Correlation of Volume of Tissue Activation Distance from Probabilistic White Matter Fiber Tractography Associated with Treatment Efficacy in Patients with Parkinson's Disease Selected for Deep Brain Stimulation

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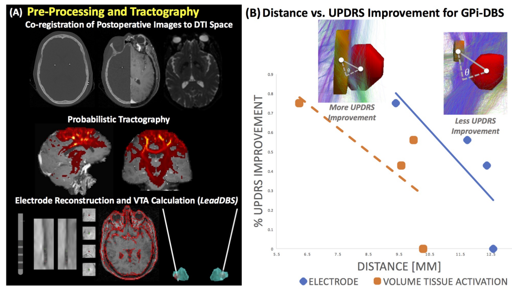
Jennifer Muller; John Pearce; Mahdi Alizadeh; Lauren Kozlowski; Feroze Mohamed; Ashwini Dayal Sharan; Chengyuan Wu
Thomas Jefferson University Hospital, Department of Neurosurgery

Introduction

High frequency deep brain stimulation (DBS) of the globus pallidus (GPi) or subthalamic nucleus (STN) has been shown to be clinically effective in relieving symptoms associated with Parkinson's Disease (PD). [6] Precision in location of electrodes within the target region is correlated with improved motor enhancement. [4][9] Calculation of the volume of tissue activated (VTA) of a DBS contact can be used to visualize the probable effect of stimulation. [3] Diffusion tensor imaging (DTI) may provide 3D visualization of neuronal pathways. [1] Here, we examine the correlation between proximity of VTA to the area of highest track density (TD) of DTI-derived tracts, with the percent improvement in postoperative UPDRS score.

Methods

Five patients (4 GPI DBS, 1 STN DBS) with PD were included in this study. All subjects underwent preoperative MRI examinations and DTI images were acquired. Track density maps were generated from probabilistic tractography using FSL. Postoperative images were registered to DTI space and DBS-Electrodes were reconstructed using Lead-DBS software (http://www.lead-dbs.org). [4] VTA was calculated using the Maedler 2012 FE model. [6] Euclidean distance, VTA volume, and dice coefficient were calculated.



Registration of postoperative images to DTI space, probabilistic tractography, and electrode reconstruction (A). Correlation of electrode and VTA distance for patients with GPi-DBS (B)

Results

Three out of four patients with GPi DBS responded well to treatment with one patient having 0% improvement. The patient with STN stimulation had 10% improvement. Overall, GPi-DBS patients had more favorable outcomes and smaller Euclidean distances from the area of highest track density in either the left or right hemisphere for both the stimulated contact position and VTA distance. Additionally, more favorable outcomes showed a greater amount of overlap between the VTA and TD map as calculated by the dice coefficient.

Conclusions

Our study suggests that both proximity of VTA to center of TD and degree of overlap is correlated with successful patient outcome. Further study including a larger patient cohort is planned to strengthen correlation.

	Electrode Coordinates					
Case No.		Left		Right	Average Distance [mm]	UPDRS Improvement
1	Contact # L		Contact # R			
	3	-10.29, -2.90, 11.20	11	62.2, 69.7, 25.5		
	2	-9.60, -3.76, 9.56	10	62.7, 56.1, 25.5		
	1	-8.91, -4.62, 7.93	9	63.1, 74.6, 29.5		
	0	-8.22, -5.48, 6.29	8	62.8, 50.9, 28.0		
Distance [mm]		10.50		19.91	15.21	10%
2	Contact # L		Contact # R			
	3	-17.12, 3.67, -25.34	11	26.68, 4.32, -21.71		
	2	-17.63, 3.74, -23.44	10	26.22, 3.99, -23.56		
	1	-18.13, 3.80, -21.54	9	25.77, 3.66, -25.40		
	0	-18.64, 3.87, -19.637	8	25.32, 3.33, -27.25		
Distance [mm]		3.19		15.45	9.40	75%
3	Contact # L		Contact # R			
	3	16.84, 36.45, 10.32	11	-30.94, 34.77, 5.90		
	2	16.75, 36.84, 8.36	10	-30.84, 35.36, 3.99		
	1	16.66, 37.24, 6.40	9	-30.73, 35.94, 2.08		
	0	16.57, 37.64, 4.45	8	-30.63, 36.52, 0.17		
Distance [mm]		8.01		15.45	11.73	56%
4	Contact # L		Contact # R			
	3	-19.87, 49.17, -20.72	11	26.06, 47.84, -25.42		
	2	-19.73, 49.94, -22.56	10	25.64, 48.76, -27.14		
	1	-19.59, 50.71, -24.39	9	25.21, 49.68, -28.86		
	0	-19.46, 51.49, -26.23	8	24.79, 50.60, -30.59		
Distance [mm]		15.14		8.86	12.00	43%
5	Contact # L		Contact # R			
	3	-13.55, 3.22, 6.56	11	25.81, 1.25, 4.21		
	2	-13.61, 3.20, 4.57	10	25.77, 1.27, 2.21		
	1	-13.67, 3.18, 2.57	9	25.73, 1.30, 0.21		
	0	-13.73, 3.16, 0.57	8	25.69, 1.33, -1.79		
Distance [mm]		15.98		9.18	12.58	0%

	VTA Left		VTA Right		Volume Overlap with TD [mm^3]		Smallest Euclidean Distance to TD [mm]		% UPDRS Improvement
Case No.	Volume [mm^3]	Radius [mm]	Volume [mm^3]	Radius [mm]	Left	Right	Left	Right	
1	38.98	0.95	2.1	0.61	40.00	0.00	8.40	19.30	10%
2	81.45	2.69	197.41	3.61	88.00	208.00	0.50	12.00	75%
3	112.21	2.99	0.61	0.53	112.00	0.00	5.02	14.93	56%
4	96.35	2.84	89.02	2.77	96.00	95.99	12.29	6.09	43%
5	53.25	2.33	48.48	2.26	48.00	48.00	13.65	6.92	0%

Electrode coordinates and distance of active contacts from highest TD area. VTA dimensions with volume overlapping the track density map.

Learning Objectives

1.Appreciate the significance of accurately revealing white matter architecture, hyperdirect, and direct pathways using probabilistic tractography for pre-surgical planning

2.Analyze the correlation of proximity of VTA to the area of highest track density

3.Investigate the improvement of precision for the location of electrodes within a target region for DBS surgery

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