Fiber orientation dependance of T2* relaxation time in the whole human brain at 3T

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Introduction: An orientation dependency of T2*-weighted images at high field strengths was described in recent publications. Wiggins et al. [1] first demonstrated a direct change in the intensity of the Corpus Callosum and the Cingulum when tilting the head and Cherubini et al. [2] demonstrated a relationship between R2* and main fiber direction when comparing R2*-maps with DTI data and suggests that fiber orientation might play an important role in all WM. Several tissues show a relationship with B0, for example peripheral nerves [3] and blood vessels [4,5]. In this study it is examined whether a real angle dependency exists for all of the WM and the results are compared with the relationships found for peripheral nerves and for blood vessels.

Subjects and Method: Data from four healthy subjects were acquired on a 3T Tim Trio Scanner (Siemens, Erlangen, Germany). All volunteers underwent the MRI protocol twice in the same session, once with the head in normal position and once with the head tilted. T2* decay was measured with 14 2D GRE-EPI sequences with TE between 21 ms and 86 ms (TR 6s, FoV 192 x 192 mm², acquisition matrix = 64 x 64, bandwidth 2520 Hz/px, four averages, flip angle 90°, 3 mm slice thickness, 33% gap, 15 slices). DTI data were acquired with the following parameters: SE EPI, TR 7.5s, TE 79 ms, FoV 232 x 256 mm², acquisition matrix 116 x 128, bandwidth 1116 Hz/px, 2mm slice thickness, 50 slices, b-value 0 and 800s/mm², 6 directions, 3 averages.

Images were evaluated in Matlab (R2008b, The MathWorks, Natick, MA, USA) with SPM5 [6]. First FA maps and eigenvector maps were calculated from the DTI dataset, then the angle θ_z between the largest eigenvector and the z-axis of the scanner coordinate system were derived. Afterwards the tilted head was realigned to the normal head position and the corresponding transformation matrix applied to the GRE-EPI images. The GRE-EPI images were resliced to the first b0 image of the DTI volume set. T2* maps were generated by fitting a straight line to the logarithmic signal decay on a voxe-by-voxel basis. All voxels with a FA ≥ 0.4 were evaluated.

Results: Figure 1 demonstrates the relationship between the relaxation rate R_2^* ($R_2^* = 1/T_2^*$) and the fiber direction in relation to the main magnetic field. Figure 2 depicts the change in θ_z and the corresponding change in T2* from tilted to normal head position for one of the subjects. Without a maximum around 55° a relationship on the magic angle term $3\cos^2(\alpha) - 1$, found in tendons and peripheral nerves [3] can be barred out. A function of the term $\sin^2(\alpha)$, a relationship known to exist for blood vessels with a main orientation [4,5], was added to figure 1 (blue line) and fits the scatter plot well.

Discussion: This work shows that R2* changes when the fiber orientation towards B0 in the scanner is altered. It extends the findings of Wiggins et al. [1] in the Corpus Callosum and the Cingulum to the rest of the WM. The origin of this relationship is unknown, but several theories exist. A magic angle effect with a maximum at around 55° from dipole-dipole interactions found in peripheral nerves [6] cannot explain the shown relationship (figure 1). Blood vessels follow mainly the main fiber direction [7] and the known relationship between R2' and the angle α between the main blood vessel direction and B0 [4,5] fits the measured data well. Therefore blood vessels could explain the shown relationship.

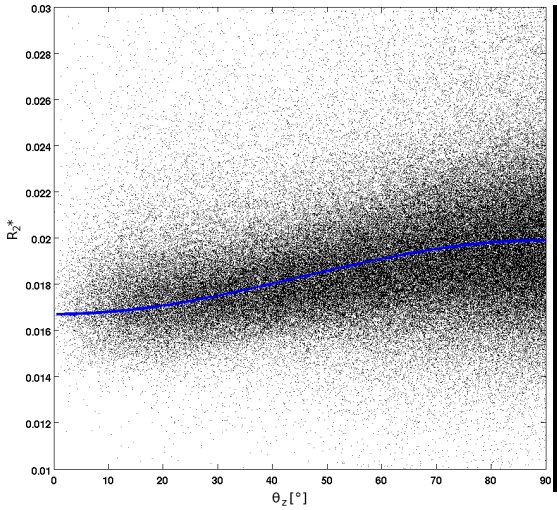

Figure 1: Relationship between R2 and fiber orientation towards B0. The blue line depicts an example of a possible $\sin^2(\theta_z)$ relationship.*

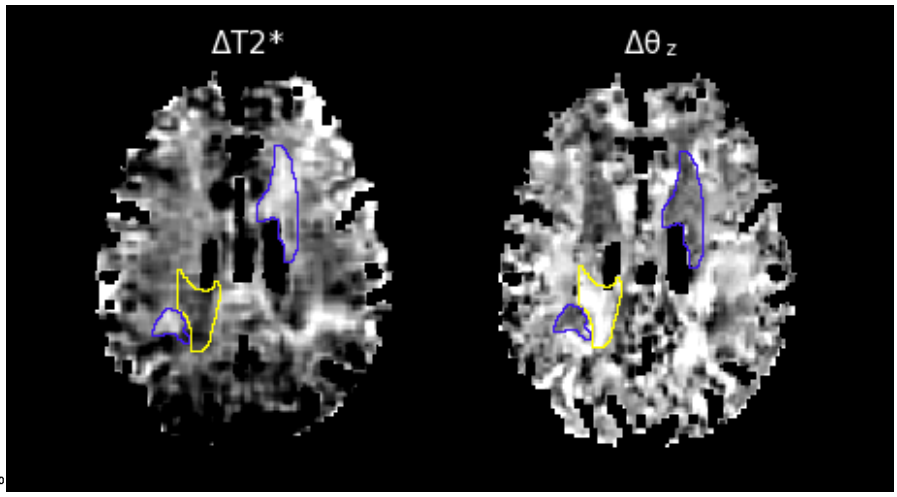

Figure 2: Change in T2(-7ms - +7ms) and change in fiber orientation towards B0 (-35° - +20°) when comparing normal and tilted head position. Same areas with a strong change are marked in both images with blue and yellow.*

References:
[1] Wiggins et al. Proc ISMRM 16:237 (2008); [2] Cherubini et al. MRM 61:1066-1072 (2009); [3] Chappell et al. AJNR 25: 431-440 (2004); [4] Yablonskiy et al. MRM 32: 749-763 (1994); [5] Yablonskiy et al. MRM 36: 214-221 (1996); [6] http://ww.fil.ion.ucl.ac.uk/spm/software/spm5/; [7] Cavaglia et al. Brain Res 910: 81-93 (2001)