Effects of conductivity perturbations of the tri-layered skull on EEG source analysis

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EEG source analysis relies on an accurate model representing the human head. In this head model, the skull plays an important role due to its complex structure and low conductivity compared to the other tissues inside the head. The skull has often been modelled as a single compartment with isotropic conductivity. However, the actual structure of the skull is tri-layered, consisting of a spongiform layer surrounded by two compact layers. Not only spongy and compact bones are part of this structure but also air-filled cavities. Therefore, the skull has different conductivities and thicknesses throughout its whole structure and so it is *inhomogeneous*.[1]

In this work, we analyse the effect of conductivity perturbations of the inhomogeneous skull compartment on EEG source analysis. For this purpose, a data set with co-registered magnetic resonance (MRI) and computed tomography (CT) images of one patient was used. A head model with an accurately segmented skull, including spongy and compact bone as well as some air-filled cavities, was incorporated in the analysis. The conductivity values for the compact (σ_c = 0.0068 S/m) and spongy (σ_{sp} = 0.0298 S/m) bone compartments of the skull were selected as the average measurements of Akhtari et al.[2], yielding a ratio of 4.38 (σ_{sp}:σ_c) for the reference model. We perturbed these values by: (i) multiplying both conductivities by the same factor, i.e., keeping the ratio constant, and (ii) doubling and halving the ratio. These perturbed conductivity values resulted in a total of seven test head models. Simulated EEG data was computed on the reference model. This data was compared to the forward solutions of the test models through the RDM and MAG error measures. The finite difference method with reciprocity (FDRM)[3] was used to calculate the forward problem in all models. To solve the inverse problem, a single dipole localization based on the minimization of a least squares cost function was performed. The source localization error was computed for dipoles placed at clinically significant brain areas: cingulate cortex, fronto-basal and mesio-temporal regions.

The results suggest that conductivity perturbations of the compact bone have the strongest influence on EEG source localization. Conversely, the perturbations of the spongy bone did not show a noticeable influence on the dipole estimation. This means that more than the spongy to compact bone conductivity ratio, the correct determination of the compact bone conductivity can improve the accuracy of the forward solution. For deep sources (cingulate cortex), the effects of conductivity perturbations were larger than for sources located at fronto-basal or mesio-temporal regions.

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