Is R2* in Human Brain White Matter Dependent on B0 Orientation?

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Introduction: The observation of T_2* heterogeneity in white matter at high magnetic field strength [1] has invited speculation that white matter fiber orientation with respect to the main magnetic field (B_0) might contribute to this contrast. A possible mechanism is the orientation dependence of microscopic field distributions in oriented structures such as the brain's major axonal fiber bundles. Orientation dependence of T_2 in peripheral nerves [2] and of dipolar splitting in spectroscopy of muscle fibers can be interpreted as evidence for this and suggest an angular dependence according to $3\cos(\theta)^2$-1. A preliminary study on a non-human primate suggest this mechanism indeed affects white matter T_2* in high field MRI of brain [3]. To further investigate this, we performed quantitative R_2* measurements at different orientations *in vivo* and in fixed brain tissue samples.

Methods: The *in vivo* experiments were conducted using a whole body GE Signa 7T MRI system. Signal reception was performed using a 32-channel whole-brain detector arrays. Whole brain R_2*mappings were conducted at two different head positions: 1) transverse slices while the subject lying supine with the head and array coil positioned flat inside the magnet; 2) transverse slices while the subject's head and the detector were tilted 27° relative to B_0. Two different data acquisition strategies were used: 1) inter-leaved spiral acquisition with dynamic increment of TE over different TRs; 2) using a multi-echo EPI style readout to acquire 20 gradient echoes in each TR. The later was found to produce more reliable R_2* measurements. Repeated whole-brain R_2*measurements at the resolution of 1x1x2 mm^3 with the multi-echo approach showed the coefficient of variance of the measured R_2* in white matter is about 3%. The acquisition parameters were: 56 transverse slices of 1.8 mm thick and 0.2 mm gap, in-plane resolution of 1x1mm^2, TR=4.1s, TE for the different echoes was varied from 8.4 to 49.4ms. Volumetric co-registration between the R_2*maps measured at two different orientations were performed by using the AIR software. R_2* mapping of formalin-fixed brain tissue samples as a function of the orientation relative to B_0 were also conducted in a similar fashion using dedicated small coil arrays at 7T. R_2* mapping φορ a small piece of corpus callosum was also performed on a Bruker 11.7T experimental system at 3 different orientations (0°, 45° and 90° relative to B_0) using a solenoid coil. The measurements at 11.7T were carried out using a multi-echo 3D sequence to achieve 100μm isotropic resolution. Other parameters were: TR=80ms NEX=16, 12 echoes with echo time varied from 2.84 to 67.74ms.

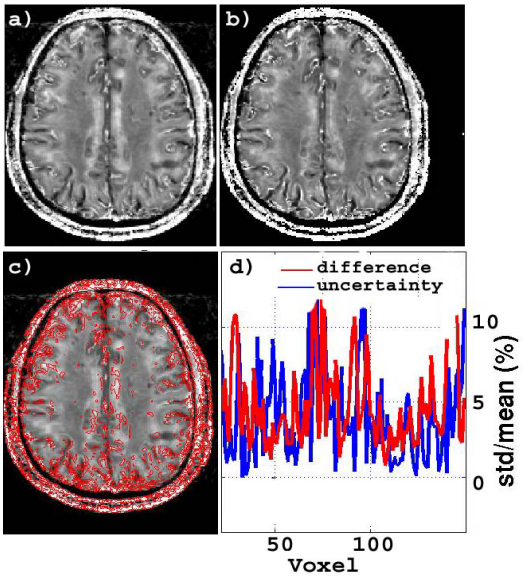

Figure 1: R2* maps at 2 didderent orientations.

Table 1: R2* mapping results in fixed tissue

Orientation	0	45	90
R2*+std (1/s)	37.8+2.9	36.6+3.3	39.5+3.3
$\|3\cos(\theta)^2-1\|$	2	0.5	1

Results: Figure 1a and b show R_2* maps measured at two different orientations: lying flat with image plane 90° to B_0 versus tilted 27° relative to B_0. The corresponding change in $|3\cos(\theta)^2-1|$ is from 1.0 to 1.4. The orientation change has no apparent effect in the R_2* contrast in white matter, e.g. the contrast between cingulum (CG) and superior coronal radiata (SCR) fiber bundles was not significantly altered. The average difference between the R_2* maps measured at the two different orientations is shown in fig. 1c as coloured contour plot over the base R_2*map. The variances are largely in the scalp and CSF regions. The change in white matter is negligible. Quantitative analysis of the line profiles across the images shows that the differences between the R_2* maps measured at the two different orientations are comparable to the magnitude of variance for repeated measurements at the same orientation. The line profiles shown in fig. 1d clearly demonstrate this. The R_2* measurements in fixed brain tissue samples further confirmed minimal dependence on orientation with respect to B_0. The experimental results for the corpus callosum sample measured at 11.7T are summarized in Table 1. The expected relative change based on the "magic angle" effect is also included.

Discussion: Within the experimental error, the measurements *in vivo* and of the fixed brain tissues indicate R_2* in human brain white matter is not significantly influenced by the tissue orientation relative to the main magnetic field. This agrees also with earlier studies on tissue samples [4] and *in vivo* [5] which showed no unique relationship between R_2* and fiber orientation angles as determined from DTI measurements.

Reference: [1] Li et al. *Neuroimage*, **32**:1032 (2006); [2] Chapppell et al. AJNR **25**:431 (2004); [3] Wiggens, C. J. Et al. *Proc. ISMRM,* p. 237 (2008); [4] Henkelman et al. MRM 32:592-601 (1994); [5] Li, T.Q. et al. *Proc ISMRM*, p.1103 (2007).