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Epileptic Source Localization: Deep Electrode Measurements versus Scalp EEG

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Abstract.

Intracranial recordings and scalp EEG are used with the source imaging techniques to determine the locations and strengths of the epileptic activity. As a source localization method, Low Resolution Electro-Magnetic Tomography (LORETA) is solved for the realistic geometry based on both forward methods, the Boundary Element Method (BEM) and the Finite Difference Method (FDM). Average current source densities are computed using BEM based LORETA scalp EEG and FDM based LORETA deep EEG spikes. Only one of the several sources of the FDM based LORETA method matches with the source obtained using the BEM based LORETA. FDM based deep EEG localization is more sensitive to the sources inside the brain.

Keywords: Deep Electrode, LORETA, BEM, FDM, EEG

1. Introduction

Epileptic source localization is a critical diagnostic step for an effective surgical or therapeutical planning. Since anatomical imaging techniques usually do not provide a diagnostic information about the location of the epileptic foci, the only way for localization remains to be the EEG and MEG based neuroimaging. Multichannel EEG recorded from the scalp surface provides a very valuable but indirect information about the source distribution. However, deep electrode measurements yield more reliable information about the source locations. BEM is a conventional approach for source reconstruction using surface EEG [Hamalainen and Sarvas, 1989]. When the deep electrode measurements are used, a better approach to use is the FDM because of its more precise electrode registration and forward modeling. In this study, the location of the epileptic foci of a subject are studied with i) BEM based forward modeling and scalp EEG and ii) FDM based forward modeling and deep electrode measurements.

2. Material and Methods

2.1 Preprocessing of MRI and EEG

In this study, a realistic head model is derived from T1 weighted MR images of the subject for the solution of the forward problem as shown in Fig. 1. The MR images, surface EEG data and the deep electrode measurements are obtained from the Department of Neurology, Brno Epilepsy Center, Czech Rebuplic. The human head is modeled as three homogeneous isotropic conductor layers; the outermost surface being the boundary for the scalp, the intermediate for the skull and the innermost being for the brain. Statistical Parameter Mapping software 2005 release (SPM05) which is developed by Wellcome Institute is used for 3-D segmentation of the brain, skull and scalp. After segmentation, the surfaces are triangulated in order to generate the realistic head model. Surfaces of the brain, skull and scalp are tesselated with 4000, 4200 and 4200 triangles respectively as seen in Fig.1a.

The sampling rates of the scalp and deep electrode EEGs are both 128 Hz. As epileptic discharge waveforms for the scalp EEG, 1150 spikes are selected by visual inspection of the C3 electrode. 1600 spikes are similarly detected from the deep electrode recordings.

19 channel electrode locations (Fp1, Fp2, F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, P8, O1, O2) are registered to the scalp surface by spline interpolation using the T1 weighted MR data and the inion, nasion coordinates. 105 contact points of deep electrodes are registered to the realistic head model as shown in Fig. 2.

2.2 Source Imaging

BEM is implemented on the realistic head model given in Section 2.1. FDM is computed only for the brain tissue because the deep electrodes are located inside the brain [Hallez et al, 2007] [Vanrumste et al, 2001]. Low Resolution Electro-Magnetic Tomography (LORETA) [Pascual-Marqui et al, 1994; Pascual-Marqui 1999] is solved for the realistic geometry based on BEM and also solved for the FDM. The grid size for both methods are taken as 4mm X 4mm X 4mm.

Inverse problem is solved using BEM based LORETA for the 1150 scalp EEG data individually and their average current source density is computed. The maximum value of this average map is determined as the source location. FDM based LORETA is applied to 1600 deep EEG spikes and their average current source distribution is computed. Several maxima of the average map are detected.

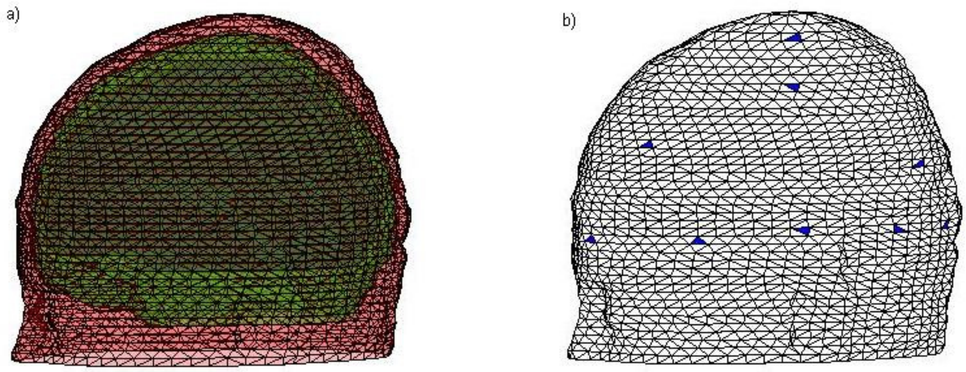

Figure 1. *a)The realistic head model formed by triangulated surfaces of the scalp, skull and brain tissues. b) 19 electrodes are registered to scalp surfaces. Blue colored triangles denote the electorde locations.*

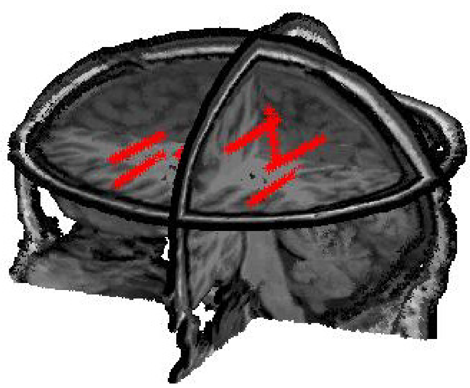

Figure 2. *Red points denote the contact points of the deep electrodes. Deep electrodes are placed to the left hemisphere of the brain.*

3. Results

BEM based source distribution of scalp EEG is given in Fig.3.b. Epileptic focus appears to be in the vicinity of the C3 electrode as a superficial activity. This result complies with the surface EEG topography as shown in Fig.4. FDM based source distribution of the deep EEG is given in Fig.3.a. Multiple sources are observed. Only one of these sources, which is also the weakest one, is close to the source obtained by the scalp EEG localization. The other sources are deeper and have higher strengths.

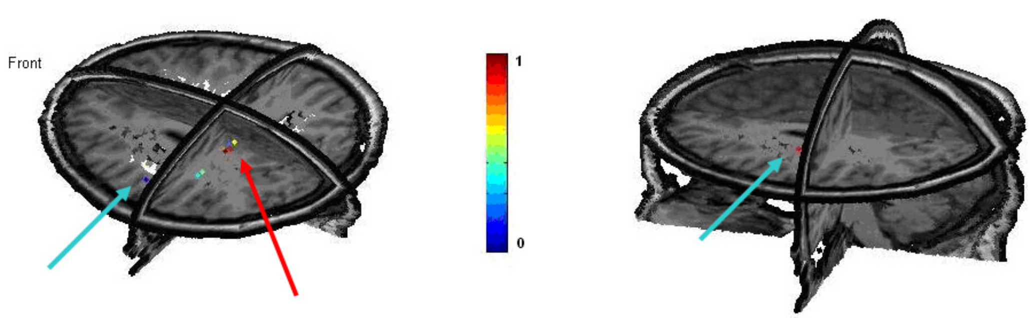

Figure 3. *a)The source locations obtained from the deep electrodes using the FDM based, b) from the scalp EEG using the BEM based LORETA approach, respectively.(Activity is normalized individually)*

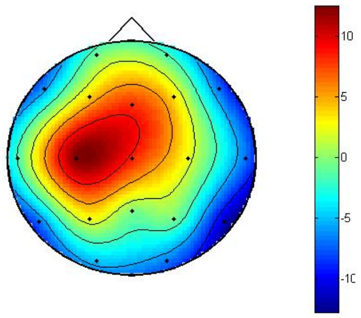

Figure 4. *Average Scalp EEG topography of the selected 1150 peaks.*

4. Discussion

105 deep electrodes provide a detailed information about the activity of the epileptic sources without a significant noise corruption and signal distortion. However, their exploitation as EEG data for the inverse modeling requires more precise registration and forward modeling. FDM gives us the opportunity to compute the electrical potential values inside the brain tissue within the millimeter resolution. Also FDM based deep EEG localization is much more sensitive to the sources inside the brain. We also observe that the weakest source among the multiple sources in Fig. 3.a. corresponds to the activity obtained from the BEM based surface EEG localization. It is well known that when we use the scalp EEG, LORETA has a poor sensitivity to the deep sources than to the superficial ones. The results indicate that using the deep electrode measurements even the deep sources can be captured by LORETA.

The simultaneous recording of the surface as well as the deep electrode EEG will enable us to investigate the possible sources of epileptic discharges in a more reliable way. The FDM can be implemented on a realistic head model which will exploit both the surface as well as the deep electrode data. Moreover, the anistropic conductivity deduced from the Diffusion Tensor Images (DTI) can be incorporated in the FDM.

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