

Localizing Value of Ictal MEG in Neocortical Epilepsy

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While MEG mapping of interictal spikes has been found to be useful for presurgical localization of epileptic foci [1,2,3], seizures have rarely been captured in MEG recordings. We have recorded seizures by MEG in 8 patients, 7 to 47 years old, with intractable localization-related epilepsy of presumed neocortical origin. Four of the eight have had resective surgery. Prior to surgery each of the four patients was averaging up to 6-40 seizures per day. Ictal MEG localizations were confirmed by subsequent intracranial EEG monitoring. One patient had a left frontotemporal lobe resection, one had a left temporoparietal resection sparing part of the epileptic focus, which was in language cortex, one had a left paracentral lobule resection, and one had a right frontal operculum resection. All four have had a dramatic improvement in seizures with simple partial seizures but no complex partial or secondarily generalized seizures in two, and only two seizures in the past year in the third. The fourth patient has not had a seizure in the 4 months since her surgery. Two of the four other patients are scheduled for intracranial monitoring, and the third has declined surgery. The fourth had simple partial seizures arising from the primary motor cortex and has had a subdural electrode array implanted for chronic direct neocortical stimulation with subsequent reduction in seizures. Ictal MEG in these patients has accurately predicted the site of ictal onset in those who have had intracranial monitoring. Resection of the MEG ictal zone has been associated with good surgical outcome in those patients. Ictal MEG is useful in determining the site of implantation of intracranial electrodes. Ictal MEG and concordant noninvasive diagnostic studies may some day replace intracranial EEG monitoring in selective patients with neocortical lesions.

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]. Little has been written about the localizing value of seizures recorded by MEG [5,6,7].

Mapping of epileptic seizures by MEG is rare since most MEG recordings last less than 1 hour, an insufficient amount of time to record a seizure in most patients. Even if a seizure is recorded, the seizure must be a partial seizure which does not produce movement that would result in shifting of the head in the MEG helmet to the degree that would interfere with localizing brain activity by MEG.

2 Methods

2.1 Patient study

Eight patients (7-47 years old) with intractable localization-related epilepsy of presumed neocortical origin were monitored with 148 channel Neuromagnetometer (4D Neuroimaging Magnes WH2500) and 31 channels of EEG and an ECG.

Each patient changed into a hospital gown and removed all metal articles from his/her 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 and side of head 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_z or O_z reference montage.

The subject laid comfortably on the bed inside of the Magnetically Shielded Room, 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. The patient was instructed to keep his/her head as still as possible. The patient's 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 508.63 samples per second.

MEG recordings of at least thirty minutes were performed on each subject. Continuous acquisition of MEG and EEG was recorded in epochs lasting up to 10 minutes. Visual inspection of the MEG/EEG real time recording was done. Seizures during which patient head movement was minimal and did not invalidate head position measurements were analyzed.

2.3 Data Analysis

Single ECD software [1,2] was used to localize the source of activity for both interictal spikes and 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 ECD model. A single ECD fit was selected to represent each sharp wave. The dipole fit 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 volume (CV) of less than 3cm^3 , preferably less than 1cm^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 calculations were performed using 35-45 magnetometer channels which were chosen to best represent the contour plot of the magnetic field. For patients undergoing phase II monitoring and surgery, the zone of ictal onset by MEG and other modalities was compared.

3 Results

The single ECD technique localized the source of activity for seizure onset to a small region in each of the eight patients. In the five patients who have had intracranial monitoring, seizures were very frequent averaging up to 6-40 seizures per day. Neuroimaging studies were variable. Two of the patients had normal MRI studies. One of the two had resection of normal right frontal lobe operculum and has not had a seizure in the four months since surgery. The other patient with a normal MRI had simple partial seizures arising from the right primary motor cortex presumably due to measles encephalitis as a child and a resection could not be performed. Instead, a subdural electrode array was implanted for chronic direct neocortical stimulation with subsequent reduction in seizures. Three others who have had resections have had lesions on MRI. One had a large area of cortical heterotopia and had a left temporoparietal resection sparing part of the epileptic focus, which was in language cortex. He has had auras but no disabling seizures in the 8 months since surgery. One patient had generalized atrophy, left greater than right, on MRI from a suspected perinatal

hypoxic ischemic event. She had a left frontotemporal lobe resection and has had only simple partial seizures in the past year. One patient had cortical dysplasia in the supplementary motor area and had a left paracentral lobule resection. She has had two seizures in the past year.

4 Discussion

The role of MEG in presurgical evaluation of patients with focal epilepsy has focused upon the reliability of interictal spikes to predict the zone of ictal onset. The localizing value of seizures recorded during MEG studies, ictal MEG, has received little attention because of the inherent difficulties in completing this type of study. Limiting factors in obtaining an ictal MEG include the likelihood of actually capturing an ictal event in a restricted time frame, and degradation of a recording when the clinical semiology a patient exhibits results in movement in the neuromagnetometer. If these limitations are minimized a quality MEG study may be obtained.

Many patients with intractable epilepsy of presumed neocortical origin have frequent seizures or have clusters of seizures. The frequency of these partial seizures combined with an ictal onset that does not result in significant head movement in the gantry may result in a valuable MEG study. If the seizures do result in a degraded study because of movement, pharmacological intervention may be considered to limit movement. Subsequently, even if no seizures are recorded, the interictal information gained is useful in determining the sites for implantation for prolonged intracranial EEG monitoring.

The findings in this small series raise the possibility that ictal MEG may noninvasively provide key localizing data in nonlesional patients. Many patients with intractable epilepsy of presumed neocortical origin have frequent seizures or have clusters of seizures. In this population, surface EEG studies, including prolonged video/EEG inpatient monitoring may have limited localizing value. Future studies may support that ictal MEG and concordant noninvasive diagnostic studies provide adequate localizing information of an epileptogenic zone. Its present role in this population is to assist in determining hypothetical sites of epileptogenicity requiring intracranial coverage. In the future, selected patients may be able to bypass intracranial implantation with this data. As with EEG monitoring, the value of a single seizure recorded with MEG does not exclude the possibility of a multifocal process.

Literature

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