

# Epileptic Seizure Localized by Whole Head MEG

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## 1 Introduction

Magnetoencephalography (MEG) is currently used clinically for presurgical localization of epileptic tissue, based on signals from interictal spikes, using single equivalent current dipole (ECD) modeling [1,2,3,4]. There has been a long-standing question "Do interictal spikes co-localize to the same area as epileptic seizures?"

Minassin, et al. found that the interictal MEG localization of spikes corresponded to ictal zones mapped by the ECoG in ten of eleven patients [5]. MEG was able to map interictal activity equally well as intracranial electrodes (ECoG). This suggests that the localizing information obtained by the invasive intracranial monitoring may also be available by noninvasive MEG.

Mappings of epileptic seizures by MEG are rare since patient movement typifies most seizures, and localizing brain activity after the patient moved is not accurate. In one study, performed by Ko et al. [6], in which an epileptic seizure was monitored by MEG, the data was compared to EEG localizations. The MEG data localized the active source more mesial in the temporal lobe than the EEG. The mean difference in localization between MEG and EEG interictal spikes was 2.1 cm (patient 1) and 3.8 cm (patient 2). The mean difference in localization between the ictal and the interictal data from EEG was 3.5 cm (patient 1), whereas the mean difference in localization between the ictal and interictal data from MEG was 1.8 cm, (patient 2). That study suggests that the MEG may be more reliable in comparing the interictal spikes with the ictal spikes.

We report a case study of localization of MEG data from both interictal spikes and an epileptic seizure captured by MEG in the same subject.

## 2 Methods

### 2.1 Patient study

A male patient (27 years old) with complex partial and secondarily generalized seizures was monitored with 148 channel Neuromagnetometer (4D Neuroimaging Magnes WH2500) and 21 channels of EEG. This patient has persistent intractable localization-related epilepsy despite two previous left frontal lobe resections.

The patient changed into a hospital gown and removed all metal articles from his body, except for dental work, which was adequately demagnetized with a commercial videotape eraser. Three small electrode coils, used to transmit subject location information to the neuromagnetometer probe were taped to the forehead with two-sided tape. Disposable ear molds of the correct size were placed in the ears and an additional localization coil was attached to each ear mold. The EEG electrodes were applied with collodion adhesive using the International 10-20 system of measurement. Impedances of all electrodes were below 5000 ohms. The montage used for recording during the MEG study was a P<sub>z</sub> reference montage.

The subject lay comfortably on the bed inside of the Magnetically Shielded Room (MSR), and automatic probe position routines were used to locate the head with respect to the neuromagnetometer detector coils. The neuromagnetometer helmet containing the detector array was then placed over the patient's head, in close proximity to most of the cortical surface. He was instructed to keep his head as still as possible. His face was visible via video camera image and there was intercom communication available between the technologist and the patient in the shielded room.

## 2.2 Data Collection

Parameters for both MEG and EEG recordings were: low pass filter - 100 Hz; high pass filter - 0.1 Hz; data was digitized at 290.64 samples per second.

Two 10 minute and one 5 minute continuous acquisitions were recorded. Visual inspection of the patient's face and of the MEG/EEG real time recording was done. During the 5-minute acquisition, a seven-second period of seizure activity was recorded by MEG and EEG. The patient demonstrated one of his typical partial seizures characterized by a staring spell with eyes wide open but with no body movement. Somatosensory evoked field studies were also recorded.

## 2.3 Data Analysis

Single ECD software [1,2] was used to localize the source of activity for both interictal spikes and the seizure onset. Waveforms were inspected visually after data was filtered with a bandpass of 3-100 Hz and a notch filter at 60 Hz. Selected interictal spikes and spikes occurring during the seizure were mapped using a single equivalent dipole model. A single dipole was selected to represent each sharp wave. The dipole selection criteria [4] included:

- 1) Correlation coefficient (R) of 0.98 or better
- 2) Root Mean Square (RMS) value of waveforms across all channels of 400 fT or more
- 3) Dipole moment (Q) generally of less than 400 nAm
- 4) Confidence region (CR) of less than  $3\text{cm}^3$ , preferably less than  $1\text{cm}^3$ .

In general, the ECD was selected from the initial onset of the spike waveform up to the point of maximum amplitude of the spike. The dipole calculation was performed using 64 magnetometer channels which were chosen to best represent the contour plot of the magnetic field.

## 3 Results

The single ECD technique localized the source of activity for both interictal spikes and seizure onset. Interictal spikes were selected from the data prior to the epileptic seizure. Waveforms in Figure 1 show the start of the 5 Hz activity which is the onset of the seizure at 93.56 seconds. Both interictal and ictal sources were localized in the left frontal region, approximately 2.2 cm apart as seen in Figure 2.

The parameters for both the seizure and interictal spikes had similar values and had high correlations and confidence regions (CR) under  $2\text{cm}^3$ . RMS values were twice the Q values and over 400 fTesla. Table 1 lists the dipole fit parameters for early latencies of the epileptic seizure and representative interictal spikes.

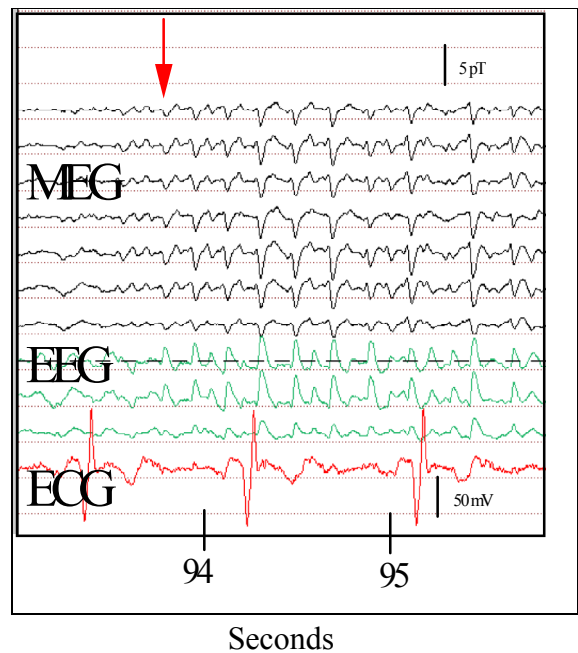


Figure 1: The MEG and EEG wave forms for epileptic seizure. Red arrow denotes onset of seizure activity.

The epileptic seizure began with an initial sharp wave arising in the left precentral gyrus (Fig 2B). The next several sharp waves arose anteriorly towards the surgical margin from the previous left frontal lobe resection where the sharp waves and spikes from the seizure clustered in tight formation. The center of activity for the interictal spikes was also located

in the anterior portion of the left inferior frontal gyrus (Fig. 2). Both ictal and interictal activity co-located in the left inferior frontal gyrus, but centers of activity were approximately 2.2 cm apart. The source of the seizure activity was

more focal than that of interictal spiking and located more mesial to the surface of the cortex along the edge of previously resected cortical tissue. The edges of the previously resected tissue are seen in the MRI scans. Multiple source analysis also located the source of activity in this same region [7]. The MRI scans on the left side of Figure 2 display the interictal localizations; the scans on the right of Figure 2 display the seizure localizations.

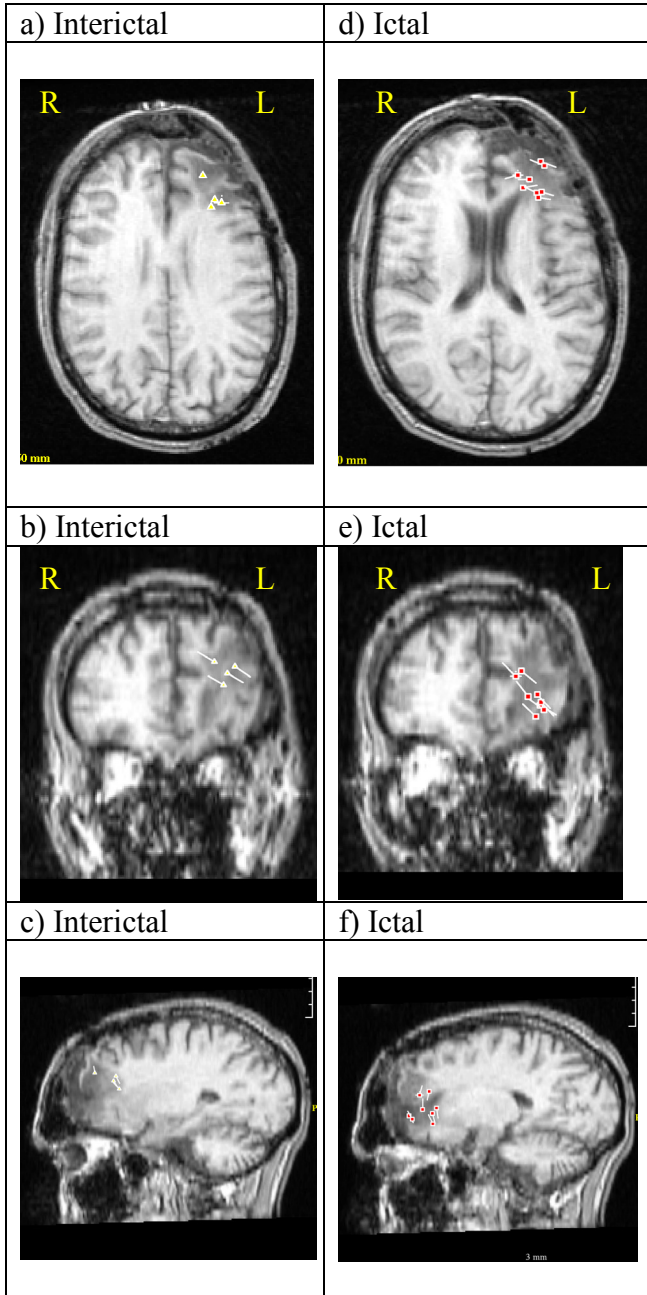


Figure 2: Interictal spike localization (yellow triangles): **a**, axial; **b**, coronal; **c**, sagittal. Ictal seizure localization (red squares): **d**, axial; **e**, coronal; **f**, sagittal.

Table 1: *The dipole fit parameters for interictal epileptic spikes.*

Interictal Latency	RMS fTesla	GoF	Corr.	Q nAm	CR cm <sup>3</sup>
166.93	98.73	0.93	0.97	216.93	0.59
174.33	80.49	0.96	0.99	132.93	1.03
505.65	48.73	0.95	0.98	91.61	1.83
512.30	58.46	0.97	0.98	117.64	0.45

Table 2: *The dipole fit parameters for ictal epileptic spikes.*

Ictal Latency	RMS fTesla	GoF	Corr.	Q nAm	CR cm <sup>3</sup>
93.56	738.93	0.87	0.89	193.90	0.91
93.68	697.59	0.94	0.93	220.47	0.74
93.79	1073.10	0.94	0.96	316.01	0.45
93.85	799.68	0.91	0.97	173.35	1.12
93.92	678.33	0.97	0.96	243.67	1.25
93.95	1474.80	0.95	0.97	335.20	0.18
94.12	1531.20	0.94	0.93	597.75	0.18
94.18	946.93	0.96	0.96	363.16	0.41

#### 4 Discussion

The question of whether interictal spikes should be used as the basis for determining the areas of resecting cortical tissue is unresolved. In the present case, the zone of ictal onset was smaller than the zone of interictal activity. The seizure activity was at the edge of the previously resected tissue, more mesial to the cortical surface than the interictal spikes. As more MEG systems come into use, the likelihood of co-localization of the epileptic tissue for seizure and interictal spikes will increase.

## References

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