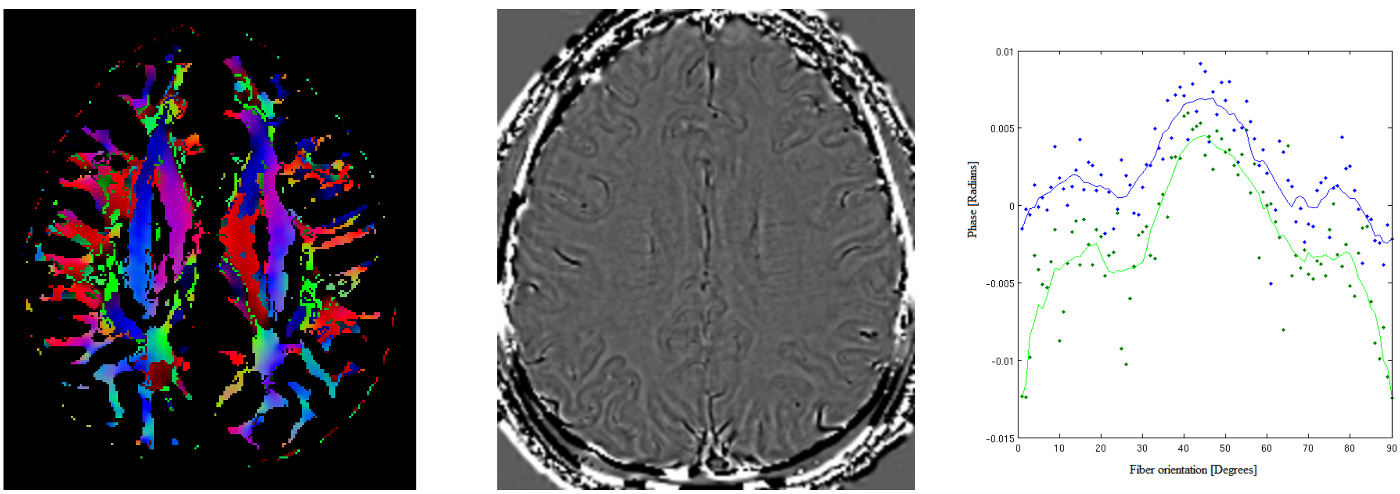

Fig 1. Left: Fiber orientation map. Blue corresponds to parallel, red to perpendicular to B0. Centre: Phase image of the same slice. Right: Plot of phase (y-axis) vs. fiber orientation (x-axis).

Discussion: Several factors could cause the observed orientation dependence of phase. One strong modifier of signal phase is deoxygenated blood in venous vessels (6). There are regional variations in vascular density and blood vessels in white matter are oriented preferentially parallel to axon fibers (7). Myelin content and macromolecular content (8) may be another explanation; however, we are not aware of any evidence for a correlation between myelin content and fiber orientation. Finally, non-heme iron may also play a role in the phase variations, since it is an important catalytic centre for the myelin production by oligodendrocytes (9). Our data were acquired for a study on multiple sclerosis and the SWI protocol was designed to be very sensitive to venous vessels. This resulted in anisotropic voxels, i.e. thick slices with high in plane resolution, which gives rise to negative phases for large veins perpendicular and parallel to the magnetic field (6). Future work will therefore also employ data acquisition with several different voxel aspect ratios.

References: **[1]** Rauscher et al. AJNR Am J Neuroradiol. 2005 Apr;26(4):736-42.**[2]** Duyn et al. PNAS, 2007. 2007 Jul 10;104(28):11796-801 **[3]** Li TQ et al. Neuroimage 2006 Sep;32(3):1032-40 **[4]** Reichenbach JR et al. NMR Biomed. 2001;14(7-8):453-67. **[5]** Witoszynskyj S et al. Medical Image Analysis, 2008, in press **[6]** http://www.fmrib.ox.ac.uk/fsl/ **[5]** Haacke EM et al. J Magn Reson Imaging. 2007 Aug;26(2):256-64. **[6]** Sedacik et al. Magn Reson Med, 2007;58(5):1035-44 **[7]** Cavaglia et al. Brain Research 910 (2001) 81–93 **[8]** Zhong K et al.2008 May 1;40(4):1561-6 [9] Levine SM et al. Ann N Y Acad Sci. 2004;1012:252-66.