Comparing Human White Matter Structure Using Diffusion Tensor Imaging and Tensor Map Deformations

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Purpose

Diffusion Tensor (DT) imaging is an emerging magnetic resonance imaging technique based on water diffusion. DT measurements can be used to non-invasively measure white matter structure and trace neural pathways in individual human brains. This technique has proved to be an important tool in localizing white matter abnormalities in several neurological disorders including dyslexia, schizophrenia, and multiple sclerosis. Most previous DT studies of white matter abnormalities have focused on point-wise comparisons of scalar indices derived from the tensor data that may correlate with white matter integrity. Here we present novel methods for comparing the spatial structure of the full tensor data (white matter morphology). We use the technique to compare dyslexic and normal-reading children.

Materials and Methods

Imaging Parameters: Whole-brain DT data were collected on a 1.5T GE Signa LX scanner using a diffusion-weighted single-shot spin echo, echo planar imaging sequence with 2x2x3mm voxels (TE =63ms; TR = 12s; NEX = 1; flip angle = 90 deg; 4 repeats). We acquired images with b = 0 and with b = ~800 s/mm^2 along 12 different diffusion directions. These DT measurements were obtained in poor and normal readers aged 9 to 13 (n=13). All subjects also underwent psychometric testing and groups were matched in age, SES and non-verbal IQ.

Image Analysis: DT volumes for each subject were deformed to match a template DT volume using a multi-channel extension of the demons algorithm (Park et al., 2003). The DT deformations measure the distance and direction of each voxel from the target brain to the corresponding voxel in the template brain. The DT template was created by deforming all brains to a representative brain, averaging the tensors across all the deformed brains, and then again deforming all brains to the new average brain. By iterating this procedure several times, we created a less-biased template..

Results and Conclusions

The DT deformations provide a quantitative measure of white matter morphological differences between each subject and the template brain. We will show maps indicating white matter regions of very high individual variability (such as the corpus callosum). Preliminary results suggest that the good and poor reading groups differ in several regions, including posterior callosal projections and anterior corona radiata.

Reference

[1] Park HJ, Kubicki M, Shenton ME, Guimond A, McCarley RW, Maier SE, Kikinis R, Jolesz FA, Westin CF. Spatial normalization of diffusion tensor mri using multiple channels. Neuroimage 2003;20(4):1995-2009.

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