Model of Selective Field Deformation in Deep Brain Stimulation (DBS)

L. Roohisefat [1], S. Mottaghi [2], M. Li[3], U. G. Hofmann[4], V. A. Coenen[5]

[1]Department of Stereotactic and Functional Neurosurgery, Medical Faculty, Freiburg University. Department of Neurosurgery, Section for Neuroelectronic Systems, Medical Center, Freiburg University, Freiburg, Germany
[2]Department of Neurosurgery, Section for Neuroelectronic Systems, Medical Center, Freiburg University, Freiburg, Germany
[3]Department of Stereotactic and Functional Neurosurgery, Medical Faculty, Freiburg University, Freiburg, Germany
[4]Department of Neurosurgery, Section for Neuroelectronic Systems, Medical Center, Freiburg University. Cluster of Excellence „BrainLinks-BrainTools“,DFG EXC 1086, Freiburg, Germany
[5]Department of Stereotactic and Functional Neurosurgery, Medical Faculty, Freiburg University. Cluster of Excellence „BrainLinks-BrainTools“,DFG EXC 1086, Freiburg, Germany

Abstract

Deep Brain Stimulation (DBS) is known to alleviate symptoms of some movement disorders and is currently tested for its clinical value in several psychiatric disorders. Although the exact mechanism of DBS is not well understood yet, an activation of white matter structures is the most likely one [1].
The spatial distribution of the electric field originating from implanted DBS electrodes is important. It is sensitive to both the electrode position and also the fiber structure close by. Previous studies have investigated the relation between the electric field and fiber activations [2].
In this study possible electrical field deformations caused by fiber bundles are assessed. Furthermore the effect of fiber bundle properties and their density around the electrode is brought into the model and examined.

For this purpose, a 3-dimensional finite element model of the Medtronic 3389 DBS lead and a simplified model of fibers surrounding it are simulated using COMSOL Multiphysics®. The Electric Currents interface of the AC/DC Module is included from the model wizard. As a starting point fibers are presented as longitudinal cylinders parallel to an electrode. Secondary, real fiber coordinates have been imported from patient specific DTI images, bringing Medtronic software (StealthViz DTI, Medtronic, USA) into the COMSOL® geometry environment.

We compared the electric field of three active electrode contacts in a volume simulating white matter electrical properties. The potential distribution and also second difference of the potential are calculated along the fiber axis. The results show a clear deviation in

potential distribution from the homogenous model depending on diameter, number, and distribution of the fibers in question.

The selective stimulation of target neural populations utilizing DBS is of great interest. Most studies assume an activation of fibers by an electric field in a homogenous tissue while the effect of fibers on potential distribution itself has not received adequate attention [3]. This study gives first evidence of electric field deformations and also the second difference of potential distribution. This study may pave the way for a patient oriented understanding of Deep Brain Stimulation in various indications.

Reference

[1] V. Gradinaru et al., Optical deconstruction of parkinsonian neural circuitry, Science, Vol. 324, pp. 354-359 (2009)
[2] K. J. van Dijk et al., A novel lead design enables selective deep brain stimulation of neural populations in the subthalamicregion, Journal of neural engineering, Vol. 12, Issue 4 (2015)
[3] C. R. Butson et al., Patient-specific analysis of the volume of tissue activated during deep brain stimulation, Neuroimage, Vol. 34, pp. 661-670 (2007)