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Correlation analysis between quantitatively analyzed stimulation effects and anatomical position during deep brain stimulation surgery.

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Background

Deep Brain Stimulation (DBS) is a routinely performed surgical procedure for treatment of movement disorders like Essential Tremor (ET). However, the target selection in DBS is not fully optimized. Incomplete knowledge of the mechanisms of action being one of the reasons, we believe, suboptimal usage of information during surgery is another. We have previously demonstrated the use acceleration sensors to quantify changes in patient tremor during deep brain stimulation surgery [1]. We analyzed the correlation of the acceleration data results with the different deep brain structures. We present in this paper the result from 6 ET patients implanted in the ventro-intermediate nucleus (VIM) of the thalamus.

Methods

PATIENTS

- 5 patients with Essential tremor (ET) participated in a clinical study
- bilateral implantation of DBS electrodes was performed in the ventro-intermediate nucleus (VIM) region.

SURGICAL PROTOCOL

- **Preoperative** manual outlining of Vim and its anatomic neighbors was done using iPlan (Brainlab, Feldkirchen, Germany) and the target point was selected (Fig 1).
- Intraoperative microelectrode recording (MER) and test stimulations (Fig 2) :
 - 124 test stimulations in total, were performed for 5 patients.
 - Maximum reduction in tremor and the corresponding amplitude were noted for all positions using visual symptom evaluation.
 - Acceleration data were recorded and evaluated for all test stimulations (Fig 3)
 - One thalamic sub-structure was attributed to every test stimulation position [2].

DATA ANALYSIS

- Statistical features were calculated from acceleration data for quantitative tremor evaluation.
- For every test stimulation, change in acceleration features was calculated for the data corresponding to the visually identified effective stimulation amplitude.
- Stimulation amplitudes were also identified based on acceleration data where the change in acceleration features was equivalent to the change observed visually during the surgery.
- Data for all stimulation positions were then grouped based on the thalamic sub-structure associated with it.

Results

- The 124 test stimulations were distributed over 7 different thalamic regions : Centre Median (CM), Intermediolateral (IML), VIM, Ventrocaudal lateral (VCL), Ventrocaudal medial (VCM), Ventro-oral (VO) and also in Prelemniscal Radiations (PreR)
- In the VCM and the VO, the improvements described by the neurologist for the same amplitude is higher than that for the VIM, and in the IML, VCL and the VO, the improvements measured by the acceleration data for the same amplitude is higher (Fig 4, Table 1). For the VO, the improvement is higher compared to the VIM when evaluated by both methods.
- For similar amount of tremor reduction, stimulation amplitude noted visually \approx 2*stimulation amplitude calculated from acceleration data

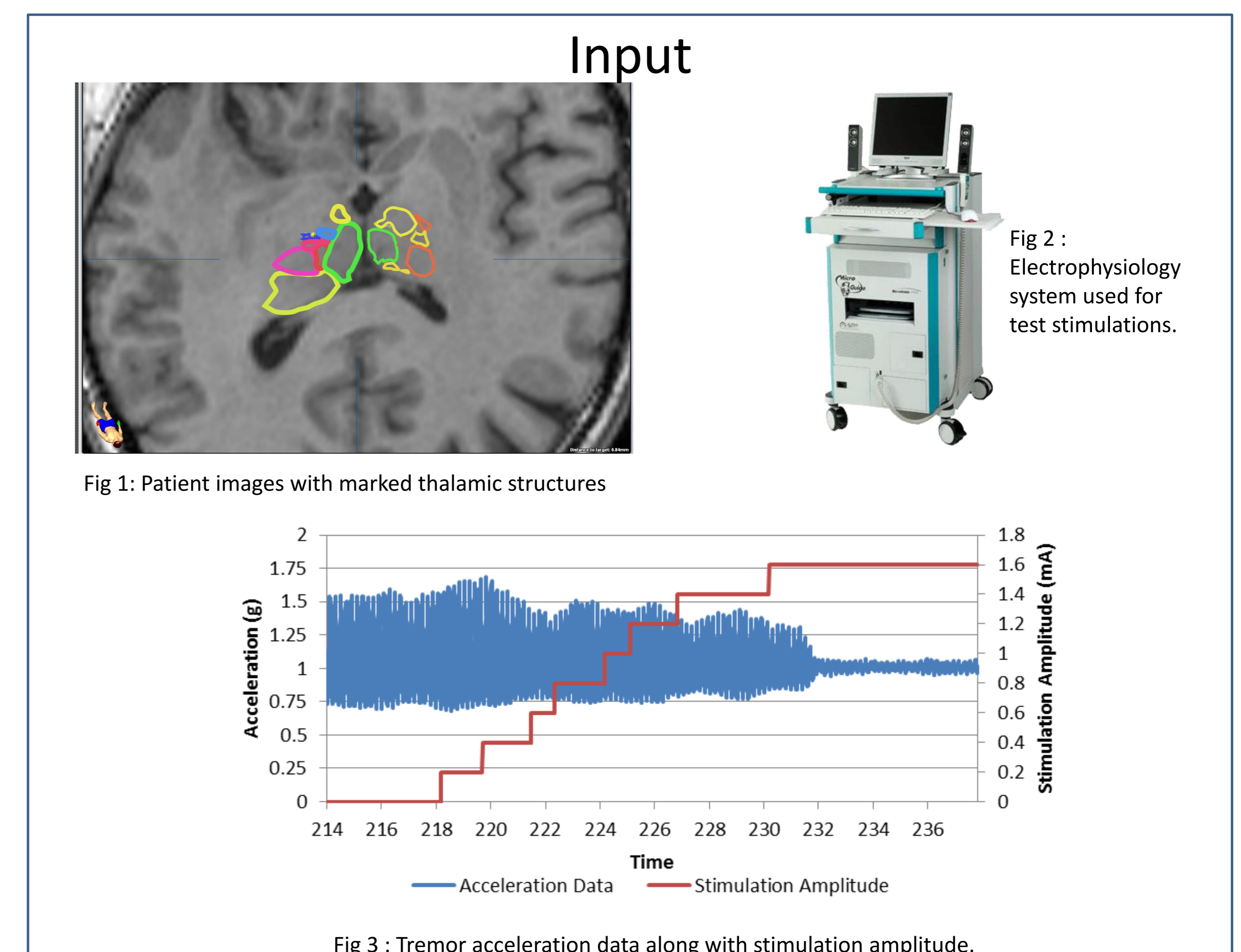
Discussion

- Quantitative analysis suggests VCL, IML and VO might be better targets than VIM with lower side effects and better reduction in tremor for less current. This is not observed with visual evaluation method (Fig 4).
- Quantitative evaluation of patient tremor assists in identifying stimulation target structures.
- New and more effective targets can be identified using quantitative evaluation along with visual evaluation.
- Higher reduction in tremor at lower stimulation amplitude will benefit patients in multiple ways : less side effects, longer stimulator battery life etc.
- More evaluations for CM are required to increase the significance of the results.
- However, one structure per stimulation position is not optimum, as stimulation creates a 3D volume of Electric Field. Further analysis necessary by considering electric field stimulations

References

[1] Shah A et al. A method to quantitatively evaluate changes in tremor during deep brain stimulation surgery. In: 2013 6th International IEEE/EMBS Conference on Neural Engineering (NER), pp 1202–1205

[2] Direct stereotactic targeting of the ventrointermediate nucleus of the thalamus based on anatomic 1.5-T MRI mapping with a white matter attenuated inversion recovery (WAIR) sequence. Brain Stimul. 5(4):625-33.



Data processing

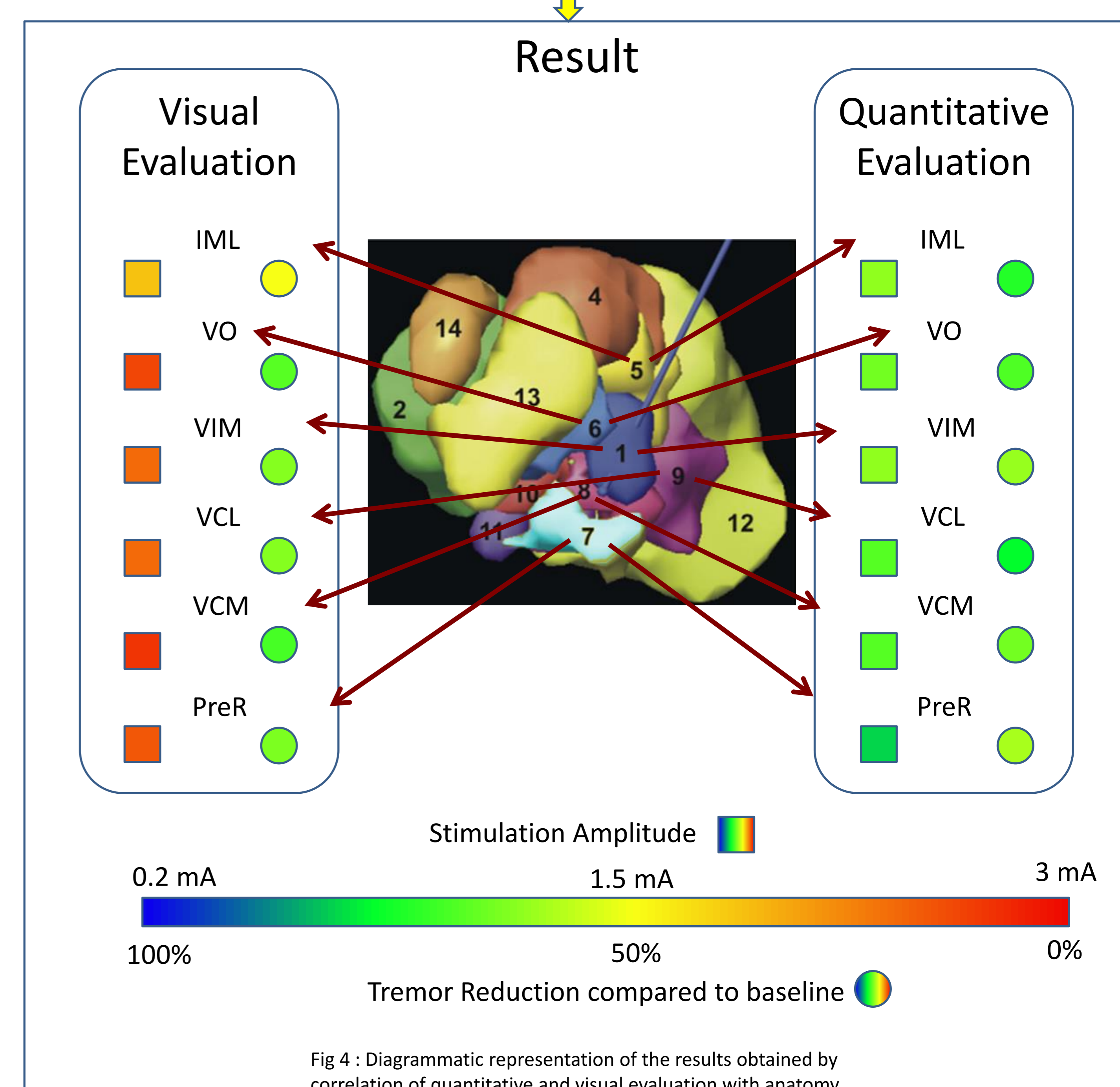


Fig 4 : Diagrammatic representation of the results obtained by correlation of quantitative and visual evaluation with anatomy.

Table 1	CM	IML	VO	VIM	VCL	VCM	PreR
No. Of Stimulations	3	12	17	45	13	19	15
Avg Visually evaluated Effect (%)	50	48	66	61	61	68	62
Avg Quant. Effect (%)	76	72	67	59	76	63	57
Avg Visual Stim. Amplitude (mA)	2	1.9	2.6	2.4	2.4	2.7	2.5
Avg Quant. Amplitude (mA)	0.4	1.2	1.1	1.2	1	1	0.6
No of Stim. with Side Effects	0	1	1	11	3	4	2

