Determinants of the electric field during transcranial direct current stimulation

Transcranial direct current stimulation (tDCS) causes a complex spatial distribution of the electric current flow in the head which hampers the accurate localization of the stimulated brain areas. In this study we show how various anatomical features systematically shape the electric field distribution in the brain during tDCS. We constructed anatomically realistic finite element (FEM) models of two individual heads including conductivity anisotropy and different skull layers. We simulated a widely employed electrode montage to induce motor cortex plasticity and moved the stimulating electrode over the motor cortex in small steps to examine the resulting changes of the electric field distribution in the underlying cortex. We examined the effect of skull thickness and composition on the passing currents showing that thinner skull regions lead to higher electric field strengths. This effect is counteracted by a larger proportion of higher conducting spongy bone in thicker regions leading to a more homogenous current over the skull. Using a multiple regression model we could identify key factors that determine the field distribution to a significant extent, namely the thicknesses of the cerebrospinal fluid and the skull, the gyral depth and the distance to the anode and cathode. These factors account for up to 50% of the spatial variation of the electric field strength. Further, we demonstrate that individual anatomical factors can lead to stimulation "hotspots" which are partly resistant to electrode positioning. Our results give valuable novel insights in the biophysical foundation of tDCS and highlight the importance to account for individual anatomical factors when choosing an electrode montage. (C) 2015 Elsevier Inc. All rights reserved.