Fiber Tract Based Interrogation of White Matter

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Introduction

Diffusion Tensor MRI (DT-MRI) has proven useful in the examination of white matter in the human brain. DT-MRI provides information regarding the local orientation of white matter fiber bundles. This orientation information allows one to trace and visualize fiber bundles [1]. DT-MRI also provides important structural information regarding white matter such as fractional anisotropy (FA), which provides an estimate of the degree of directional specificity of diffusion. In this paper, we present a method that uses fiber tracking to identify white matter fiber bundles and interrogate the structural properties of the underlying tissue.

Methods

DT-MRI

A single-shot, spin-echo, diffusion-weighted echo-planar imaging (EPI) sequence was used for the DT-MRI. The diffusion scheme incorporated one image without diffusion gradients (b = 0 s/mm2) and twelve images measured with non-collinear diffusion encoding directions (b = 1000 s/mm2). Each volume was 128 x 128 x 40 with a resolution of 1.72 x 1.72 x 3.0mm. Data was acquired for 10 pediatric patients diagnosed with chromosome 22Q11.2 deletion syndrome and 5 age matched controls. Tensor reconstruction was performed using singular value decomposition, as implemented in ITK [2].

Fiber Tracking

FA volumes were calculated from the tensor volumes, and all voxels found to be within the brain and having an FA of 0.2 or greater were used as seed points from which fiber tracts were advanced. Linear interpolation of the eigenvector associated with the principle eigenvalue was used to estimate fiber direction at a given point. Fiber tracts were advanced using 4th order Runge-Kutta method with a constant step size of 1.0mm. A fiber was terminated if FA was below 0.2 or the angle between consecutive steps was greater than 45 degrees. The midsagittal cross-section of the corpus callosum was manually segmented and used a target region. Any fiber that did not pass through this target region was discarded. An example of the fiber tracking results is illustrated in Figure 2.

Fiber Tract Evaluation of White Matter

Each arc length parameterized fiber, $f(s)$, described a path through the corresponding tensor volume. At a given point on the fiber, s, the tangent to the fiber, $t(s)$, was used to determine the diffusion coefficient in the direction of the fiber, and this fiber direction diffusion coefficient was integrated along the length of the fiber:

$$D_f = \int_0^l \vec{t}(s)^T \overline{D}(s)\vec{t}(s)ds$$, where l is the length of the fiber.

Partitioning & Analysis

The midsagittal corpus callosum was partitioned using the scheme developed by Witelson, *et. al.* [3]. For each data set, the average D_f was found from the set of all fibers that passed through the partition. Permutation testing was used to examine the results and identify potential regions of interest. The results of this analysis are illustrated in Figure 1.

Results

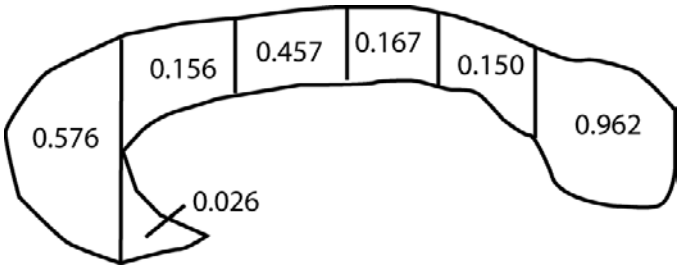

Figure 1. Illustration of the partitioning scheme [3] and associated probabilities calculated via permutation testing.

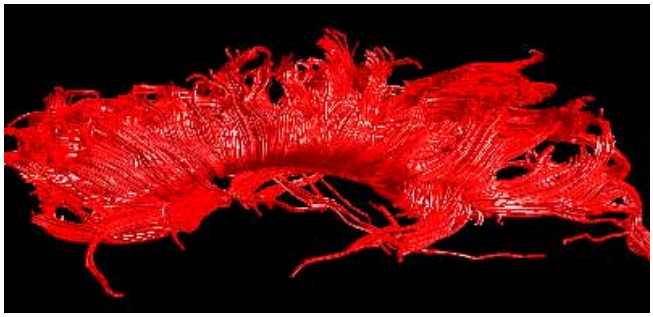

Figure 2. Sample results of fiber tracking method

Discussion

The integration of diffusivity along fiber tracts provides a method for interrogating the nature of white matter associated with a specific region of interest. The results suggest that in patients diagnosed with 22Q11.2 chromosome deletion syndrome, there is a difference in the white matter fiber tracts that pass through the anterior of the corpus callosum. However, it will be necessary to extend the methods to examine the entire three-dimensional structure of the corpus callosum in order to obtain more insight into potential differences in both structure and connectivity in the patients. An additional consideration that needs to be addressed is brain volume. Currently, differences in brain volume are not accommodated for, and that is a possible source of bias in D_f. The methods presented above may also be used to examine various metrics such as FA and lattice index, thus gaining further insight into possible white matter variation.

References

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