A method for side effect analysis based on electric field simulations for intraoperative test stimulation in deep brain stimulation surgery

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Despite an increasing use of deep brain stimulation (DBS) the fundamental mechanisms underlying therapeutic and adverse effects remain largely unknown. The simulations of electric entities are increasingly used to evaluate stimulation effects. To our knowledge, so far no group has considered such simulations combined with a side effect analysis of data obtained during intraoperative test stimulations. The aim of the present paper is to introduce a method allowing patient-specific electric field simulations for stimulation amplitudes inducing side effects during deep brain stimulation surgery.

Two female patients presenting essential tremor, both bilaterally implanted in the ventral intermediate nucleus (VIM) region in the Clermont-Ferrand University Hospital were included in the study. Intraoperative test stimulations were performed on central and posterior trajectories in each hemisphere at 8-9 positions per trajectory. At each position in addition to the evaluation of the therapeutic effects, side effects such as pyramidal symptoms and paresthesia without localization indicator or paresthesia with localization indicated by the patient (in the hand or in the fingers) were noted. The anatomical structures such as VIM and its neighbors were preoperatively manually outlined using the iPlan software (Brainlab, Feldkirchen, Germany) according to spontaneous MRI contrasts [1]. The so identified structures were exported via a specifically designed interface (VVLink, Brainlab, Feldkirchen, Germany). Whenever side effects occurred the inducing stimulation amplitude was chosen for electric field simulations. A finite element method [2] was applied to calculate the electric field distribution. Conductivity values were deduced from the patient's T1 weighted MRI. An isofieldlevel of 0.2V/mm was chosen and the points of the isosurface were exported. They were visualized together with the extracted anatomical structures and the trajectories. The different structures present inside the volume defined by the isofield level and their appearance were determined. Combinations of structures always appearing together for a specific side effect were identified.

For both patients, 8 electric field simulations were successfully performed. A first analysis showed that pyramidal effects appear when parts of the ventrooral nucleus (VO) and the VIM were present inside the isosurface. The ventrocaudal lateral nucleus (VCL), the ventrocaudal medial nucleus (VCM) and the VIM were among the identified structures in hand paresthesia (VCL, VIM), finger paresthesia (VCL, VCM, VIM) and paresthesia with location not formally identified by the patient (VCM, VIM).

The application of our method to two patients has shown its feasibility. Our results are consistent with anatomical knowledge that stimulation of VCL and VCM induce paraesthesia in the body and the face respectively. Nevertheless, more patient data have to be analysed to draw any conclusions on the regions responsible for inducing the side effects. The present method will allow an optimised data exploration than by taking into account only the anatomical position of the center of the measurement electrode.

References

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