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S09_3. Modeling the Skull Fine-Structure With Boundary Element Method

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In neuroelectromagnetic source imaging, the conductivity profile of the head needs to be modeled. In this forward model, the poorly conducting skull plays a large role; errors and simplifications in the skull model may be detrimental to source localization. In experimental EEG and combined MEG + EEG use, the head model typically contains 3 homogeneous compartments (brain, skull, and scalp). The skull, however, contains regions of compact and spongy bone that have different conductivities. This fine-structure has previously been modelled with the finite element method (FEM). In this study, we show that accurate skull modelling is feasible with the boundary element method (BEM) as well.

An anatomical head model was built using the Curry software and T1-weighted MR images of a volunteer. The inner and outer boundaries of the skull and scalp were segmented using standard procedures, and the 4 regions of spongiosa were segmented manually. Three- and 4-compartment boundary element models were built using the linear Galerkin BEM formulated with the isolated source approach (LGISA)[1] at various mesh densities, and the skull conductivity of the 3-shell models was optimized. The most dense model (37 074 vertices) was used as the reference. Forward solutions of cortically constrained sources were then compared across models using relative error (RE) and relative difference (RDM) metrics.

The results showed that all 4-compartment models performed considerably better than the best 3-shell model; the mean REs and RDMs of these models were <2% and 6.9% and <1.1% and 4.9%, respectively. When only the regions affected by the spongiosa were compared, the corresponding REs were <2.2% and 10.1% and the RDMs <1.3% and 6.6%. The RDMs are similar to those obtained using the FEM by Dannhauer et al.[2] The use of our most coarse spongiosa mesh (1707 vertices) increased the RE for some occipital and anterolateral sources by a couple of percents. A similar increase of error was obtained with a very coarse inner skull mesh (938 vertices). A good balance between the accuracy and computational cost was found with a model comprising a total of 9671 vertices; the mean RE of this model was 0.8%. Such a model can be built in a standard workstation in less than 1 hour.

The results of this study show that the skull fine-structure can be modeled with the LGISA BEM without using especially fine meshes. The challenges of BEM skull modeling are thus in segmentation, meshing, and estimating the conductivities, not in numerical computation.

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