Dependence of the Fast Diffusion Component Fraction on the Angle Between Fiber Tract and Diffusion Gradient Direction

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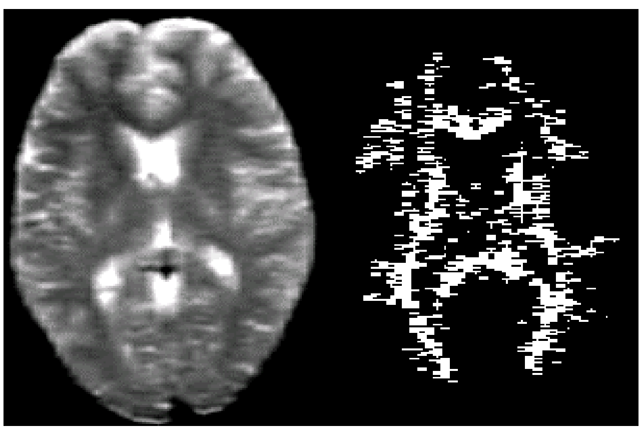
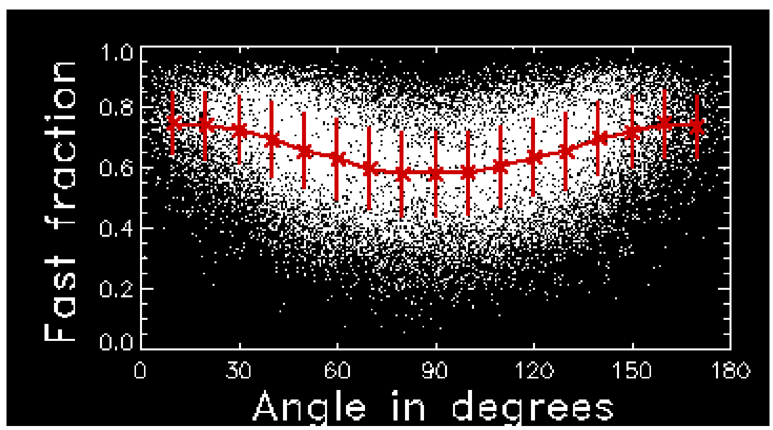
Introduction: The non-monoexponential decay of human brain water with increasing b-factor is well-established, along with the empirical value of biexponential fits to the signal decay (1-3) and tensor analyses of the fast and slow diffusion coefficients have been presented previously (3). The purpose of this study was to determine the dependence of the fractional amplitudes obtained from biexponential fits on the angle between the local fiber tract, as determined by diffusion tensor analyses of the fast diffusion coefficient, and the diffusion sensitization direction.

Methods: Line scan diffusion imaging (LSDI) at 16 b-factors from 5 to 5000 s/mm^2 (3) was performed in 3 healthy adult volunteers using 9 linearly independent diffusion directions given by (1,-1,-1/2), (1/2,1,-1), (1,1/2,1), (-1,-1/2,1), (1,-1,1/2), (1/2,1,1), (-1/2,1,-1), (-1,1/2,1), (1,1,1/2). A 6 mm thick axial slice encompassing corpus callosum and internal capsule was scanned in all cases. For each diffusion direction, signal (S) decay curves from each voxel were fit with the biexponential $S = A \exp(-D_A b) + B \exp(-D_B b)$ where D_A and D_B are the fast and slow diffusion coefficients with amplitudes A and B, respectively. The principal eigenvector of the fast component was calculated using a mono-exponential fit through the lowest 3 b-values for the nine different gradient sensitization directions. Previous studies have shown a close fit between the monoexponential principal eigenvector and the principal eigen vector of the fast component (3). White matter voxels were identified on the basis of fractional anisotropy values (FA>0.4) and the angle between the principal eigenvector and each of the nine diffusion sensitization gradients was calculated for each white matter voxel.

Results: Figure 1 shows a typical axial slice and the white matter areas chosen for analysis in one of the subjects. Figure 2 shows the composite graph plotting the fractional amplitude A/(A+B) against the angle between the diffusion sensitization direction and the principal eigenvector. The graph represents composite data from approximately 34,500 data points as sampled in all three individuals. The red crosses and bars show the means and standard deviation at 10^o intervals. A sinusoidal dependence with a minimum of A/(A+B) when fiber tract and diffusion directions are perpendicular is observed.





Discussion: It seems increasingly unlikely that the fast and slow diffusion components in brain directly represent different water compartments with different diffusion components. Rather, we suspect that restricted diffusion effects play the most prominent role in the actual shape of the decay curves and, subsequently, on the biexponential parameters used to characterize them. Here, a significant decrease ($t \ll 0.001$) in the relative size of the fast fraction A/(A+B) is observed for diffusion directions perpendicular to primary fiber tract directions. This observation is difficult to reconcile with a simple model of two water compartments with different diffusion coefficients.

References:
1. Clark CA, Le Bihan D, Magn Reson Med 2000;44: 292-300.
2. Beaulieu C, NMR in Biomed 2002;15:435-455.
3. Maier SE, Vajapeyam S, Westin C-F, Mulkern RV, Magn Reson Med 2004;51:321-333.