A Study of MS Based on a Fusion Quantitative Analysis Model of DTI

Heather Ting Ma[1,2], Pengfei Yang[1], Chenfei Ye[1], Jun Wu[3], Xuhui Chen[3], and Jinbo Ma[1]

[1]Department of Electronic and Information Engineering, Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, Guangdong, China, [2]Radiology Department, Johns Hopkins University, Baltimore, MD, United States, [3]Department of Neurology, Peking University Shenzhen Hospital, Shenzhen, Guangdong, China

Introduction: Generally, most multiple sclerosis (MS) plaques can be showed on conventional MRI, while some occult lesions cannot be seen, such as optic tract lesions. Region of interest (ROI) method of DTI analysis has demonstrated that FA values of optic fiber bundles were significantly decreased in MS [1]. But this method has low reproducibility and strong subjectivity. A fusion quantitative analysis model was proposed in this study, based on tract-based spatial statistic (TBSS) and voxel-based analysis (VBA). Further, an anisotropic filter was specially designed for the DTI preprocessing. The proposed method was applied on DTI data of MS patients to localization lesion in the brain tissue.

Methods: A fusion quantitative analysis model on DTI was set up by adopting TBSS and VBA with a structure-adaptive anisotropic filter. The pipeline of the model is showed in Fig 1. This is a retrospective study where the clinical DTI data were collected from Peking University Shenzhen Hospital. Eighteen subjects were recruited that 5 with MS (age: 34±6) and 12 normal control (age: 36 ±9). Preprocessing begins with automatic image registration which applied to DWI images. FA map of each subject was calculated with removing the skull. ICBM_81_FA image was selected as the registration template both in VBA and TBSS for its high resolution and widespread use. Spatial normalization was used to achieve the best inter-subject registration for VBA. Smoothing was achieved by spatial filtering with the 3D structure-adaptive anisotropic filter in VBA, instead of the usually used Gaussian kernel. Finally, statistical analysis and a correction were performed on a voxel-by-voxel basis. The projection of TBSS was achieved by searching perpendicular to the local skeleton structure for the maximum value in the subject's FA image. This maximum value was assumed to represent the nearest relevant tract center. Voxel-wise statistics was then carried out across all voxels in the skeleton to identify areas of FA changes in patients. Finally, the results of both VBA and TBSS analysis were fusion together, which could reflect not only the exact location of MS lesions, but also the voxels in the region of lesions.

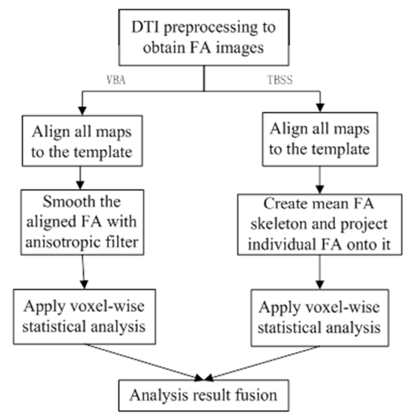

Fig 1. Pipeline of the fusion analysis model

Results: Figure 2 shows the results from VBA, TBSS and the fusion model in comparison. From result derived from VBA (Fig.2a), the red region indicates the significantly decreased FA values in patients, which reflects the MS lesions. The lesions mostly occurred in corpus callosum, which is the largest fiber tract connecting the right and left hemispheres. This result is consistent with a previous study [2] that corpus callosum is proved to impair easily in MS, due to consist of numerous fiber tracts with smaller diameters. Figure 2b shows the analysis result using TBSS method. The active areas are much smaller than that in VBA, mainly because lesions localized by TBSS are concentrated in the fiber skeleton with less voxels. However, this method with more accurate image registration algorithm shows more reliable location of lesions. Analysis report based on the fusion model is shown in Table 1. Besides of the lesions in corpus callosum, the table shows that the detected lesions locate in the corticospinal tract and occipital lobe affecting the sensory conduction and the visual system respectively. Moreover, the proposed method reveals the optic tract lesions missed by previous VBA or TBSS studies. Such damage is associated with retinal injury and visual disability.

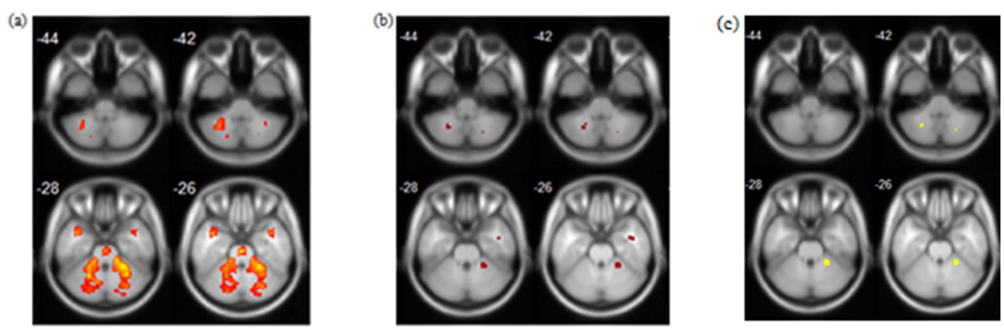

Fig 2. (a) Result of VBA; (b) Result of TBSS. (c) Result of Fusion model. FA values in red and yellow areas are decreased significantly ($p<0.05$). Background is MNI152 atlas.

Table 1. MS DTI data analysis report based on the fusion analysis model

Areas with significant FA reduction	Number of voxels	AAL subregion	MNI coordinates (X, Y, Z)	P value
Left optic tract	30	NA	(22,-18,-8)	0.0033
Right occipital white matter	102	Occipital_Inf_R	(36,-78,-14)	0.0029
Corpus callosum	557	Cingulum_Ant_R	(8,24,18)	0.0264
Right corticospinal tract	65	Thalamus_R	(20, -14, 8)	0.0247

Discussion: In this study a fusion quantitative analysis model on DTI was proposed and applied for MS lesion localization. Significant FA decrease has been found in the optic nerve, which could not be seen in conventional MRI scans. The previous voxel-wise analysis methods failed to report any significant changes in the optic nerve maybe because the smoothing process and registration steps ignored small clusters of active voxels. In sum, by fusing VBA based on adaptive anisotropic filter and TBSS with the accurate image registration,

Acknowledgement: This study is supported by Hong Kong RGC grant SEG_CUHK02, CUHK418811, and China NSFC grant 81201076.

Refernces: [1] Y. K. Tee, A. A. Khrapitchev et al, MRM, 70:1251-1262, 2013; [2] Michael A. Chappell, Manus J. Donahue et al, MRM, 70:556-567,2013