Orientation Dependence of White Matter T_2^* Contrast at 7 T : A Direct Demonstration

C. J. Wiggins[1], V. Gudmundsdottir[1], D. Le Bihan[1], V. Lebon[1], and M. Chaumeil[1]

[1]CEA/NeuroSpin, Saclay, France

Recently a great deal of interest at fields of 7T or more has been high resolution T_2^*-weighted images [1,2]. A FLASH-like sequence [3] can easily generate very high resolution (e.g. 0.2x0.2x1.0mm voxels) images in a reasonable time frame (<10 minutes), with relatively low distortion and SAR load. An impressive level of structure can be seen, not just due to the resolution but also because of increased contrast between tissues, especially around blood vessels. However, as explored by Li and colleagues [4], there is also considerable contrast in white matter areas that is not properly understood. Li suggests various contrast mechanisms including differences in iron concentration and/or organization/orientation, variation in myelin density, and variation in density and orientation of venous micro-vascular elements. This study attempts to directly address the question of possible orientation components to the contrast.

With available magnet technology, ultra-high field MRI systems for human use are invariably based on solenoid geometry with the long axis of the subject along the axis of the magnet. Rotation of the head or body around the long axis of the subject, in this geometry, does not change the orientation of the main field compared to the brain, and other rotations of the head are quite limited in scope, with maximum angle considerably less than 90°. To be able to perform a larger rotation, we chose instead to use a macaque model. T_2^* heterogeneity can also be seen in the macaque, but the smaller dimensions of the body allow at least two orthogonal head positions, the sphinx position (face pointing along the magnet axis) or supine (face pointing perpendicular to the magnet axis).

Experiments were performed on a single animal, and all work was conducted according to local experimental approvals. Animals were anesthetized using a continuous intravenous infusion of propofol (100µg/kg/min) and physiological parameters (temperature, cardiac and respiratory frequencies) were kept in normal ranges during the acquisition. Scanning was performed on a 7T human scanner equipped with a head gradient set (Siemens, Erlangen, Germany) A human head coil was used to avoid RF field homogeneity issues. The animal was initially set up in the sphinx position. After a localizer scan, a set of 10 images were acquired with a coronal (with reference to the brain, not the magnet) slice orientation in an area around the anterior commisure. Imaging parameters were TE 25ms, TR 500ms, Flip Angle 25°, slice thickness 1mm, FOV 128x107mm, matrix 384x320, 6 averages. The animal was then put in a supine position and rescanned with slices positioned to cover the same area of the brain. To determine the robustness of any contrast change, the animal was then placed in the sphinx position again, rescanned, and then scanned once more in the supine position (Figure 1).

In interpreting the results, we mainly concentrate on the area of the corpus callosum and cingulum (Figure 2). The corpus callosum has an orientation that is predominately transverse to the magnet in both orientations. The cingulum, however, is close to axial in the sphinx position and close to transverse in the supine position. Even a casual examination of the images shows a dramatic and repeatable change in contrast between these two structure when the orientation of the brain is changed. This was confirmed by examining the intensities of ROIs placed in the corpus callosum and cingulum (Figure 3) using the standard ROI tool of the system software.

These results show unambiguously that tissue orientation relative to the main magnetic field can be a major component of the white matter contrast in high field T_2^* imaging. This leads to a variety of potential experiments, in particular in combination with other orientation dependent contrasts such as DTI and DSI. Further work is required, however, to determine whether this is the dominant contrast mechanism in all the white matter, and from where this orientation dependence arises (e.g. iron deposits or vasculature). It should also be noted that a previous study by Henkelman et. al. [5] showed no orientation dependence on the relaxation time of excised bovine corpus callosum. However this study was performed at 1.5 T, so it is possible that the increase in applied field strength increases susceptibility effects, and so these orientation effects may only start to be apparent at higher field.

1: Robitaille et al. J. Comput. Assist. Tomogr. **24**:2-8 (2000), 2: Duyn et al. PNAS **104**(26):11796-11801 (2007), 3: Haase et al. J. Magn Res. **67**:258-266 (1986), 4: Li et al. Neuroimage **32**:1032-1040 (2006), 5: Henkelman et al. MRM **32**:592-601 (1994)

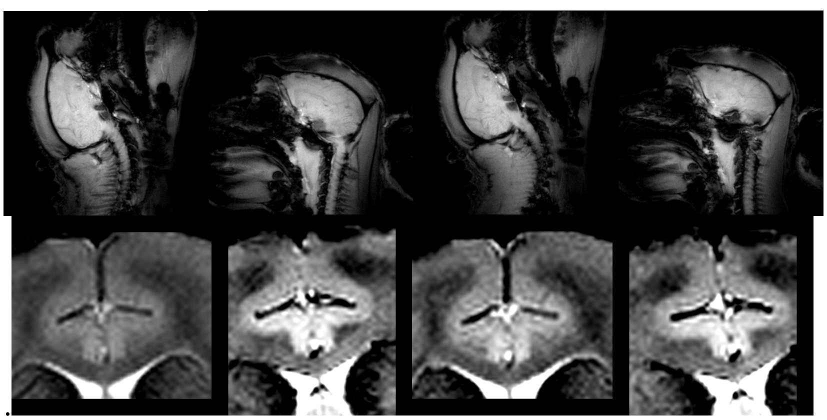

Figure 1: Sagittal (magnet coordinates) localiser (upper row) and zoomed view of coronal (brain coordinates) for the two sphinx orientations (far left and center right) and two supine positions (center left and far right)

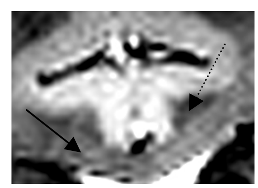

Figure 2: Corpus Callosum (solid line) and Cingulum (dotted line). These structures have fibers that are oriented nearly perpendicular to each other.

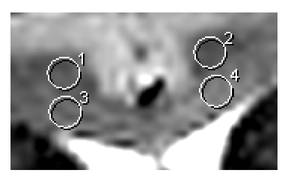

Figure 3: ROI definition for analysis: 1,2 – Left and Right Cingulum, 3,4 – Left and Right Corpus Callosum.

	Left Cingulum		Right Cingulum		Left Corpus Callosum		Right Corpus Callosum	
	ROI values	Norm	ROI values	Norm	ROI values	Norm	ROI values	Norm
Sphinx 1	705.9±35.1	1.27±0.06	712.8±37.6	1.28±0.07	556.9±42.4	1.00	583.8±27.2	1.05±0.05
Sphinx 2	603.5±35.5	1.12±0.07	671.5±22.2	1.25±0.04	537.6±25.4	1.00	531.3±21.7	0.99±0.04
Supine 1	557.5±35.6	0.94±0.06	499.5±33.9	0.84±0.06	593.4±59.7	1.00	646.2±32.2	1.09±0.05
Supine 2	538.8±23.9	0.91±0.04	525.7±30.3	0.89±0.05	593.4±58.9	1.00	652.8±36.7	1.10±0.06

Table of pixel values from ROIs as defined in Figure 2. Values given are mean ± standard deviation. Normalised values are the pixel values divided by the value for the left corpus callosum ROI for each orientation.