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The effect of the ventricular system on the electric current in deep brain stimulation

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Background

In deep brain stimulation (DBS) for movement disorders, the electrode is implanted in the basal ganglia and thalamus, where the electrode is surrounded by gray and white matter. In contrast, when DBS is used for suppressing neuropathic pain, the electrodes are implanted in the periventricular/periaqueductal gray (PVG/PAG) region and are usually situated very close to the third ventricle and the aqueduct [1]. These structures are filled with cerebrospinal fluid (CSF), having higher conductivity and lower reactivity than that of brain tissue. We hypothesized that the proximity of these CSF volumes would have a significant effect on the current distribution and the predicted volume of tissue activated (VTA).

Methods

We constructed a finite element model of the electrode and surrounding tissue including the ventricular system, based upon a post-operative MRI of the patient [2]. This geometrical domain was used to solve the Laplace equation and to visualize the potential distribution induced by DBS [3-5]. In order to quantify the VTA, we used coupled compartmental neuronal models based on cable theory to predict the volume around the electrode in which neuronal firing could be modulated [6].

Results

Results showed that the high-conductivity CSF regions attenuated the distribution of the induced potential in the surrounding tissue, and the electric field lines were skewed towards the ventricles. This in turn affected the VTA as predicted by the compartmental axon models, such that the amplitude of the stimulus had to be doubled in the model including the ventricles in order to stimulate the same number of nearby axons. Factors such as position, size and shape of the CSF-filled space relative to the electrode position were quantified to uncover general principles of current spread in the model.

Discussion

The pain suppression effect of DBS highly depends on the location of the DBS electrode. This patient specific model indicates the influence of previously overlooked biophysical features of the surrounding brain tissues on the predictions made by FEM models of DBS. We speculate that the significant alteration of the stimulation current by the high-conductivity ventricular volumes may also have a significant impact on achieving the therapeutic outcomes.

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