Biomed Tech 2012; 57 (Suppl. 1) © 2012 by Walter de Gruyter · Berlin · Boston. DOI 10.1515/bmt-2012-4061

Modelling the human skull using FEM – effects of errors and simplifications

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Introduction

The conductivity properties of the human skull have great influence on the way electrical brain activity expresses as EEG features on the head surface. Its proper modeling is therefore of paramount importance for EEG source modeling. Here we investigate the relative accuracy of different skull modeling approaches and quantify the effects of common errors and simplifications.

Methods

We used computer simulations to investigate finite element models [1] of the human skull in EEG source analysis. In the first part, we present a systematic investigation on the accuracy of different ways to account for the layered skull structure. We investigated local models, where each skull location was modeled differently, and global models, where the skull was assumed to be homogeneous, both using isotropic as well as anisotropic conductivity assumptions. We determined errors both in the forward calculation and the reconstructed dipole position [2].

In the second part, we investigate the effect of a number of common errors and limitations in skull modeling, using both forward and inverse simulations. Test models included erroneous skull holes, local errors in skull thickness, modeling cavities as compact bone, downward extension of the volume conductor and simplifying the inferior skull and the inferior skull and scalp as layers of constant thickness.

Results

Our results show that accounting for the local variations over the skull surface is important, while assuming anisotropic skull conductivity has little influence. Furthermore, it was found, that large skull geometry inaccuracies close to the source space led to considerable errors more than 20 mm for extended regions of the source space. Local defects, e.g., erroneous skull holes, caused non-negligible errors only in the vicinity of the defect.

Conclusions

In terms of the general method to model the skull, we recommend: if compact and spongy bone can be identified with sufficient accuracy, one should model these explicitly by assigning each voxel to one of the two conductivities. Otherwise, one should model the skull as either homogeneous and isotropic, but with considerably higher skull conductivity than the usual 42 mS/m, or as homogeneous and anisotropic, but with higher radial conductivity than the usual 42 mS/m and a considerably lower radial:tangential conductivity ratio than the usual 1:10. Furthermore, we derived detailed guidelines for modeling the skull geometry in individual volume conductor models.

References

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