# Localization of Epileptic foci from EEG data

This document introduces the electrophysiological localization of epileptic focus on the MRI of the patient based on the EEG and the use of realistic head models to be used, together with other techniques, in the pre-surgical evaluation of epilepsy.

For additional information see also the companion documents:

*Head_model_example.pdf*: Example of application illustrating the head model construction and its application in a patient with temporal lobe epilepsy.

*Head_model_algorithm.pdf*: Detailed description of the standard procedure (as used in our lab) to construct the realistic head model allowing the source localization procedure in the subject MRI image. Mainly of interest for methods oriented people.

## Introduction[1]

Epilepsy surgery is probably the only alternative and established treatment in pharmacoresistan focal epilepsies and the so-called cryptogenic focal epilepsies. However, before considering this treatment a pre-surgical evaluation to assess the feasibility of the surgical procedure should be considered. In brief, the decision is based on the following points:

a) The medical history (e.g. ictal and interictal symptoms).
b) Functional deficits as well as the possible output deficits associated to the surgery procedures.
c) Assessment of the patient's psychiatric state.
d) The anatomical location and the electrophysiological localization.

On this document we considered techniques to localize the epileptic focus on the anatomical MRI of the patient with high precision as requested for last point (d). In particular we propose the use of a new method (EPIFOCUS) developed at the Functional Brain Mapping Lab of the Geneva University Hospital[2]. The location found with EPIFOCUS might correspond with one of the cortical zones related with the epileptic activity, that is, the irritative zone[3] or the seizure onset zone[3] from which clinical seizures are actually generated and closely related with the epileptogenic zone[3]. For the localization we can use (average) spikes or any other type of surface EEG (derived) data associated with previously described zones.

## What is EPIFOCUS:

Summarizing **EPIFOCUS** offers the following three main advantages:

1) High **accuracy** in the localization of focal sources.

2) Very **simple** implementation for arbitrary head models and in particular for realistic head models derived from subjects MRI.
3) **Fast** computation of the source location associated with any EEG (or derived) data in the time or the frequency domain.

EPIFOCUS is a linear source localization method aimed to the accurate estimation of focal sources as appear in several epileptic data. The accuracy of this method is provided by the mathematical know-how used in its development, that is, somehow similar to some dipolar methods EPIFOCUS detect the focal sources (punctual or not) by projecting the data on a new solution space where orthogonal projectors have increased localization power. For mathematical details see Grave et al. 2001[2].

## Mathematical Validation of EPIFOCUS

This method has been extensively evaluated using theoretical models with and without noise. Grave et al. 2001[2], and Grave and Gonzalez 2002[4] demonstrated that EPIFOCUS is an efficient alternative for the accurate localization of focal sources compared with all the linear inverses explored so far in the same configuration, and for both cases: clean and noisy data. The performance in the analysis of real data was illustrated for two patients[4] remarking the advantages over other linear solutions as the Weighted Minimum Norm.

A more recent work[5] demonstrated that high accurate localization can be obtained already with relatively low density electrode arrays, i.e., that zero dipole localization error is already possible for 60 electrodes. The zero dipole localization error is also illustrated in Grave and Gonzalez 2002[4].

## Physiological validation of EPIFOCUS with clinical data

In Lantz et al.[6] EPIFOCUS was physiologically evaluated using simultaneous surface and depth recording corresponding to four types of epileptic activity identified by intracranial recordings on the temporal lobe. In spite of the low number of surface electrodes (33) EPIFOCUS was able to significantly differentiate the location of the four groups inside the temporal lobe in contrast with dipolar or minimum laplacian methods that failed with the same data.

In another work[5], 14 epileptic patients were studied using different electrode configurations confirming that the accurate localization is already possible with 63 electrodes. For other applications of the method see Lantz et al. 2001[7].

The localization accuracy of EPIFOCUS motivated it use to study the relationship between interictal epileptiform activity and the epileptogenic zone presented in 16 epileptic patients as presented in Lantz et al. 2003[8].

The interrelationship between all the cortical zones and the localization obtained by source localization algorithm is not straightforward. It depends upon the type of data we use (i.e. where are the sources responsible for the EEG data recorded) and the

anatomical location and extension of each cortical zone. For that reason to evaluate the performance of our source localization algorithm we evaluated the distance from the brain site identified by EPIFOCUS and the resected region. The following figure depicts the case of 19 patients operated and seizure free. For a detailed description of this study see Michel et al. (2003)[9] that included 23 patients and several modalities (PET, SPECT, MRI, etc).

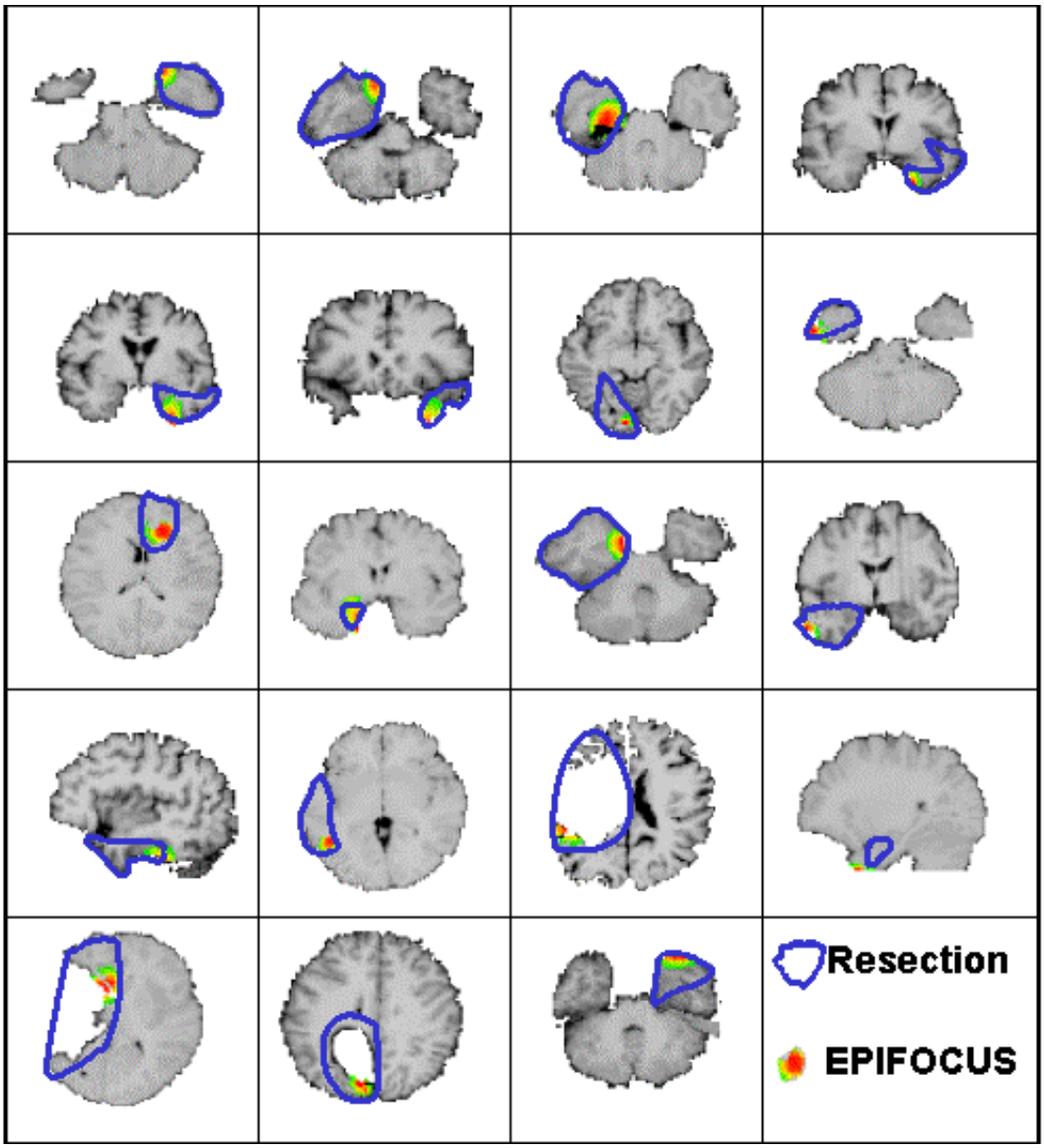


**Figure 1.** Comparison of EPIFOCUS source localization using averaged (EEG data) spikes and the resected areas for 19 epileptic patients operated and seizure free.

[1] Pre-surgical evaluation for epilepsy surgery- European Standards. European Federation of Neurological Societies Task Force. / Prof. Hermann Stefan, Erlangen, Germany.

[2] Grave de Peralta, R. Gonzalez, S.L. Lantz, G. Michel, C.M. Landis, T. Noninvasive localization of electromagnetic epileptic activity. I Method descriptions and simulations. Brain Topography 2001. Vol 14, Number 2, p:131-137.

[3] Rosenow, F. and Lüders, H. Presurgical evaluation of epilepsy. Brain, 124,1683-1700. 2001.

[4] Grave de Peralta, R. and Gonzalez Andino S. Comparison of algorithms for the localization of focal sources: Evaluation with simulated data and analysis of experimental data. International Journal of Bioelectromagnetism, 2002. http://www.ee.tut.fi/rgi/ijbem/volume4/number1/toc.htm

[5] Lantz, G. Grave de Peralta, R. Spinelli, L.Seeck, M. Michel, C.M. Epileptic source localization with high density EEG: How many electrodes are needed?. *Clin. Neurophysiol.*, 114, 63-69. 2003.

[6] Lantz, G. Grave de Peralta, R. Gonzalez, S. Michel, C. M. Noninvasive localization of electromagnetic epileptic activity. II. Demonstration of sublobar accuracy in patients with simultaneous surface and depth recordings. *Brain Topography*, 14, 139-147, 2001.

[7] Lantz G, Spinelli L, Grave de Peralta R, Seeck M, Michel CM. Tomographie électrique en épilepsie : localisation de sources distribuées et comparaison avec l'IRMf. *Epileptic Disorders*, 3, 2001.

[8] Lantz, G, Spinelli' L, Seeck, M, Sottas' CC, Michel, CM. Propagation of interictal epileptiform activity can lead to erroneous source localizations: A 128 channel EEG mapping study. Accepted for publication 2003.

[9] Michel C.M. et al. In preparation 2003.