In vivo Mapping and Comparative Analysis of Human Saccadic Eye Movement Pathways by Diffusion Tensor MRI-based Tractography

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Purpose

Saccadic eye movements (SCM) are under the influence of the basal ganglia (BG) and SCM circuitry within the BG represents a good model for studying pathology in this system. The diagnosis of Parkinson's disease (PD) which affects SCM and its distinction from non-dopaminergic, essential tremor (ET) can be challenging and relies on clinical observations. Diffusion tensor imaging and fiber tractography (DTI-FT) a new MRI technology, can be used to evaluate the presence and integrity of white matter tracts using directional diffusion patterns of water. The purpose of this study is to use DTI-FT to analyze SCM networks within BG and compare PD and ET.

Methods

We analyzed DTI-MRI images of 30 human brains: 20 pre-operative patients undergoing deep brain stimulation treatment for tremors – 10 PD and 10 ET; and 10 healthy control subjects (CS). 1.5 and 3 Tesla MRI were used for the image acquisition and BrainLab iplan 3.0 software used for mapping regions of interest (ROI) and deriving color-coded white matter tracts or tractography. BG pathways known to be involved with SCM were identified and the volume and size of the bundles representing their probabilistic connections measured. For each subject the 4 ROIs of BG: caudate nucleus (CN), external globus pallidus (GPe), subtantia nigra (SN) and subthalamic nucleus (STN); pedunculopontine tegmental nucleus (PPN) and superior colliculus (SC) were outlined in both hemispheres. Fiber tracking was applied to analyze the probability of connection between ROI of the two BG. Mann-Whitney test was used to compare BG volumes; ANOVA and Tukey's tests were applied for multiple comparisons. Significance was set at $p<0.05$.

Results

The mean ages were 31.5years for CS, 62 for PD and 65 for ET. 50% were female in each group. The mean disease duration was 10.5years (PD) and 15.6years (ET). The volumes of SN, Gpe and CN were significantly larger in CS than both PD ($p<0.005$). However, the nigro-striatal connectome (neural connections) was reduced by 45.8% in PD and only 2.5% in ET compared to the CS group.

Conclusions

We have shown that DTI-FT can be use for *in vivo* assessment of SCM pathways in BG. This new technology when used to complement routine clinical evaluation may represent a means for diagnosing PD and structurally distinguishing PD and ET. Thereby assisting with determination of targeted treatment regimes.

Illustrations

Example of acquired 3D images of bilateral CN (green) and SN (purple) connectome.