Slow Diffusion Tensor Imaging (SDTI) Provides Enhanced Anisotropy and Tractography in Human Brain

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Introduction

The diffusion characteristics of slowly diffusing water populations in the human brain can be determined by employing higher levels of diffusion sensitivity than have been used previously (1). Here we measure the diffusion tensor at high b values (up to 3000 s mm^{-2}) and demonstrate that the slow diffusion tensor (determined between b=2000 and 3000 s mm^{-2}) exhibits enhanced diffusion anisotropy and white-grey matter contrast compared with the fast tensor (determined between b=0 and 1000 s mm^{-2}) and the intermediate tensor (determined between b=1000 and 2000 s mm^{-2}). We also show that the slow tensor is advantageous for tractography of the white matter structures of the brain, providing longer track lengths for a given anisotropy and angular threshold.

Methods

MRI Data Acquisition

Five healthy volunteers were scanned at the Institute of Psychiatry on a 1.5T General Electric Signa MRI system with a maximum field gradient strength of 40 mT m^{-1}. Diffusion tensor imaging (DTI) was achieved using a single shot echo planar imaging sequence with 12 diffusion sensitising gradient directions as described previously (1). b values of 1000, 2000 and 3000 s mm^{-2} were obtained for each of 12 gradient directions following three acquisitions with b=0 s mm^{-2}. Whole brain coverage was achieved with two interleaved acquisitions comprising of 12 slices each. Slices were 5 mm thick with an image matrix of 96 by 96 and field of view of 24 cm. The interleaved acquisitions were repeated five times consecutively and the magnitude data averaged prior to the diffusion tensor calculation. Other sequence parameters were TE = 82 ms, TR = 2.75 s, total imaging time = 15 mins. Images were realigned to remove eddy current effects by affine registration prior to the diffusion tensor calculation. Fast, intermediate and slow diffusion tensors were calculated from the signal decay between b=0 and b=1000 s mm^{-2}, b=1000 and b=2000 s mm^{-2} and b=2000 and b=3000 s mm^{-2} respectively. The mean diffusivity (MD) and fractional anisotropy (FA) were calculated for each of the tensors (2).

Fibre tracking

Subvoxel tracking was performed by interpolation of the tensor field as described previously (3). Vector step lengths of 1 mm, angular threshold of 45° and FA threshold of 0.15 were used. Tracking was initiated in every voxel of the brain with FA above 0.15 and maps of track length were synthesised in which a grey level was assigned to each voxel based on the length of the track passing through the voxel.

Results & Discussion

Representative maps of the fast, intermediate and slow MD and FA maps are shown in Figure 1, panels a to f respectivley. For ease of comparison the FA maps are windowed to the same level. Track length images for the fast, intermediate and slow tensors are shown in panels g to i. Whole brain histograms of the MD, FA and cumulative track length for the five subjects and each of the tensors are shown in Figure 2.

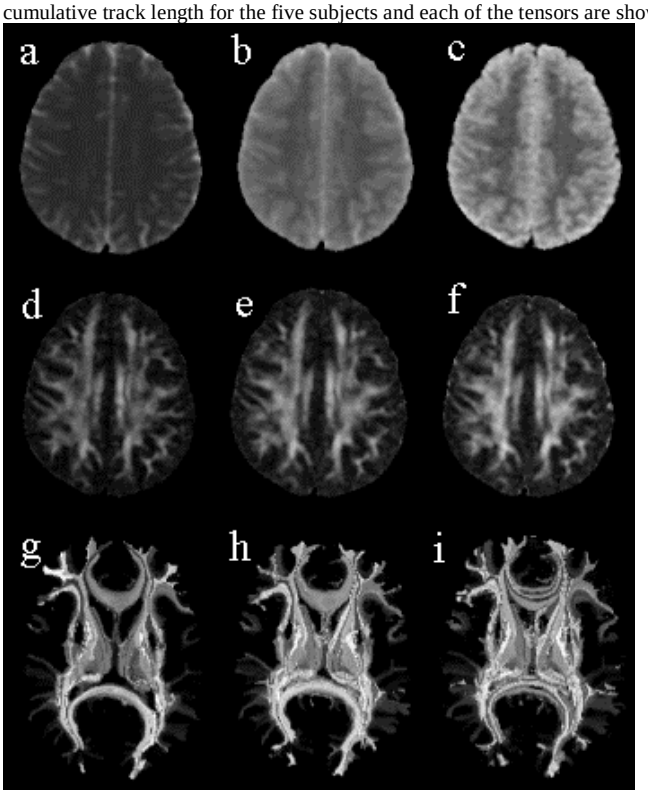

Figure 1

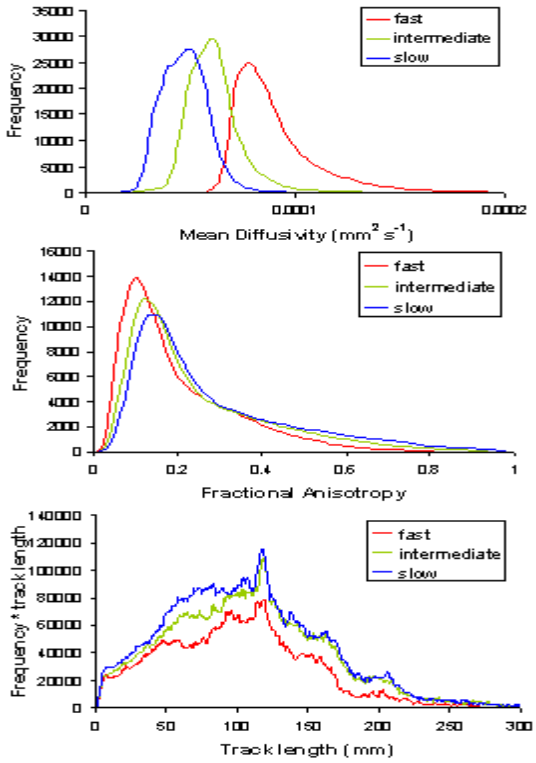

Figure 2

The results indicated increased anisotropy and anisotropy contrast between white matter and grey matter in the slow tensor compared with the fast and intermediate. Whole brain tractography indicated that the slow tensor provided the longest track lengths for given angular and anisotropy thresholds. Overall the results indicate that in addition to providing mean diffusivity contrast between white and grey matter, the slow tensor is also advantageous for the study of anisotropy and tractography in the human brain. These findings appear to be consistent with the general hypothesis that the slow tensor is a more sensitive marker of tissue structure than the conventional fast tensor. Optimisation of the slow tensor acquisition and clinical studies examining the slow diffusion tensor in neuro-degeneration are now required.

References

[1] Clark et al, Magn Reson Med 2002; 47 623-8.

[2] Basser et al, J Magn Reson 1996; 111:209-19.

[3] Barrick and Clark, ISMRM 2002; 2158.