MULTI-TE DIFFUSION TENSOR IMAGING IN VIVO

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Introduction

Diffusion tensor imaging (DTI) has unique sensitivity to tissue anisotropy, and has been applied in many recent neuroimaging studies to assess white matter diffusivity, anisotropy and integrity. Given the importance of myelin in brain development, the applicability of diffusion tensor imaging (DTI) can be further improved in developmental neuroimaging if diffusion properties of axonal (intermediate T_2) and myelin (short T_2) water can be separated. Recent DTI and multi-TE imaging studies conducted in animal specimens have shown that FA and radial diffusivities vary significantly across the T_2 spectrum [1-2]. A preliminary attempt to characterize these differences in vivo has also been recently reported [4]. To achieve a rigorous and quantitative assessment of diffusion tensor properties across a large range of T_2 values in vivo, in this study we develop a stimulated echo (STE) DTI spiral imaging sequence that can acquire images with the same b-value over a large range of TEs (from 20 ms to >100ms). Moreover, we propose a clinically feasible approach for achieving short T_2 (myelin water) specificity by acquiring DTI datasets at only 2 different echo times. It is hoped that this acquisition strategy could improve our understanding of developmental white matter diseases by better characterizing changes in myelin microstructure.

Methods

To achieve adequate diffusion sensitization while imaging with a wide range of echo times multi-shot STE DTI sequence with spiral-out SNAILS readout was implemented. In order to ensure perfect registration between datasets at different TEs, each segment is acquired with different echo times in consecutive shots within the same diffusion encoding phase. Healthy subjects were scanned on a GE 750 MR scanner with the following parameters: 5 slices, imaging matrix 96x96, FOV 24cm, slice thickness 6mm, 4 interleaves, TE / TI / TR = 22, 29, 37, 42, 48, 54, 62, 69, 75, 82 /125 /4000ms, b=600 s/mm^2 and 15 directions. Subsequently, a rank-2 diffusion tensor was estimated for every dataset and the FA, axial and radial diffusivities calculated within a white matter region of interest (ROI).
Further, to achieve myelin water weighting (MWW) within clinically acceptable imaging times a second scan was acquired with a matrix of 192x192, 10 interleaves and only 2 TEs = 22, 78ms. For a more differentiated weighting on myelin water, the two datasets were first subtracted, then fitted with a tensor model.

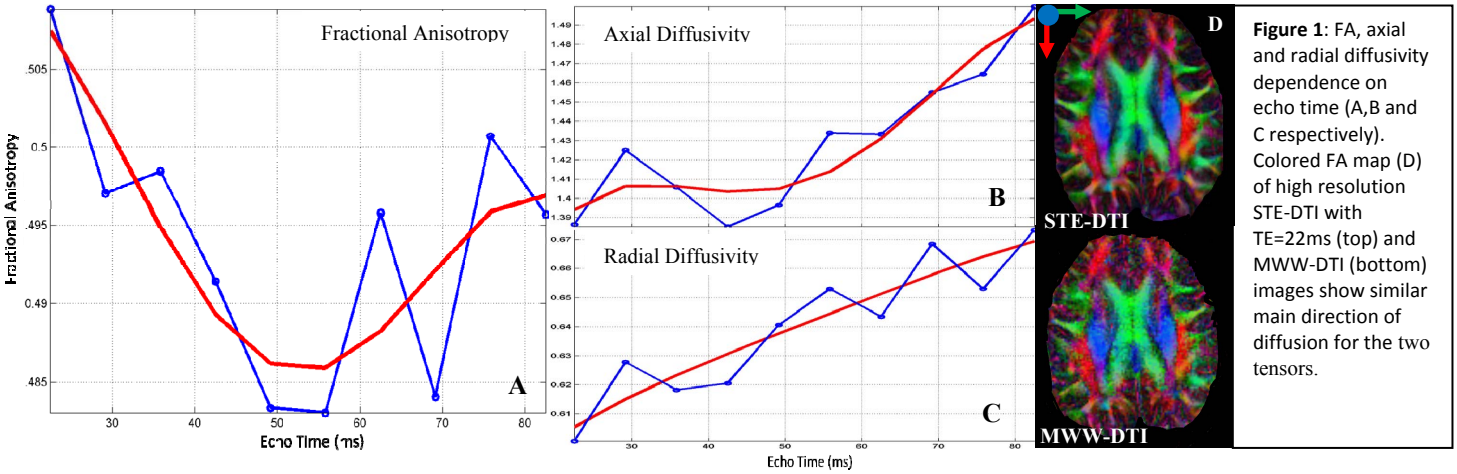

Figure 1: FA, axial and radial diffusivity dependence on echo time (A,B and C respectively). Colored FA map (D) of high resolution STE-DTI with TE=22ms (top) and MWW-DTI (bottom) images show similar main direction of diffusion for the two tensors.

Results and Discussion

The results show an initial decrease of 5.08% in FA (Fig1. A) with increasing echo time (from TE=20ms to TE=60ms). This finding is consistent with the diminishing input from the short T_2 species (e.g. myelin water) which has higher anisotropy [4]. For TE>60ms the FA experiences an increase which is possibly due to the known "upward bias" in the presence of reduced SNR [5]. Separate analysis for axial and radial diffusivities revealed a continuous increase of radial diffusivity (up to 8.71%), confirming the reduced input from the short T_2 species with lower radial diffusivity (Fig1. C). Axial diffusivity (Fig. 1B), in comparison, remains relatively independent of TE (up to 60ms), as the short T_2 species has similar axial diffusivity and its reduced contribution does not impact the overall axial diffusivity. There is, however, a notable increase of axial diffusivity for TEs > 60 ms, which is possibly due to a relative larger weighting of CSF at long TEs.

Conclusion

Overall, our results are in line with previous reports and confirms that the short T_2 myelin water has a more anisotropic diffusion compared to axonal water, mainly due to its hindered radial diffusivity. Further, this study also provides initial evidence that it is possible to achieve sufficient sensitivity to short T_2 water within a clinically feasible time frame (e.g. <10 minutes).

References: **1**. Peled et al. MRM 1999;42:911, **2**. Andrews et al. MRM 2006;56:381, **3**. Liu et al. MRM 2004;52:1138, **4**. Avram et al., Neuroimage 2010;53:132, **5**.Farrell et al., JMRI 2010;26:756