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# Localization of Epileptic Foci by Means of Cortical Imaging using a Spherical Head Model

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## Abstract

A cortical imaging technique (CIT) with a three-sphere head model was used to estimate cortical potentials from scalp EEG recordings in 2 pediatric epilepsy patients. For patient #1, the cortical potentials during interictal spikes and seizure onset were estimated. For patient #2, the cortical imaging analysis was performed during interictal spikes. In all cases analyzed, localized areas of activity were observed, overlying with the epileptogenic zones, as confirmed by the post-operative ECoG recordings and neurosurgical resection in the patients. The present study suggests that CIT may provide a useful alternative for noninvasive localization of epileptic foci from pre-operative EEG recordings.

**(1000-words description – 949 words)**

## 1. Introduction

Long-term electroencephalogram (EEG) and video monitoring of epileptic patients is a well-established procedure in the diagnosis and management of epilepsy. It is of importance to accurately localize the sites of seizure onset to improve the surgical outcome and avoid neurological deficits from the surgical removal of lesion. Due to the volume conduction effect of the skull, the scalp EEG is severely smeared, not providing spatial details on the underlying brain electrical activity [2,4]. Electrocorticography (ECoG) has been employed for the direct inspection of the epileptogenic zone on the cerebral cortex. However, invasiveness, risk of morbidity, limited availability, and high costs of this technique limit its use in the clinical routine. It is highly desirable to significantly enhance the spatial resolution of the noninvasive scalp EEG, thus enabling the prediction of the location of epileptic foci from noninvasive scalp EEG monitoring.

A recently developed cortical imaging technique [3] can directly link the cortical potentials with scalp potentials by a lead field matrix. By solving the EEG inverse problem, the cortical potentials can be estimated from the scalp potentials with much enhanced spatial resolution, by compensating the blurring effect of the head volume conductor. In the present study, we examine the feasibility of noninvasive localization of epileptic foci from pre-operative EEG measurements by means of the cortical imaging technique.

## 2. Methods

## 2.1 Data Acquisition

Two pediatric patients with intractable seizures were included in the present study according to a protocol approved by the IRB of The University of Chicago. For each patient, the long-term vedio EEG monitoring was conducted in the Pediatric Epilepsy Center at the University of Chicago Children's Hospital. 24 channels' pre-operative scalp EEG was sampled at 400Hz and band-pass filtered from 1-100Hz. The scalp electrodes were uniformly distributed over the scalp according to the 10-20 system. The intracranial electrode pads were placed directly on the surface of brain, and post-operative ECoG was recorded for intracranial monitoring. The seizure onset from pre-operative EEG data were visually detected via simultaneous video recording, and were subjected for cortical imaging analysis.

## 2.2 Data Analysis

The cortical potential imaging algorithm used in the present study has been detailed in [3]. Briefly, the head volume conductor was approximated using an inhomogeneous three-concentric-sphere model, in which the radii of the brain, the skull, and the scalp spheres were taken as 0.87, 0.92, and 1.0, respectively. The normalized conductivity of the scalp and the brain was taken as 1.0, and that of the skull as 1/80. Each surface of the three spheres was discretized uniformly into 1280 triangle elements. The lead field matrix, which directly connects cortical potentials with scalp potentials, is calculated by the boundary element method [3]. By solving the inverse problem using zero-order Tikhonov regularization [5], the cortical potentials can be estimated from the scalp potentials, and the regularization parameter which is used to suppress the effect of noise, is determined by the L-curve approach [1].

## 3. Results

Patient #1 is a 7 year-old girl with intractable seizures. Her intracranial monitoring suggests epileptogenic zones being in the right medial temporal lobe, and a small area in the right posterior temporal-parietal lobe. The outcome of subsequent neurosurgical resection confirmed the epileptogenic zones. The present cortical imaging analysis performed on both interictal spikes and seizure onset clearly revealed localized areas of negativity overlying with the right medial temporal lobe and the right posterior temporal-parietal lobe, which are consistent with the findings of post-operative intracranial recording and surgical resection. It is of interest that in this patient the two areas of negativity localized by the present cortical imaging analysis were consistent for both the interictal spikes analyzed and the seizure onset. Notably, the scalp EEG map shows widely distributed pattern not revealing the spatial details on the underlying multiple epileptogenic zones, as compared with the cortical potential map.

Patient #2 is an 8-year-old girl with intractable seizure. Cortical imaging analysis was performed during interictal spikes in this patient. Areas of negativity were observed, which overlie with the epileptogenic zone on the left temporal lobe, which is consistent with the post-opeartive recording and confirmed by the surgical resection.

## 4. Discussion

In this pilot study, we have applied the boundary element method based cortical imaging technique to estimate the epileptic foci from pre-operative EEG recordings in two seizure patients. Enhanced spatial resolution has been achieved by the estimated cortical potential maps as compared to the blurred scalp potential maps, thus fascilitating noninvasive localization of the seizure foci. Promising results have been obtained in the present study, in that the estimated cortical potential maps revealed localized epilepti foci overlapping with the clinical findings and confirmed by the surgical resection. More accurate inverse estimation is expected to achieve by employing more scalp recording electrodes, and by using realistic geometry head model constructed from each patient's MR images. Nonvertheless, the promising results obtained from the present pilot study strongly suggests that the cortical imaging technique may become a useful alternative tool for non-invasive localization of epileptic foci from pre-operative EEG monitoring.

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