Computational Study on Transcutaneous Frontal Nerve Stimulation: Simplification of Human Head Model

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Abstract

I. INTRODUCTION
Migraine is a neurological disorder which affects nearly 15% of the population and it has been estimated that the European Community spends about €27 billion in a year. Its symptoms may be categorized as attacks of often severe, throbbing head pain with sensory sensitivity of light and sound. It is mainly related to trigeminal nerve, the supraorbital nerve (SON) and supratrochlear nerve (STN) arise from the frontal branch of the ophthalmic division of the trigeminal nerve.
The available pharmaceutical treatments and invasive neuromodulation techniques are not completely effective due to their troublesome side-effects. Among the different transcutaneous electrical nerve stimulations, the transcutaneous supraorbital nerve stimulation has been applied on a large group of people who have episodic migraine. However, nearly 50% of this population were not satisfied. Therefore, it is assumed that this limited efficacy may be associated with the neuro-anatomical variations across different subjects. Therefore, using computational models of human head tissues, electrode patch and, stimulator may be readily investigated to estimate current thresholds in neuromodulation therapy. After studying these thresholds in a simplified nerve and head model, as shown in Fig. 1a, in our previous work, the present study aims to generate a highly detailed human head model to investigate the effect of model complexity on stimulus current threshold estimates. Both studies will be compared to regarding stimulus current level and efficacy of model computation.

II. METHOD
A more realistic three dimensional (3D) model of human head was derived from magnetic resonance imaging (MRI) scans. Different head tissue layers were segmented based on both automatic and manual segmentation processes in Simpleware ScanIP (Synopsys, Mountain View, USA), as shown in Fig. 1b. However, the more realistic SON and STN nerve trajectories were extracted based on literature, and together with Cefaly's electrode patch were modeled from geometric shapes. Since in a complicated geometry the underlying differential equations cannot be solved analytically, finite element method (FEM) was used to solve for the electrical potential distribution for each medium. The simulations were carried out using COMSOL Multiphysics® while considering the Laplace equation as shown in (1).

(1): $\nabla.(\sigma\nabla V)=0$

III. RESULTS

The percentage activation (PA) of fibers was measured based on the fifth current pulse with the Cefaly stimulator parameters.Although STN has multiple branches in RM and single branch in SM, the PAs with respect to stimulus current level follow nearly the same tract. For the case of SON, to stimulate the nerve fibers around 50%, the needed stimulation current levels were nearly the same, however, to activate all fibers of SON, the required stimulus current levels are different.

Figures used in the abstract

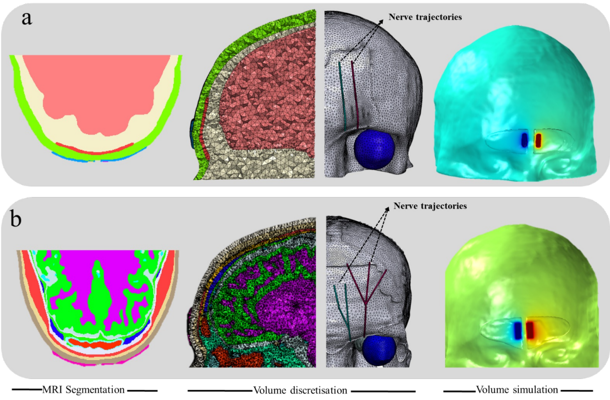

Figure 1: Showing simplified (a) and realistic human head models (b).