Direct experimental validation of computational current flow models with intra-cranial recordings in human and non-human primates

Belen Lafon[1]*, Anli Liu[2]*,
Preet Minas[1,2], Kohitij Kar[3], Marom Bikson[1],
Daniel Friedman[2], Bart Krekelberg[3], Lucas C Parra[1]

1: Biomedical Engineering Department, City College of New York
2: Comprehensive Epilepsy Center, NYU Langone Medical Center.
3: Center for Molecular and Behavioral Neuroscience, Rutgers University
* Contributed equally

Abstract:

Transcranial electrical stimulation (TES) is emerging as a promising therapeutic tool to treat a range of neurological and psychiatric disorders. During TES, electric currents (of approximately 2mA or less) flow between electrodes placed on the scalp generating weak electric fields inside the head (<1 V/m). Computational modeling has been extensively used to predict the precise intensity and distribution of electric fields across the brain. The goal of such computational modeling is to guide the targeting of particular brain areas for clinical trials and research studies. While models have increased in sophistication and detail, to date there is no conclusive empirical validation for their predictions. Previous efforts have been limited to comparing model predictions with voltage recordings on the scalp surface and have left the accuracy of model predictions inside the head entirely undetermined. To address this, we recorded intra-cranial electric fields generated by low-frequency AC currents delivered through two scalp surface electrodes in patients undergoing invasive monitoring for epilepsy surgery (N=3 patients to date). High-resolution finite element models were constructed from patient's MRIs at 1 mm^3 resolution, and voltage distribution inside the head were simulated for 1 mA currents. Model predictions have been compared against intra-cranial recordings (in over 150 cortical and subcortical electrodes per subject) and preliminary results show a general correspondence of model and recordings. To determine specific conductivity value *in-vivo* for different tissues we are in the process of recording from depth electrodes also in rhesus macaque monkey leveraging ongoing neurophysiology experiments with TES. We have already segmented the macaque head anatomy for one subject at 1 mm^3 resolution and completed current flow modeling. The combined human and non-human primate recordings will provide strong constraints on modeling efforts and will establish firm guidelines for model parameters such as tissue conductivity and anisotropy. We expect that this work, once completed, will put future clinical efforts to target specific brain areas on firms empirical grounds.