USING THE CHARMED MODEL TO ELUCIDATE THE UNDERPINNINGS OF CONTRAST IN DIFFUSIONAL KURTOSIS IMAGING

Silvia De Santis¹, Yaniv Assaf², and Derek K Jones¹

¹CUBRIC, Cardiff University, Cardiff, United Kingdom; ²Tel Aviv University, Tel Aviv, Israel

Introduction

Conventional DTI measures [1] are affected by a lack of specificity that complicates the interpretation of the results, because very different configurations of axon density, size and myelination may generate the same measured DTI parameters. Moreover, in white matter (WM) diffusion-induced MRI signal loss deviates from mono-exponential decay, particularly at high diffusion weightings or b-values. To address these issues, both model-based and model-free approaches have been proposed. Diffusional kurtosis imaging (DKI) [2] is a model-free technique that estimates the kurtosis from the expansion of the logarithm of the MRI signal intensity in powers of b, without a priori hypotheses on the biophysics. CHARMED model [3] expresses the information between the kurtosis and the del-free approaches have been investigated to elucidate the relationship between DKI and investigated as a function of the CHARMED parameters (restricted volume fraction $RF$ and axial diffusivity $D$). The correlation between these measures was then investigated in vivo in 5 healthy young subjects that underwent a combined CHARMED/DKI protocol at 3T[5], according to the following parameters: TE/TR=114/1700ms, 130 unique gradient directions, maximum b-value=7500s/mm². A cardiac-gated DTI protocol was also used (TE=93ms, 45 directions, maximum b-value=1200s/mm²) to derive maps of the intra-voxel directional coherence (IVDC) [6], a measure of the local fibre dispersion. Inter-subject alignment and statistical analysis were performed combining the TBSS approach [7] with an automatic region-of-interest (ROI) selection using WM labelling in standard space. Non-parametric Spearman correlation and multiple linear regression coefficients were calculated in Matlab.

Results

For a fixed diffusion time, the value of K from the theory has a monotonically increasing trend for both increasing RF values and increasing D (Fig1a). A significant positive correlation ($p<0.001$) was found in vivo between the kurtosis orthogonal to the main fibre direction ($K_{ORTHO}$) and RF (Fig1b). The positive correlation found between $K_{ORTHO}$ and D is not statistically significant at a 0.05 level. A multivariate linear regression showed that $K_{ORTHO}$ values are better explained by a mixed contribution of both RF and D ($p<0.001$), according to the model $K_{ORTHO}=\alpha RF+\beta D+\gamma$ (whit $\alpha=4.65/\beta=0.12/\gamma=0.22$). In Fig1c, the data are divided into two equally sized groups, corresponding to low and high values of IVDC. The correlation coefficient calculated separately for the two groups shows that in ROIs characterized by high inter-voxel directional coherence among fibres, the correlation between $K_{ORTHO}$ and the regression model $\alpha RF+\beta D+\gamma$ is stronger ($p<0.83$) as compared to the correlation calculated in ROIs of lower inter-voxel directional coherence ($p=0.67$).

Discussion and Conclusion

We report for the first time the dependency of the CHARMED parameters RF and D by calculating K directly from the propagator used in the CHARMED model and verifying the correlation between $K_{ORTHO}$ and the CHARMED parameters in vivo. By calculating the kurtosis associated to the CHARMED model, it is possible to interpret the results of a model-free approach in terms of the underlying biophysics. When the correlation between the kurtosis and the CHARMED model parameter is calculated separately for high and low values of IVDC, a stronger correlation is found in ROI characterised by higher IVDC. This suggests that DKI and CHARMED overlap where the hypothesis of a simple cylindrical geometry holds, showing instead a different information content in areas of non-negligible fibre dispersion.

References