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Effect of Dura Layer on Scalp EEG Simulations

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Abstract. The dura layer which covers the brain is less conductive than the CSF (cerebrospinal fluid) and therefore, could significantly influence scalp EEG. Scalp EEGs were simulated with a finite element model of the adult human head consisting of 19 different tissue-types. It was found that inclusion of the dura layer severely reduced the scalp EEG amplitudes as compared to EEG simulated with the model where the dura layer was replaced with CSF. These findings are of importance for accurate EEG simulations under normal and diseased conditions.

Keywords: Dura Effect on EEG, EEG Simulations, Human Head Model

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1. Introduction

In this brief report we show our preliminary results on the effect of the dura layer for scalp EEG simulations. The conductivity of the dura layer is approximately 0.04 times the conductivity of the CSF (cerebrospinal fluid) and thus, could significantly reduce the volume currents flowing from the cortical neurons to the scalp. The effect of the dura layer on scalp EEG simulations was examined with an anatomically realistic finite element method (FEM) model of the human head of an adult male subject. The conductivities of the dura layer and CSF used in our model were 0.1 S/m and 1.538 S/m, respectively. It was found that the inclusion of the dura layer in FEM models of the head severely reduced the scalp EEG amplitudes. These results are new and suggest that for accurate simulations of scalp EEGs, one should include the dura layer in human head models. No detailed and accurate studies are available which have examined the effect of dura on scalp EEGs. Recenlty, one studay [Slutzky et al., 2010] has examined the possible effects of dura on the spacing of surface electrodes for brain-computer interfarce applications. They performed the study by use of a six tissue FEM model of the human head with a single dipolar soucrce in the brain. Compared with that, the FEM model used by us has 19 different tissues which provides an accurate accounting of volume currents in the head and helps in accurate modeling of the scalp EEGs. Also, we used 120 distributed dipolar soucres to model the electrical activity of the brain. Details of our methods and results are given below.

2. Material and Methods

The scalp EEGs were simulated with a 1.0 mm resolution FEM model of a human head constructed from segmented magnetic resonance (MR) images. Our procedures for segmentation of MR images and FEM model constructions are described elsewhere [Ramon et al., 2006]. Similar procedures were used and are described in brief. The T1 weighted MR images were collected with a 3 Tesla Siemens scanner at the University of Oregon. The slice resolution was 1×1 mm and the contiguous slice thickness was 1.0 mm. This was a volumetric scan. With a semiautomatic image segmentation software [Ramon et al., 2006], we identified 19 different tissue-types in the slices. These included: basal ganglion, blood, hard and soft skull, gray and white matter, cerebellum, corpus callosum, CSF, dura, eye, fat, muscle, salivary glands, scalp or skin, soft tissues, internal air and thalamus. Detailed structure of the eyes, nose, ear canals and blood-filled sinus cavities were included. See Fig. 1 for details of a segmented MR slice.

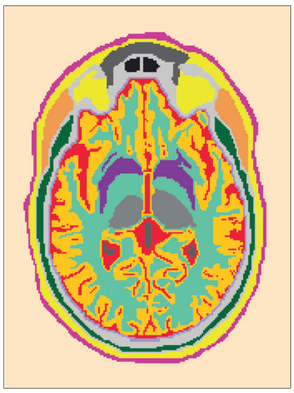

Fig. 1. A segmented slice with major tissue surfaces identified in it.

A FEM model was constructed out of 120 segmented axial slices extending from top of the head to the bottom of the cerebellum. The voxel resolution was 1×1×1 mm. The electrical conductivities of various tissues were obtained from the literature and are summarized in our previous work [Ramon et al., 2006]. The conductivity of the dura matter is not well established and it was found to have a large range from 0.02 to 0.1 S/m [Oozeer et al., 2005]. For our work, we used a value of 0.1 S/m. The conductivity value of the corpus callosum was 0.12 S/m [Sekino et al., 2004].

The electrical activity in the top portion of the brain above the eye level was simulated with randomly placed 120 dipoles located in different parts of the brain. The dipole intensity distribution was in the range of 0.0 to 0.4 µA. Scalp EEGs were simulated for two head models with an adaptive finite element solver. One model had the dura layer and in the other model, the dura layer was replaced with the CSF. Spatial contour plots of the scalp potentials above the eye-level were constructed.

3. Results

The plot of scalp potentials are given in Fig. 2. In all plots, the nose on the top and left side of the subject is the left side of the plot. The color intensity scale is in mV and is same for all three plots. The left plot is for the model where the conductivity of the dura layer was set equal to the CSF conductivity and the middle plot is for the model where the dura layer was included. The differences of scalp potentials for the two models are shown in the right plot. These plots show that the inclusion of the dura layer significantly reduces the scalp potentials. In the top portion of the left plot, the peak value is 21.2 mV at the coordinates (57, 110). At the same location in the middle plot the value is 15.1 mV. Thus, the inclusion of the dura layer has reduced the amplitude of the scalp potential by 29% at this location. At other locations the changes varied between 0.0 to 29%. Overall, one can conclude that the inclusion of dura layer significantly changes the simulated EEGs.

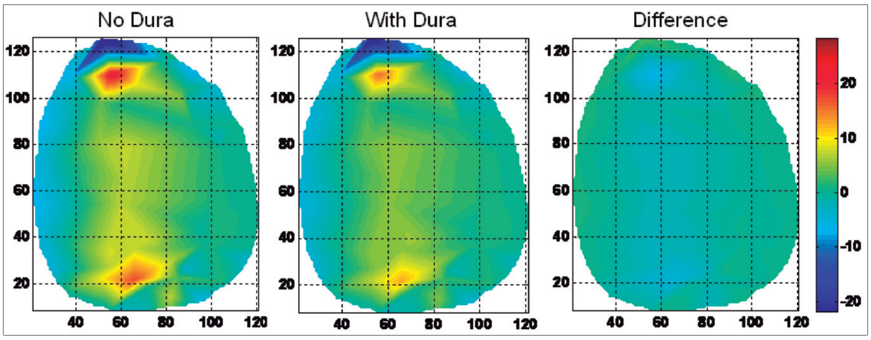

Fig. 2. Plot of scalp potentials. (Left) model in which the dura layer was replaced with CSF; (middle) model that contained dura layer and (right) difference of the two plots. The color intensity scale is in mV and is same for all three plots. In general, the inclusion of dural layer in the FEM model severely reduces the magnitude of the scalp potentials as shown in the middle plot.

4. Discussions

These are our preliminary results on the effect of inclusion of dura layer in finite element method models to simulate scalp potentials. These results suggest that the dura layer should be included in human head models for accurate simulation of scalp EEGs. This is also important for accurate reconstruction of the sources in the brain from the inversion of the scalp EEG data. Here we have used only 120 dipoles randomly distributed in the upper portion of the cortex to examine the effect of dura layer. It does not represent the spontaneous or cognitive electrical activity of the brain. The research should be further extended by representing the electrical activity of the brain with a large number of dipoles. However, we believe, that effect of the dura layer will still yield similar results. This research is in progress and we plan to present a detailed report in the near future.

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