Voxel-Based Diffusion Tensor Analysis Using Tract Based Spatial Statistics in Patients with Parkinson Disease Treated by Deep Brain Stimulation

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Introduction

Diffusion tensor imaging (DTI) is widely used in neurological and neuropsychiatric diseases, such as Parkinson’s disease (PD) [1]. We intended to evaluate the effectiveness of white matter tract based spatial statistics (TBSS) generated from DTI in patients with PD in detecting differences in patient motor response to deep brain stimulation (DBS).

Methods

Six subjects with advanced PD from 55-66 years old were scanned for DTI protocol under anesthesia in a 3.0T Philips Achieva MR scanner before surgery. Motor scores (UPDRS-III) were collected before and after DBS (mean follow-up 5.9 months). The raw data set of the diffusion volumes were first corrected for eddy current distortions and motion artifacts. Diffusion tensors were computed then for each subject. Various DTI indices such as fractional anisotropy (FA), mean diffusivity (MD), and diffusion traces along main Cartesian axes (L1, L2 and L3) were generated. To generate TBSS, all DTI maps were aligned to MNI space using affine registration algorithm and skeletonisation was then created from FA images with a threshold of 0.2 set to only constrain analysis to highly anisotropic white matter tissue [2]. Finally, a two-tailed t-test was applied to extract voxels with significant differences between patients who had response and no response to DBS.

Results

Significant differences were identified between ‘responders’ and ‘nonresponders’ (Figure 1). In summary, FA shows high number of white matter skeleton voxels (4.23%) were altered significantly between two groups compared to the other DTI maps. Compared to the patients with low UPDRS-III score, FA shows significant increase in responders and diffusion trace along z direction shows significant decreases in nonresponders.

Table 1

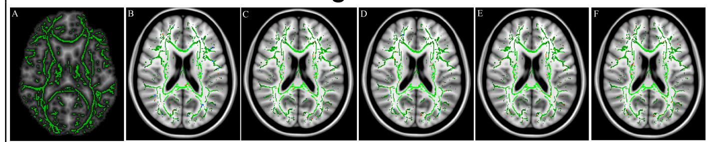
	FA	MD	L1	L2	L3
# of voxels with significant increases	4083 (2.89%)	273 (0.19%)	1142 (0.8%)	268 (0.19%)	323 (0.23%)
# of voxels with significant decrease	1896 (1.34%)	4126 (2.92%)	2880 (2.04%)	4522 (3.2%)	4813 (3.41%)
# of voxels with significant differences	5979 (4.23%)	4399 (3.11%)	4022 (2.85%)	4790 (3.39%)	5136 (3.63%)

Number of white matter skeleton voxels with significant differences ($p<0.05$) in different DTI maps. Notice that total number of white matter skeleton mask is 141321.

Conclusions

The results suggest that many regions of white matter pathology were altered differently and show the variability of DTI parameters related to the neuropathology of the PD patients. While the focus has generally been on the motor component of the cortico-basal ganglia-thalamo-cortical circuit, diffuse changes affecting the associative and limbic components may also play a role in DBS response.

Figure 1



White matter skeleton generated from FA map (A), TBSS computed from FA images (B), MD (C) and diffusion traces along x direction (D), y direction (E) and z direction (F). Notice that voxels with red and blue shows significant decrease/increase diffusion indices between patients with improvement and worsening motor dysfunction.

Learning Objectives

While studying all brain networks is not feasible, TBSS has potential to serve as an screening tool to identify regions of interest.Further studies directed at investigating these regions may provide new insights to understanding clinical response to DBS. While these preliminary results are encouraging, they warrant further studies with a larger population.

References

[1] Charlotte L. Rae, Marta M. Correia, Ellemarije Altena, Laura E. Hughes, Roger A. Barker, James B. Rowe. White matter pathology in Parkinson's disease: The effect of imaging protocol differences and relevance to executive function, Neuroimage, 2012; 62(3-2): 1675–1684.

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