Co-registering Thalamus for Analysis of Patient-specific Intra-operative Improvement Maps in DBS

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Dorian VOGEL (Speaker), Ashesh SHAH, Fabiola ALONSO, Jean-Jacques LEMAIRE, Jérôme COSTE, Karin WÅRDELL, Simone HEMM

Deep brain stimulation (DBS) is used for symptomatic treatment of movement disorders. In many centers, the optimal DBS position is identified by intra-operative stimulation tests, which are performed at several positions along the planned trajectories toward the target structure with various stimulation amplitudes. The aim of the study was to propose a methodology summarizing all available intra-operative data of different patients to an atlas to provide targeting guidelines in the thalamus.

Data was collected for 8 patients (6 Essential Tremor, 2 Parkinson's Disease) who underwent bilateral implantation toward the ventral intermediate nucleus (Vim) (16 trajectories). Stereotactic MRI (T1, WAIR [1]; 1.5T, Siemens Sonata) were acquired prior to DBS surgery. An acceleration sensor was mounted on the contralateral wrist of the patient during intraoperative test stimulation to quantify tremor improvement. Written informed consent was obtained from the patients (ref.: 2011-A00774-37/AU905). A conductivity model of each patient's brain was derived from the intensity values of the T1 image. Finite element simulations were performed using these models for the positions and amplitudes (between 0 and 3 mA) with the best improvement. A 0.2 V/mm isolevel [2] was used to visualize the electric field. Improvement maps of each patient’s brain were visualized by affecting to each voxel in simulation results the maximum improvement measured. These maps were further enhanced by 14 subthalamic structures per side labeled by the neurosurgeon [3]. The resulting Improvement Map was visualized together with the patients' anatomy and the implant position providing a summary of the intraoperative testing [4]. An example view of this visualization is presented in Figure 1. In order to proceed to group analysis, a normalization pipeline for the improvement maps was designed as a two-step process: the first step uses the MNI152 template [5] and tools from FSL [6] to proceed to an initial linear registration. The T1 image for each patient was aligned and then registered to the MNI template. The WAIR image was then aligned to the aligned T1 and the registration transformation was applied. Both transforms were also applied to the anatomical structures. A result of this first normalization is presented in Figure 2 for the ventro intermediate nucleus (Vim). Those results show the necessity of a finer registration step, allowing local displacement of voxels in order to provide a better definition of the anatomical labels after normalization. In the second step, several normalization templates as well as non-linear group registration tools were evaluated in order to obtain the best probabilistic definition of the labeled sub-thalamic structures after application of the disformation field. Future work will focus on transferring the improvement values and spatial distribution of the electric field to the anatomical atlas to create an improvement atlas, and select appropriate statistical methods to visualize it. The atlas will present a summary of the complete patient pool, to be used as an assistance tool during planning. As the number of patient increases, this type of atlas will help analzing the mechanisms of action.

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