Fine-grained comparison of anisotropy differences between groups of white matter tracts

J. D. Clayden[1], S. Zhang[2], S. Correia[3], and D. H. Laidlaw[4]

[1]Neuroinformatics Doctoral Training Centre, School of Informatics, University of Edinburgh, Edinburgh, United Kingdom, [2]Computer Science and Engineering Department, Mississippi State University, Mississppi State, MS, United States, [3]Psychiatry & Human Behavior, Brown Medical School, Providence, RI, United States, [4]Computer Science Department, Brown University, Providence, RI, United States

Introduction

In this work we present a methodology for comparing anisotropy "profiles" along white matter tracts between subjects. The development of white matter tractography techniques has provided new possibilities for segmentation of white matter structures from MR images *in vivo*, allowing for tract-specific studies of the effects of pathology. Given a segmented tract of interest in a group of subjects, fractional anisotropy (FA)—a mathematical proxy for white matter integrity derived from the tensor model of diffusion—is commonly averaged within each region for statistical comparison between groups. However, macroscopic decreases in FA have been shown in a large number of pathologies, and so such observations are becoming increasingly nonspecific. Studying the anisotropy profiles of tracts, as we do here, facilitates the comparison of FA at a more fine-grained level.

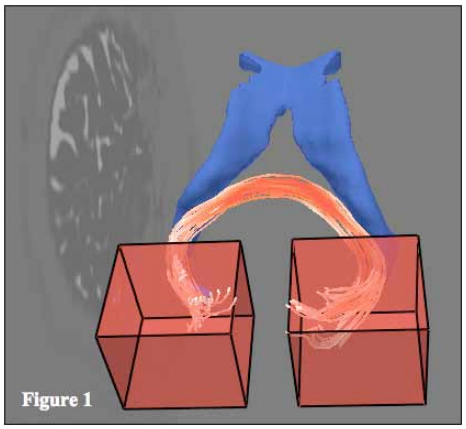


Figure 1

Methods

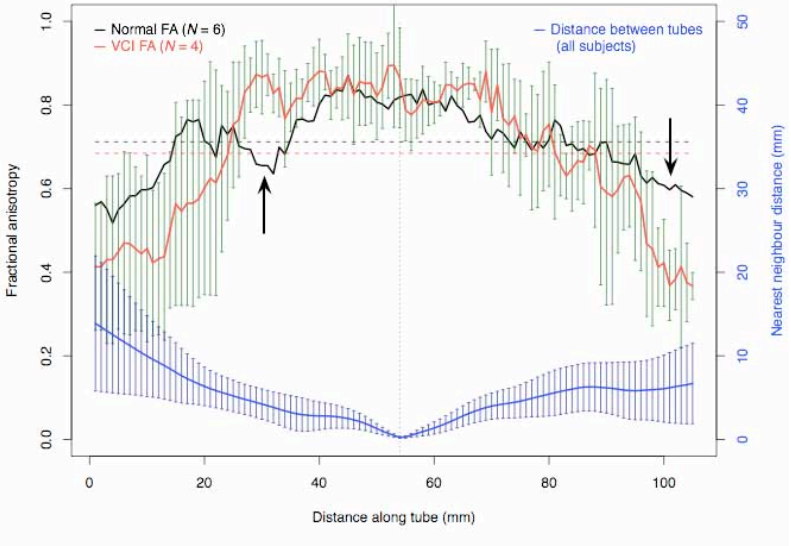
Six normal volunteers and four patients with vascular cognitive impairment (VCI) underwent a DTI protocol at 1.5 T, with 12 noncollinear diffusion weighting gradient directions at a *b*-value of 1000 s mm^{-2}. Whole brain streamline tractography was performed and visualised in terms of streamtubes as described previously [1]. The corpus callosum splenium was segmented in each subject by placing two cuboidal volumes of interest near each end of the structure and retaining only those streamtubes which passed through both volumes (see Fig. 1; the blue surface represents the ventricles).

Defining the distance between streamtubes to be the average distance from the points on the longer tube to the shorter tube, we find for each subject a single median tube which minimises the average distance to each other tube in the splenium. We handle intersubject translational differences by setting the origin of coordinates to be the point where each median tube crosses the brain's midsagittal plane. In order to deal with shape differences among the subjects, we then find an intersubject median tube in this normalised space, and calculate the FA for each subject at the closest available location to each point on this intersubject spatial reference tube.

Results

Fig. 2 shows the results of applying the above described method to our data. The vertical dotted line indicates the (normalised) location of the midsagittal plane. The black and red lines indicate the mean FA value corresponding to each point on the intersubject median tube in the normal and VCI groups, respectively. One standard deviation across the VCI group is shown with green error bars. The black and red horizontal dashed lines indicate the grand average FA value, across all points, for each group. There is no significant difference between these grand means, but there are two regions (arrows) in which FA differs substantially between the groups. The blue line in the figure indicates the mean (± 1 std dev.) distance from the intersubject median to the individual median tubes at each point along the splenium. This distance is zero by definition at the midplane.

Figure 2



Discussion

We have developed a methodology for comparing FA profiles of comparable tracts within and between groups of subjects, and presented some early results using the method. These results are not intended to be definitive, but rather to demonstrate the potential benefits of this type of analysis. These benefits include the ability to test more specific hypotheses than can be studied with a region averaging approach; and the elucidation of cases where combinations of anisotropy differences with opposite sign may mask an effect of interest when only the regional mean is examined. Note that FA was *increased* in the VCI group in one of our regions of difference, which could be due to a loss of integrity to one white matter fibre population in an area of crossing fibres.

Our method compensates for the relative translation and scaling differences between individuals' brains. We work with median tubes because they will be closest to the centre of the tract of interest and therefore least susceptible to partial volume issues. There are some limitations to our method at present—in particular, not all tracts in the brain cross the midsagittal plane, so this part of the process will need to be made more generally applicable. Nevertheless, we conclude that comparative study of anisotropy profiles between groups of equivalent tracts can uncover small-scale effects that may otherwise be missed, and we hope that a method such as ours will enable future examination of the effects of pathology on white matter with greater specificity than has been possible in the past.

Reference

[1] Zhang *et al*. (2003). *IEEE Trans Vis Comput Graph* **9**(4):454.