Dependence of eigenvector coherence on b-value range using the bootstrap method

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Introduction

Recent studies suggest that increased diffusion sensitization may provide new structural information in terms of white/grey matter (WM/GM) contrast in mean diffusivity (MD) and increased values of fractional anisotropy (FA) [1]. It is, however, the case that a rise in b is accompanied with a reduction in SNR. The question we pose is how much of the seemingly enhanced values of FA with increased b-values are attributed to noise. In our experiment, we compared the signal from fast and slow DTI [1] by using the method of bootstrapping to generate data samples and measuring their principle eigenvector coherence, κ [2, 3], on a per voxel basis. We found that as the minimum b-value in a two point fit increased, the coherence in the principle eigenvector across 1000 bootstraps decreased indicating that reduced SNR may be responsible for augmenting the true values of FA. Conversely, eigenvector coherence was preserved (as was FA) when the maximum b value was increased from 1000 to 3000 s mm^{-2} with a minimum b value fixed at 0 s mm^{-2}.

Method

Two healthy adult males were scanned on a 1.5T Siemens Avanto MRI system with a double refocused pulsed diffusion weighted EPI sequence. The maximum gradient strength = 40mT m^{-1} was used with twenty diffusion sensitized directions. Voxel resolution was 2.5 x 2.5 x 5mm. Four acquisitions were made with whole brain coverage over 25 slices with b = 0, 1000, 2000 and 3000 s mm^{-2}. Other sequence parameters were TR/TE/NEX = 4100ms/112ms/2. 1000 bootstraps were generated of b0, b1000, b2000 and b3000 samples from the four averages. Images were skull stripped with BET [4] and CSF masked via simple thresholding. Tensors were then created from the 1000 bootstraps, between b0-1000, b0-2000, b0-3000, b1000-2000 and b2000-3000. The principle eigenvector coherence, κ, was then derived for every voxel for each tensor [2, 3]. FA and MD maps were also generated from the average of the four acquisitions and the contrast in the b2000-3000 MD map used to segment WM and GM values of FA.

Results

Fig 1 shows axial images of a) FA, b) MD and c) κ images at varying b-value pairs. Fig 2 shows frequency histograms depicting the change of GM and WM FA, and κ populations with each b-value pair. It can be observed that as the minimum b increases, the coherence of the eigenvectors in the bootstraps reduces as evidenced by loss of WM definition in the κ maps in fig 1. This is also observed in the κ frequency histogram where there is a redistribution of κ values from the high WM coherence peaks on the right of the graph for a minimum b of 0 s mm^{-2} into lower κ values for b2000-3000.

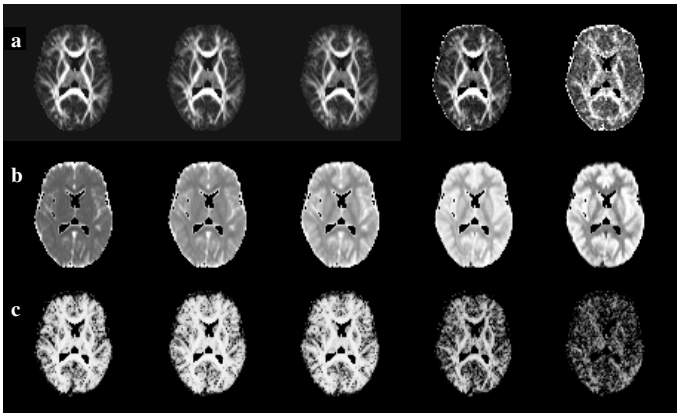

Figure 1 - Axial slice of a healthy subject. Rows a-c are FA, MD and κ maps respectively, with increasing b-value pairs from left to right, b0-1000, b0-2000, b0-3000, b1000-2000, b2000-3000, respectively.

Discussion

We have found that as the minimum b-value increases in b0-1000, b1000-2000 and b2000-3000, FA increase arises primarily from GM with FA reductions in WM (see fig 2 A and B). Overall there is a loss of coherence amongst the principle eigenvectors across bootstrap samples. This is likely to be due to low SNR, giving the effect of increased FA values in GM. In contrast FA remains largely unchanged for b0-1000, b0-2000 and b0-3000 as shown previously by Yoshiura et al [5] and this behaviour is accompanied by the preservation of κ. This suggests that the combination of low SNR at both the minimum and maximum b value leads to poorer κ values. These results also have implications for tractography, which relies on confidence in the assignment of the principle eigenvector. It would appear that using a b value of 0-3000 s mm^{-2}, which may be useful for detecting crossing fibres, does not produce a reduction in coherence when fitting a tensor, whereas combining this with a minimum value of 2000 s mm^{-2} provides less reliable results. Our findings can be further clarified with improved SNR and a greater number of gradient directions during acquisition. However, our initial results suggest that SNR may have a detrimental effect on the precision of the principle eigenvectors, particularly at high b-values.

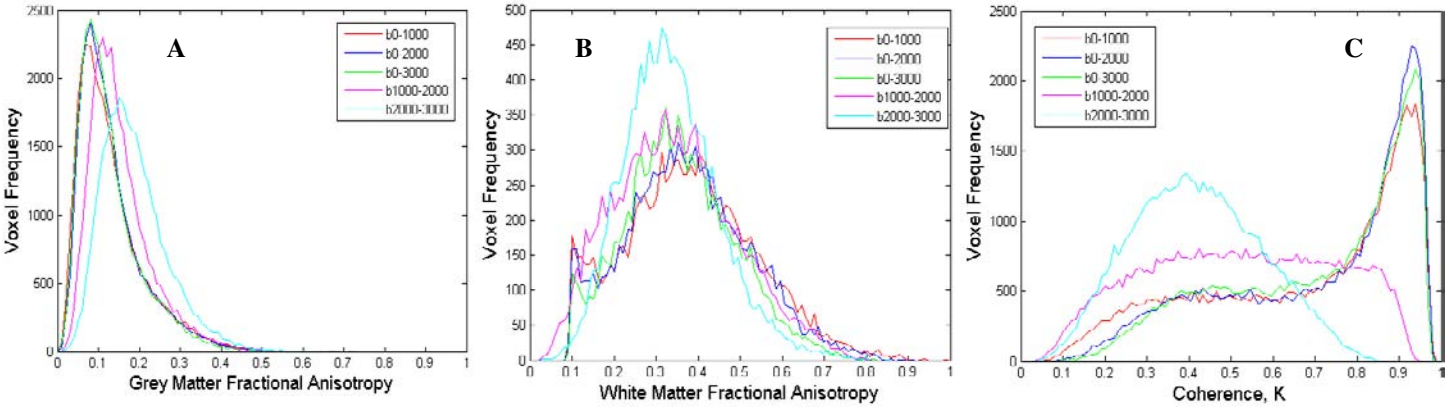

Figure 2 - Voxel frequency histograms of A) Grey matter FA B) White matter FA and C) κ with varying b-value pairs. A and B are derived from four averaged acquisitions and κ from 1000 bootstrap samples.

References: [1] Clark CA et al 12th ISMRM, 2004, #1218. [2] Basser PJ and Pajevic S MRM 2000; 44:41-50, [3] Jones DK MRM 2003; 49:7-12, [4] http://www.fmrib.ox.ac.uk/fsl, [5] Yoshiura T et al MRM 2001; 45:734-740. Sponsored by Research into Ageing grant number 256.
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