Correlation between R2* and FA in Human Brain White Matter

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Introduction: High resolution MRI at 7T suggests that T_2* contrast may be sensitive to white matter composition and microstructure [1]. Preliminary histological and MRI results show that the T_2* heterogeneity in white matter may be in part reflect its myelin content [2]. In this study, the quantitative correlation between T_2* relaxation rate ($R_2^*=1/T_2^*$) and diffusion fractional anisotropy (FA) in white matter was investigated in normal volunteers at 3T and 7T.

Methods: The experiments were conducted on whole body GE Signa 3 and 7T MRI systems equipped with Twin-Speed gradient sets. Signal reception at 3 and 7T was performed using 16 and 32-channel whole-brain detector arrays (NOVA Medical Inc, MA), respectively. Whole brain diffusion tensor imaging (DTI) measurements were performed at 3T with 3 repeat measurements. R_2* mapping was conducted at both 3 and 7T with at least 2 repeats. 12 normal volunteers (aged 23-52, 5 females) were studied on both scanners. The FA and R_2* mapping at 3T were performed at the same slice location. The 3T protocol included the following: 1) repeated sets of R_2* mappings using an EPI style readout to acquire 20 gradient echoes. The acquisition parameters were: 56 transverse slices of 1.8 mm thick and 0.2mm gap, in-plane resolution of $1\mathrm{x}1\mathrm{mm}^2$, TR=4.1s, TE was varied from 8.4 to 49.4ms; 2). Three sets of DTI measurements based on the single-shot SENSE EPI method. The acquisition parameters were: 56 contiguous axial slices of 2mm thick with locations coinciding with those of the R_2* measurements, in-plane resolution of 2x2 mm^2, TR=13s, b=1000s/mm^2, an optimized DTI scheme with 6 T_2-weighted and 50 diffusion-weighted scans. The same R_2* mapping protocol was also used on the 7T. To facilitate the co-registration between the 3T and 7T MRI data, facial stickers were used when positioning the volunteers into the magnets. Experiments at 3 and 7T lasted 120 and 90 minutes, respectively. The FA and R_2* maps were extracted by standard non-linear curve fitting procedures. To mitigate the effect of macroscopic inhomogeneities on R_2* mapping, a model based on first-order correction was used [3]. For each R_2* mapping data set, the even and odd echoes were evaluated separately. Therefore, the triple measurement protocol produced 6 sets of R_2* maps. Motion correction and image co-registration were performed by using the AFNI and AIR software packages, respectively. A dedicated graphical interface program based on MATLAB was used to evaluate FA and R_2* values in the identical regions of interests (ROIs).

Results: As shown in Fig. 1a, R_2* and FA maps measured at 3T can be precisely co-registered. Since they were measured by at the same slice locations, the extracted parameter maps are of high quality and similar contrast in white matter. As estimated from the repeated measurements, the uncertainties (std/mean) for the R_2* measurements at 3 and 7T were about 2 and 3%, respectively. The uncertainty in the measured FA values in white matter was about 4%. Fig. 1b shows the scatter plot of R_2* versus FA values for ROIs (circular areas of 78 mm^2) randomly selected in brain white matter. Based on the analysis of 160 ROIs per subject, the estimated average correlation coefficients between R_2* and FA were 0.32 and 0.53 for the 3 and 7T data, respectively (p<0.01). The $\Delta R_2^*/\Delta FA$ ratios for the 3 and 7T data were 13 and 38 s^{-1}, respectively.

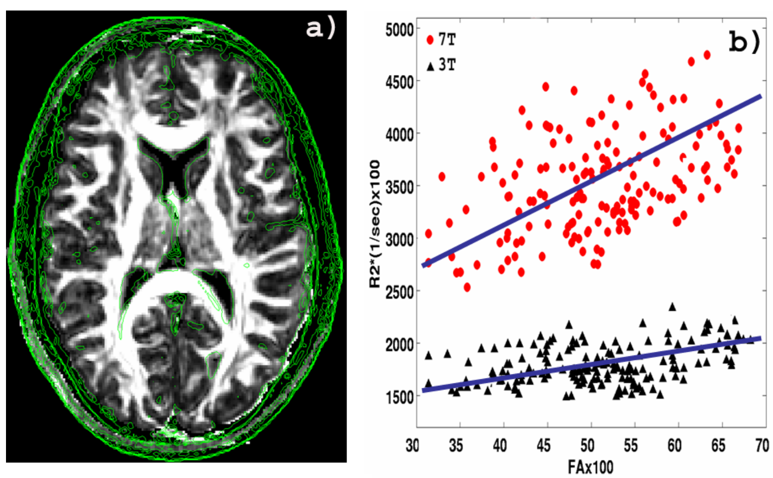

Figure 1: FA with overlaid R2* contour plots (a), scatterplot of ROI R2* values at 3 and 7T versus FA for one subject (b).

Discussion: The $\Delta R_2^*/\Delta FA$ ratio and correlation coefficient between R_2* and FA measured at 7T are much higher than those at 3T, despite the increased scatters apparently associated with the imperfect co-registration between 3T DTI and 7T R_2* data. This suggests that at higher magnetic field strength, R_2* becomes a more sensitive measure of FA. The correlation between R_2* and FA is partly attributed to fiber myelination, which increases both FA and R_2*. iron could also be the cause, as it often co-localizes with myelin. The significant correlation between R_2* and FA suggests that high field T_2* weighted imaging may be as an alternative to DTI for the discrimination of fiber bundles based on their myelination. DTI at 7T and above are hampered by the increased gradient stress and significantly shortened T_2. On the other hand, quantitative R_2* mapping can be readily performed at much higher resolution, down to 0.5x0.5x1 mm^3 or better.

Reference: [1] Li,T.Q. et al. *Neuroimage*, **32**:1032 (2006). [2] Li,T.Q. et al.*Magn Reson Med*, submitted (2008). [3] Fernadez-Seara et al. *Magn. Reson* **44:**358 (2000).