Sensitivity analysis of the field distribution in Deep Brain Stimulation with respect to the anisotropic conductivity of brain tissue

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Introduction

Deep Brain Stimulation (DBS) of the subthalamic nucleus (STN) is a common neurosurgical method to treat symptoms of Parkinson's disease. Nevertheless, knowledge about the fundamental mechanisms of this method is still scarce. The neural response in the target area, for example, is affected by the field distribution generated by the stimulating electrode, which is dependent on various factors like the electrical tissue properties and its anisotropic nature.

Methods

An idealized 3D finite element model of the head comprising heterogeneous and anisotropic tissue properties was generated using magnetic resonance imaging and diffusion tensor imaging data from an multi-channel brain atlas. Deviations between the field distribution within the surroundings of the stimulating electrode contact (SSEC) in an isotropic and anisotropic head model were computed for different locations of the stimulation centre around the STN.

Results

The deviations between the isotropic and anisotropic field distribution within the SSEC remained below 4 % for the variation of the stimulation centre location. Averaged over all locations, the deviation was determined to be below 2 %. The pattern of the averaged anisotropic ratio within the SSEC with respect to the stimulation centre location corresponded to the pattern of the field deviations in this region, resulting in a discrepancy of below 10 %.

Conclusion

In the presented model of DBS, the anisotropic conductivity was shown to be of minor influence on the shape and expansion of the field distribution in the proximity of the stimulating electrode contact. The highest effects of anisotropic conductivity were found to be close to the electrode contact surface. The deviation between the isotropic and anisotropic field distribution changed with the stimulating centre location and increased in areas with a high anisotropy ratio. These results propose that a simplified isotropic head model could be sufficient in various models of DBS.