DTI to inform deep brain stimulation (DBS) programming: clinical applications

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Background: Deep brain stimulation (DBS) is an effective surgical treatment for movement disorders. Although stimulation sites for movement disorders such as Parkinson’s disease are established, the therapeutic mechanisms of DBS remain controversial. We have previously demonstrated that clinically beneficial contacts have larger connectivity to the thalamus (Vanegas-Arroyave et al, 2016). Here, we further investigated the specific thalamic nuclei influenced by subthalamic nucleus (STN) DBS.

Methods: Subjects: 35 patients with idiopathic Parkinson’s disease who received bilateral STN-DBS surgery (age 58.8 ± 8.3 y, disease duration 12.2 ± 6.2 y) were included on a consecutive basis. All patients were implanted with DBS Lead Model 3389 (Medtronic). Each contact was screened and defined as clinically effective (CE) or non-effective (NE). The minimum voltage producing a clinical response was recorded, together with impedance value to estimate the volume of tissue activated (VTA). Images: MRI (Philips Achieva XT) included pre-operative T1w turbo-field-echo, T2w turbo-spin-echo and high-angle echo-planar diffusion weighted images at 3.0T and post-operative T1w fast-field-echo at 1.5T. Head CT (Siemens SOMATOM) was collected post-operative. Using DBSproc (Lauro et al, 2016) and TORTOISE (Pierpaoli et al, 2010), DBS contacts were extracted from CT images, structural and diffusion MRI data were preprocessed and registered to a subject specific space and VTAs were computed. Connectivity analysis: Probabilistic tractography between each VTA and 11 thalamic nuclei, transformed from atlas to each subject’s space, was estimated in FATCAT (Taylor et al, 2016). We investigated the ‘frequency of connectivity’ (FoC) to thalamic nuclei by assigning ‘1’ for the presence of connectivity between the contact’s VTA and a thalamic nucleus, and ‘0’ otherwise. Using a within-lead analysis for relevant ROIs from the FoC, we investigated the association between clinical effectiveness and contact strength of connectivity. Each ROI’s discriminant power was expressed as a proportion of the leads on which the contact with the strongest connectivity was CE.

Results: The binarized FoC analysis showed that CEs were most frequency connected to the motor nuclei of thalamus. The frequency of VTA-ventrolateral nucleus (VL) connectivity in CE contacts (n=197) was the highest (85.8%), followed by that of VTA-ventroanterior nucleus(68.0%). VL nucleus had the largest discriminant power (0.911; p=0.041; odds ratio 2.49).

Conclusions: The connectivity pattern observed suggests that the modulation of white matter tracts directed to the VL is associated with favorable clinical outcomes. The VL comprises the nucleus ventralis intermedius (Vim) and receives cerebellar inputs from the dentate nucleus implicated on the management of various types of tremor.