How Does B-Value Affect the Estimation of Ensemble Average Propagator in HARDI?

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Introduction:

In recent years, high angular resolution diffusion imaging (HARDI) has been widely used in revealing the micro-geometry of nervous tissues and exploring white matter fibers in living human brains thanks to its potential to resolving multiple intravoxel fiber populations. There are two primary parameters in HARDI data: the number of diffusion weighted gradients and the value of diffusion weighting factor, b-value. A recent study suggested that the minimum number of diffusion weighted gradients is 45 for HARDI in in-vivo human brain data[1]. However , the effect of b-value, on the quality of reconstruction and the optimal b-value for HARDI in human brain data remain unclear. In this study, we applied a HARDI method called analytical spherical polar Fourier imaging (SPFI)[2,3] to estimate both the Ensemble Average Propagator (EAP) profiles and Orientation Distribution Function (ODF), and then compare their performance to investigate appropriate b-value for analytical SPFI.

Methods:

In this study, to investigate the effects of different b-values, diffusion-weighted data were acquired from two healthy subjects(male), by MRI scanner GE Discovery 750 3.0T, with echo time (TE)/repetition time (TR) = 9000/80ms, 2mm isotropic voxel size, field-of-view (FOV) = 256mm * 256mm, matrix size = 128 * 128, five b-values, 650, 1000, 1500, 2000, 2500s/mm^2. For each b-value, 64 noncollinear diffusion gradient directions were applied and an equivalent non-diffusion-weighted data set was acquired.
For the data preprocessing, we performed eddy current correction on all diffusion weighted images using FSL(http://www.fmrib.ox.ac.uk/fsl/).
We applied analytical SPFI to the data with 5 b-values respectively to estimate EAP profile P(R_0r) at R_0 = 15μm and ODF proposed by Wedeen in DSI[4] for whole brain. For SPFI, we set the scale ζ based on typical Apparent Diffusion Coefficient (ADC) value, L = 4 in the spherical part and N = 1 in the radial part. Then we selected multiple ROIs and compared the qualities of EAP profiles/ODFs reconstructed from different b-values data to assess how diffusion weighting factor affect the estimation of diffusive directions.

Results:

Our results demonstrated that, as expected, the quality of the estimated EAP profiles/ODFs was improved using higher b-values from 650s/mm^2 to 2500s/mm^2 with 64 diffusion gradients in clinical human brain data. The EAP profiles/ODFs reconstructed from b = 650, 1000s/mm^2 failed to disclose many locations containing cross fibers and hence it will degrade the quality and accuracy of white matter tractography. Compared to the result from b-value = 1500s/mm^2, the result from b-value = 2000s/mm^2 did not seem to improve the performance significantly on visual inspection. However, both results can resolve most intravoxel multiple fiber populations. The results from b-value = 2500s/mm^2 have the highest angular resolution, sharper than others and keep clean. The comparisons on two specific ROIs were presented in Fig. 1&2.

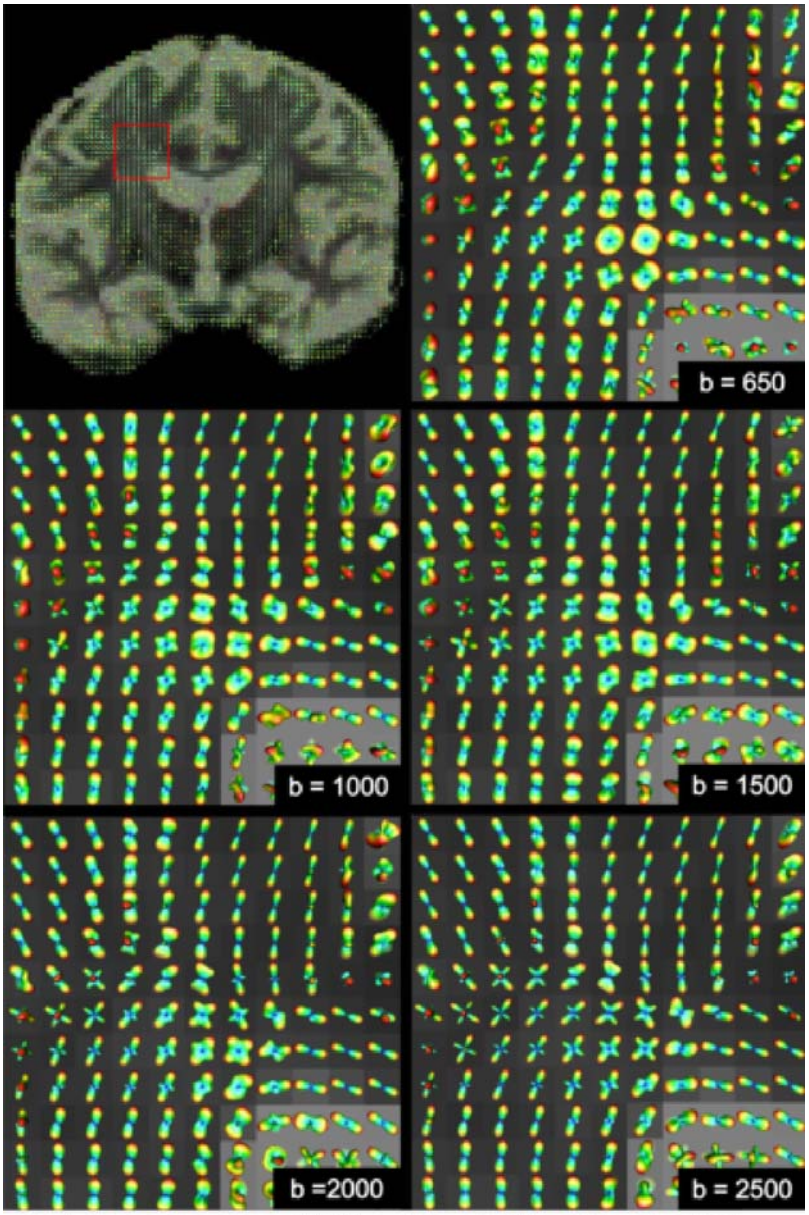

Fig. 1. The comparison of EAP profiles of different b-value DW data in the centrum semiovale of human brain in vivo.

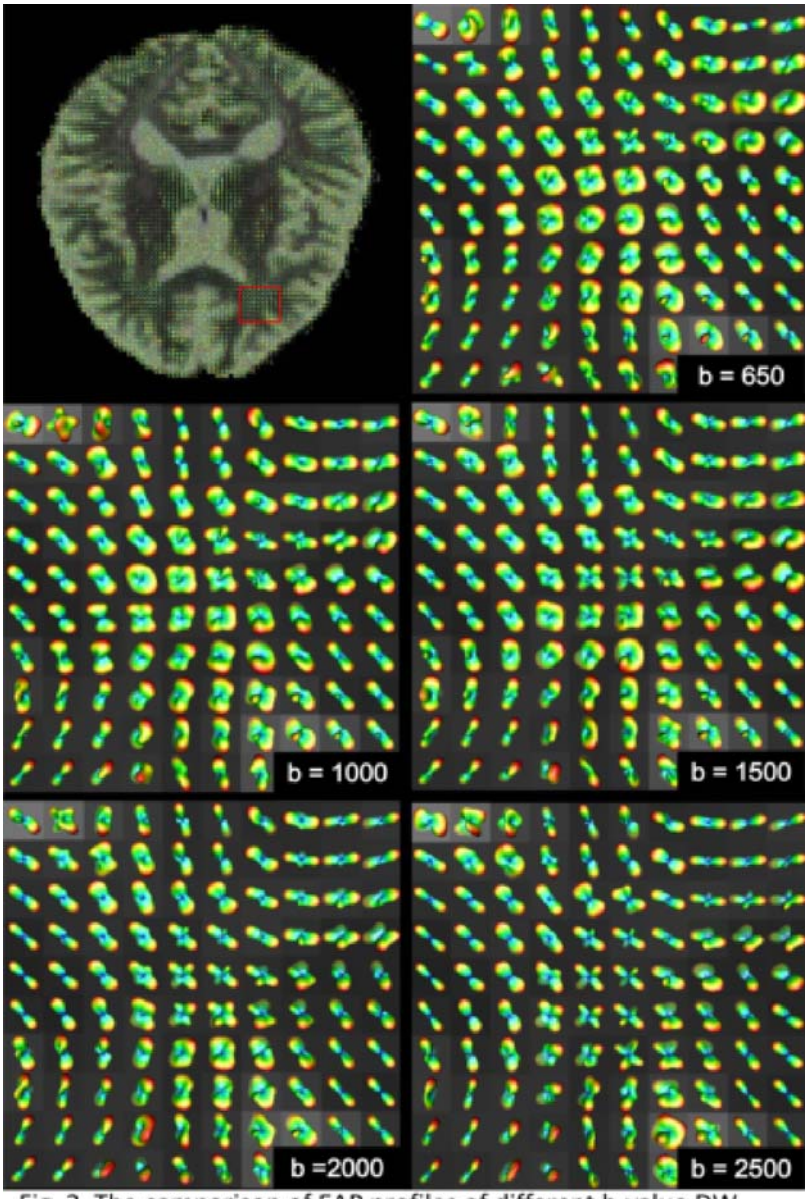

Fig. 2. The comparison of EAP profiles of different b-value DW data in the fiber tract anterolaterally to genu of corpus callosum of human brain in vivo.

Conclusions:

Our study indicates that higher b-value in an appropriate range can largely improve the quality of EAP profiles/ODFs for SPFI. The EAP profiles/ODFs reconstructed from higher b-value data achieve better angular resolution and reveal more complex situation of multiple crossing fibers. Since b-values beyond 1500s/mm^2 are not able to produce distinct improvement for dissecting crossing fibers, it may suggest that b-value = 1500s/mm^2 is an optional diffusion weighting factor value clinically and b-value = 2500s/mm^2 is a suitable value in scientific research for SPFI, having regard to signal-to-noise ratio in data and acquisition time. This provides a reference for neuroscientists and clinicians to set appropriate scan parameters for HARDI experiments.

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Imaging Methods:

Diffusion MRI

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