Automated Tract-Specific Quantification Using Probabilistic Atlas Based on Large Deformation Diffeomorphic Metric Mapping and Its Application to Alzheimer's Disease

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Introduction: The goal of this study is to construct probabilistic maps of major white matter tracts based on DTI and tractography. The maps can be superimposed on various types of MR images and quantify MR parameters such as T2, ADC, and FA along the tracts without tractography in each subject. Previously, we have constructed probability maps of twenty major white matter tracts in the human brain using affine transformation [1]. In this study, we refined these maps by using B0-distortion correction and highly non-linear image registration method called Large Deformation Diffeomorphic Metric Mapping (LDDMM)[2]. The maps were incorporated into JHU white matter atlas, with which it is possible to perform automated assessment of pixels that belong to specific white matter tracts. In this study, this tool was applied to DTI datasets of Alzheimer's disease patients and age-matched controls. **Method:** For the atlas reconstruction, data from 29 healthy adults (mean 29 +/- 7.9 years old, male 14, female 15, right handed) were obtained from an existing database [3]. After motion correction and B0-susceptibility distortion correction, diffusion tensor images were first registered to JHU-DTI-MNI single-subject template [3] using 12 mode affine transformation (AIR). FACT method and multi-ROI approach was used to reconstruct twenty white matter tracts in each subject data after the affine registration. Dual-channel (B0 and FA) LDDMM was used to register DTI images to the JHU-DTI-MNI template and the deformation field was applied to the subject's fiber tracts. Averaged map was generated for before and after LDDMM, respectively. The automated quantification was tested using 10 AD and 10 age-matched controls, which were not used for the atlas construction. **Results and Discussion:** Fig.1 compares registration accuracy of affine and LDDMM transformation, in which several probabilistic tract maps are superimposed on a FA image of a subject with severe brain atrophy. For a subject with this amount of atrophy, normalization based on LDDMM is necessary to accurately map the pre-defined tract maps. Fig. 2 shows results of automated tract-specific FA quantification of CST, ATR, Fmajor, and Fminor after LDDMM transformation. The blue and red lines compare FA values of the control and AD patients along the tracts. The FA values of the two groups agree almost perfectly for each tract, except for Fmajor. Further analysis shows that the lower FA is caused by increase in radial diffusivity as shown in Fig. 3. This tool is expected to be a powerful automated method to quantify the status of the white matter. **Reference:**[1] Hua et. al. Neuroimage. 2008. [2] Miller et. al. Annu. Rev. Biomed Eng. 2002. [3] Oishi et. al. Neuroimage. 2009 **Acknoledgement:** This study was supported by NIH grant RO1AG20012 / P41RR15241

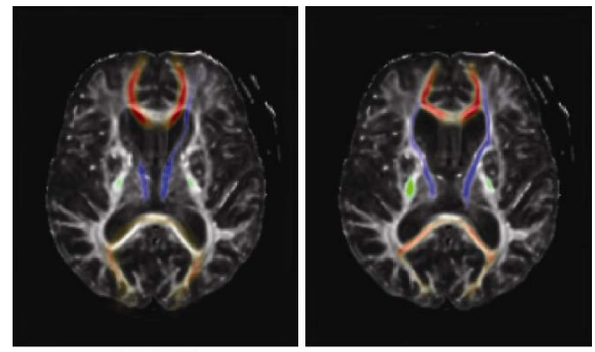

Fig 1: Probability maps of ATR(Blue), CST(Green), and Fmajor & Fminor(Red) transformed to a 71 years old AD patient FA image using Affine and LDDMM. The color intensity represents the probability. The abbreviations are; CST: corticospinal tract, ATR: anterior thalamic tract, Fmajor: forceps major, Fminor: forceps minor.

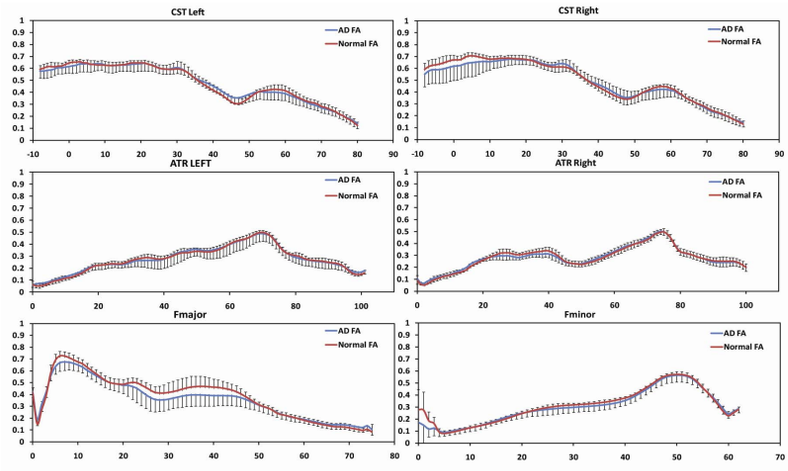

Fig 2: Results of tract-specific automated FA measurements along 4 major white matter tracts.

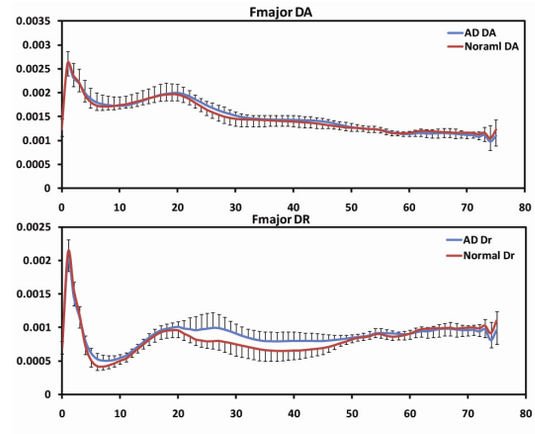

Fig 3: Averaged diffusivity along axial (DA) and radial (DR) directions of Fmajor.