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Importance of including anisotropic conductivities of grey matter in EEG source localization

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Abstract

Electroencephalogram (EEG) dipole source localization is a usefull tool in the diagnosis of patients suffering from epilepsy. The anisotropic conductivities of brain tissues are still subject to investigation. The anisotropic conductivities can be derived from diffusion weighted imaging. These images show that not only white matter has anisotropic properties, but also grey matter. In this study we want to investigate the dipole estimation errors due to neglecting anisotropic conductivities of grey matter. The results showed that the dipole location error was on average 2,1 mm with a maximum of 9,6 mm, while the dipole orientation error had a mean of 5,2 degrees with a maximum of 40,2 degrees. Conclusions are that compared with estimation errors due to neglecting skull anisotropy or white matter anisotropy, these estimation errors are small. Hence the effect of grey matter anisotropy is negligible.

1. Introduction

Electroencephalogram (EEG) dipole source localization has been proven its usefulness in the presurgical evaluation of patients suffering from epilepsy. The problem can be subdivided into two problems: (1) by solving the forward problem we obtain the electrode potentials given a dipole source in a specific head model, (2) by solving the inverse problem we estimate the optimal dipole components that minimize the difference between the electrode potentials measured at the scalp and those provided by solving the forward problem.
Head models with isotropic conductivities are typically used. In reality the skull, white matter and grey matter have an anisotropic conductivity. The anisotropic conductivities can be derived from diffusion weighted images [1]. The images show that there is diffusion in the white matter, but also in the grey matter[2]. Although the fractional anisotropy is lower than that of white matter regions, still it would be worthwhile investigating the dipole estimation error due to not incorporating the anisotropic conductivities of grey matter.

2. Methods

Head model: The head model was constructed by segmenting a T1 MR image (see figure 1). The anisotropic conductivity of the skull was set 10 times larger in the tangential direction than in the radial direction. The anisotropic conductivity in the white and grey matter was derived from diffusion weighted MR images. The direction facilitating the diffusion of water is also the one with the highest conductivity. The anisotropic conductivities of skull, white matter and grey matter were derived from the isotropic conductivity according to the volume constraint [1].

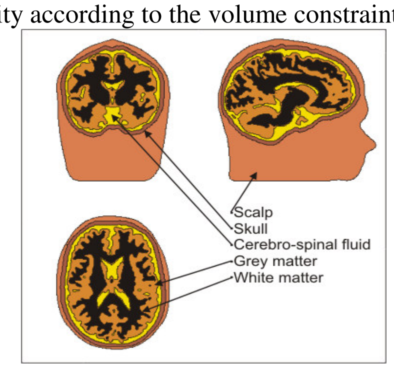

Figure 1: an illustration of the realistic head model used in this study. An axial, coronal and sagital slice is shown.

Forward problem: The forward problem is calculated using a finite difference method where anistropic conductivities can be incorporated using tensor calculus [2]. In an XY-, YZ- and XZ-plane, we placed 3 dipoles (along the X-, Y- and Z-axis) in each voxel belonging to the white and grey matter of the brain.

For each dipole the forward problem was solved in a head model with anisotropic conducting skull, white and grey matter compartments. This resulted in a set of electrode potentials.

Inverse problem: The electrode potentials were then used to solve the inverse problem in a head model where the conductivity of grey matter was set isotropic. This resulted in a new dipole localization and orientation estimate. By taking the Euclidian distance between the estimated dipole and the original dipole, the dipole localization error was investigated due to neglecting the anisotropic conductivity of grey matter. The angle between the estimated and original estimation, denotes the dipole orientation error due to not taking into account anisotropic grey matter anisotropy. A schematic of the simulation setup is shown in figure 2.

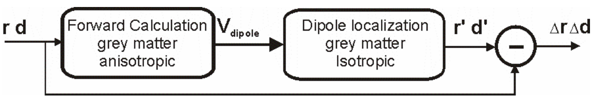

Figure 2: a schematic of the simulation setup. A dipole at position **r** and with components **d** is placed in a head model with grey matter anisotropy. The result of a forward calculation is then used to estimate the dipole sourc in a head model with isotropic grey matter. Using the dipole location error and orientation error, the importance of grey matter anisotropy can be quantified.

3. Results

In figure 3 we can see that the dipole location error due to neglecting the conductivities of grey matter is always below 1 cm. The average dipole location error was 2,1 mm and the maximum was 9,6 mm. In results not shown here, the large errors were found at the base of the brain compartment.

Figure 4 shows that the orientation error between the test and estimated dipoles was below 10 degrees in 90 % of the cases. The average dipole location error was 5,2 degrees with a maximum of 40,2 degrees.

4. Discussion and Conclusions

In this study we showed that the error due to neglecting the anisotropic conductivities of grey matter is very low. This is due to the fact that grey matter has a low fractional anisotropy, whereas in white matter the fractional anisotropy is bigger [3].

The large location errors were found at the base of the brain compartment. In a clinical setting, one is more interested in cortical grey matter area's, where the dipole estimation errors are very small. Therefore, we can conclude that the dipole errors due to neglecting the anisotropic conductivities of grey matter are negligible.

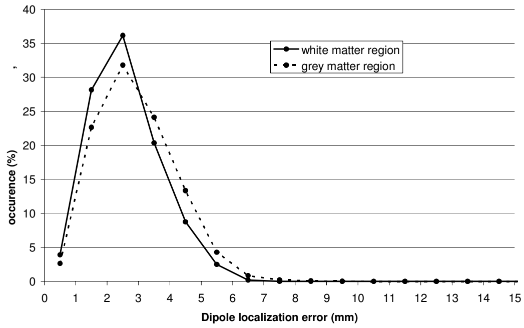

Figure 3: A histogram of the dipole location error due to neglecting anisotropic conductivities of grey matter when the test dipoles are placed in the white matter (solid line) and grey matter region (dotted line).

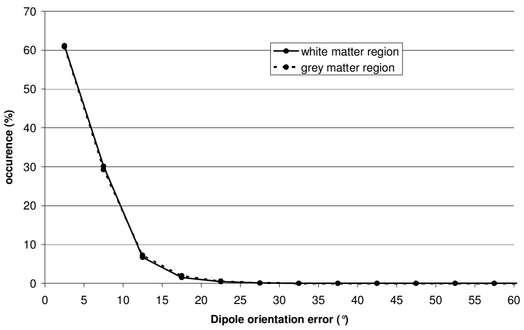

Figure 3: A histogram of the dipole orientation error due to neglecting grey matter when the test dipoles are placed in the white matter (solid line) and grey matter region (dotted line).

5. References

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