

Title: A COMPUTER MODELLING STUDY ON MOTOR CORTEX STIMULATION

Authors: Lj. Manola, B. Roelofsen, J. Holsheimer and E. Marani

Institute for Biomedical Technology, Department of Electrical Engineering,  
University of Twente, P.O. Box 217, 7500AE, Enschede, The Netherlands

Introduction: Motor Cortex Stimulation (MCS) is a promising clinical technique for chronic pain treatment [1]. However, since the underlying biophysical mechanisms are not yet known, different stimulation configurations and parameters are used with varying success. The goal of this modelling study is to help to understand the immediate effects of stimulating the precentral gyrus and ultimately help to improve the efficacy of MCS.

Methods: A 3D model of the precentral gyrus with surrounding sulcii and an epidurally placed electrode was developed using University of Twente SCS software [2]. The geometries and electrical conductivities of the structures in the model were derived from human data. The electrical potential field in this model was calculated for monopolar (cathode) and bipolar (cathode-anode) stimulation with standard contact distance of 10 mm. Finally, the resulting response of various afferent and efferent (entering and leaving the cortex respectively) myelinated fibers at various positions in the cortex was calculated [2].

Results: While the width of the sulcii did not influence the distribution of the electrical potential field in the gray and white matter of the precentral gyrus, the thickness of the cerebrospinal fluid under the electrode did substantially. By increasing this thickness while keeping the voltage applied to the electrode at a constant value, the penetration of the electrical field in the cortex and the load impedance were reduced. By decreasing this thickness the opposite occurred. In bipolar stimulation, the electrical field at a certain depth in the cortex under the cathode had a similar shape as the corresponding field imposed by monopolar stimulation with an equal current. Activating function concept and simulation of the response of the nerve fiber models to the imposed electrical field predicted that the fibers perpendicular to and under the cathodal surface were hyperpolarized, whereas the fibers (with a part) parallel to it were depolarized and could be excited. Under the anode the opposite was observed. The distribution of the fibers along the curvature of the precentral gyrus results in their different excitability depending on their position.

Conclusions: Due to a rather big contact distance of the commonly applied electrode (10 mm) the bipolar stimulation acts like a virtual monopolar under the cathode, but is less energy efficient than true monopolar. The presence of anode(s), however, opens the possibility to excite some (possibly undesirable) neural structures under the anode(s). Thickness of the cerebrospinal fluid layer under the electrode could be very important parameter for the efficacy of the therapy.

Just like in SCS case, computer modelling of MCS can be a useful predictive tool that should lead to optimization of the MCS technique. In order to achieve that, further modelling studies that would be supported with clinical and electrophysiological data are needed.

#### References:

[1] Nguyen JP, Lefaucheur JP, Keravel Y. Motor cortex stimulation. Electrical stimulation and relief of pain, Pain research and clinical management. Vol. 15. Elsevier Science, 2003.

[2] Manola Lj, Roelofsen B, Holsheimer J, Marani E, Geelen J. Modelling Motor Cortex Stimulation for Chronic Pain Control: Electrical Potential Field, Activating Functions and Responses of Simple Nerve Fibre Models. Medical & Biological Engineering & Computing. (accepted for publication).