AbstractID: 13324 Title: Evaluation of the Intracellular and Extracellular Anomalous Diffusion from MR Diffusion Tensor in Neural Structure

Purpose: To improve the characterization of the distribution and microarchitecture of white matter by comparing Monte Carlo simulations of the diffusion weighted MR signal from both the Gaussian and non-Gaussian PDF with generalized models of anomalous diffusion $\langle \Delta x^2 \rangle \propto t^{\alpha}$, $\alpha \neq 1$ that allows for deviations from standard Fickian diffusion as a function of axon diameter, packing fraction, and fiber spatial distribution.

Method and Materials:

The diffusion weighted MR signal is evaluated from a 3D Monte Carlo simulator that tracks the pulsed gradient spin echo within a voxel size $100\times100\times100\mu m^3$, TE= 80ms, Δ =40ms, δ=30ms . White matter is modeled as cylindrical fibers with intracellular and extracellular molecules distributed homogeneously under δ correlated and general stochastic force within and between the axons. The semi-analytic models are taken from a general Fokker-Planck equation that allows deviations from Gaussian diffusion. The mean square displacement predicted from the models is compared to the results of the Monte Carlo simulations for different fiber configurations.

Results: Fickian diffusion assumption in conventional diffusion tensor imaging (DTI) can only sustain in a condition of mean spatial homogeneity that depends on the architecture and measurement time. Non-Fickian diffusion are predicted and observed in the simulations at early times and weaken at very late times. Even when the diffusion is inferred to be Fickian, higher order statistical measures of the molecular distribution such as kurtosis reveal an opposite distribution to apparent diffusion coefficient. The mean diffusivity increases with α, while the fractional anisotropy remains yet to indentify relationship between the fiber packing geometry.

Conclusion: We develop a novel tool to evaluate the MR diffusion weighted signal from the intracellular and extracellular compartment as a function of fiber diameter, fraction, and geometry using tunable parameters and find that the observed diffusion anisotropy mainly originates from the extracellular compartment between axons.