Motor evoked response (MER) measured by MEG Utilizing MR-FOCUSS

Arcila-Londono X., [1], Bowyer S.M., [1,2,3], Mason K.M., [1], Moran J.E., [1], Tepley N., [1,2] and Barkley G.L., [1,3]
[1]Henry Ford Health System, USA; [2]Oakland University, USA; [3]Wayne State University, USA.

ABSTRACT

MER cortex can be identified by direct cortical stimulation. Therefore, in this initial study, we set out to determine the current density mapping response using MR-FOCUSS in control subjects and patients with epilepsy. This paper suggests that a current density mapping of MER may be more useful to neurosurgeons.

KEY WORDS Motor Evoked Response, MER, MEG, MR-FOCUSS

INTRODUCTION

There are various techniques that have been used successfully used in localizing the motor cortex, including Functional MRI [Beisteiner, 2001], Magnetic Resonace Axonography [Kamada, 2002] PET [Meyer, 2003] and MEG [Pederson , 1998]. MEG and a neuronavigational system have been used to determine the validity of the ECD localization technique for Motor mapping with MEG, where the preoperative magnetic source imaging was comparable to Electrophysiological Cortical mapping (ECM) during neurosurgery [Schiffbaur, 2002]. Those findings indicate that MEG can localize the motor cortex accurately, helping in Neurosurgical planning to avoid or decrease Neurological deficits post-procedure. To date most MEG studies have used ECD localizations. Recently a paper was published utilizing a current density mapping technique to localize the Motor Evoked Field 100 ms after electromyographic onset (MEF1) [Woldag, 2003]. MEF1 is associated with the onset of muscle movement and is usually contaminated with movement artifact. It was found that localization of MEF 1 was similar in active and passive movements: "in the region of central sulcus, directed slightly toward the precentral cortex". That establishes the localization of the readiness potential.

In contemplating the use of MEG localization information on presurgical epilepsy patients, the volume of the involved tissue is of interest to neurosurgeons. When identified, ECDs are overlaid on an MRI image, they may be misleading if the symbol locating the ECD represents a large CV. Therefore, we set out to determine if current density mapping with MR-FOCUSS is a more suitable imaging technique for brain mapping of motor cortex and investigated its routine use for the evaluation of this data. In the present study we localized the MER using an evoked finger tapping paradigm in patients with medical refractory partial epilepsy and control subjects recorded with MEG.

METHODS

Eight control subjects (4 male, 4 female) and 11 patients (7 male; 4 females) ages 7 to 60, with medical refractory partial epilepsy were monitored with 148 MEG channels (Magnes WH2500, 4D Neuroimaging). Each subject changed into a hospital gown and removed all metal articles from his/her body, except for dental work, which was demagnetized with a commercial videotape eraser. Subjects with metallic or electrical device implants were excluded. Three small coils, used to transmit subject location information to the neuromagnetometer probe, were taped to the subject's forehead with two-sided tape. One coil was located in the center of the forehead and one coil on each side, approximately 2 cm apart. Disposable ear molds of the correct size were placed in the ears and an additional localization coil was attached to each ear mold. The subject then lay 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 subject's head in close proximity to most of the cortical surface. The subject was asked to avoid both eye and body movements during data collection. Changes in the subject's position during the study were detected by changes in magnetic field locations from the coils on the forehead and ears. Runs during which the subject moved more than 0.8 cm were repeated. Data were digitized at 509 samples per second from 0.01 Hz to 100 Hz. The subject pushed a button every time he/she heard the word "on". Button pushes were performed with the middle digit. Eighty trails were averaged together to create one evoked set of data. This was performed twice on each hand.

Data analysis was carried out utilizing MR-FOCUSS [Moran, 2001] to determine location and amplitude of the cortical responses of each individual during task performance. Localizations were mapped on to each subject's MRI image. If the subject did not have an MRI scan, localizations were mapped on to a standard MRI data set of images, rescaled to fit each subject's digitized head shape [32, 33]. All MEG data was forward and backward filtered 1-50 Hz. For each subject the latency (in ms), location (x, y, z coordinates) and average amplitude of response (nAm/time point) were extracted from the MR-FOCUSS imaging results during each motor process step. The cortical regions of interest identified included: Primary and supplementary cortical areas for the motor cortex and somatosensory cortex, activation and any significant activation before or after each of these steps.

RESULTS

In our patients with focal epilepsy, the MER in 8/10 localized to the contralateral precentral gyrus. Figure 1 displays the MER localization in the in the contralateral precentral gyrus in a patient with epilepsy during a right handed finger tapping. Of the 2 that did not localize in the contralateral precentral gyrus the first was a 40 year old female patient with focal epilepsy that localized to the ipsilateral (right) precentral gyrus in both runs of right finger tapping. Her epileptic discharges were in the left fronto/parietal lobe and her seizures were associated with right arm flexion. The second was a 27-year-old male with maximal response to left hand finger tapping in the contralateral postcentral gyrus in the first run. In the second run with the same finger he had maximal response in the precentral gyrus, which also extended to the postcentral gyrus on the same side. His seizures were seen in the frontal lobe near the midline. It was not uncommon to find submaximal response in the extended area surrounding the motor cortex, such as the postcentral gyrus and middle frontal sulcus.

In our control subjects, the MER localize to the contralateral precentral gyrus in all eight. There was also submaximal response in surrounding areas, but not as widespread as with our patients with focal epilepsy.

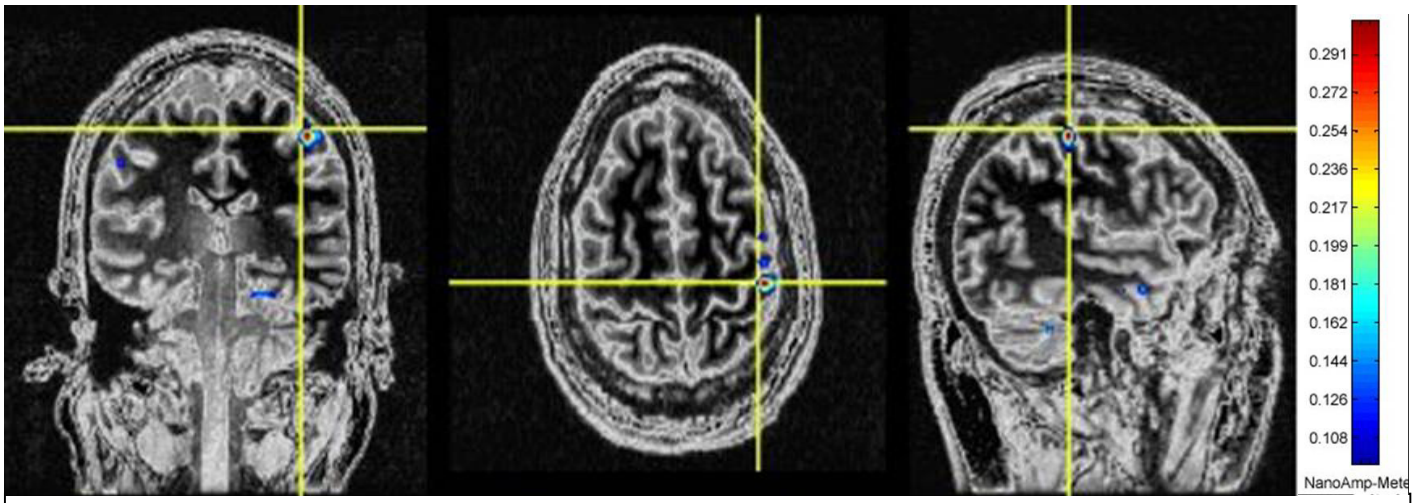

Figure1. Motor localization in the contralateral precentral gyrus in a patient with epilepsy during a right handed finger tapping.

DISCUSSION

Our goal for the last few years has been to develop ways, to measure motor response without having to resort to invasive techniques like electrocorticography. Some techniques have been useful for good temporal resolution, like somatosensory evoked potentials (from which MER is inferred), and EEG (which cannot be readily correlated with MRI). There is difficulty with functional MRI in localizing the MER if it is close to vascular lesions. SPECT and PET provide good spatial resolution, but involve radiation exposure.

In contrast, MEG measures the magnetic field produced by intracellular neuronal activity. When using ECD, it is difficult to localize the motor cortex. This technique's results represent the "center of gravity" of the source, and which is useful with stationary, non-dynamic sources (unlike movement itself). MR-FOCUSS, on the other hand is insensitive to noise and can differentiate between levels of activation. With this technique, we were able to localize the motor cortex both in patients with epilepsy and control subjects, with no significant differences in both groups

We also found that the motor evoked response usually spreads through more than one gyrus. Also the maximal response in one of our epilepsy patients corresponded to the ipsilateral precentral gyrus (with lesser activation of the contralateral precentral gyrus) and in another to the contralateral postcentral gyrus (with lesser activation of the precentral gyrus and middle frontal gyrus). That is in agreement with previous work reported by Brodal [1997] and others, and it reminds us that the motor cortex by itself is a broader area that includes, but is not limited to, the precentral gyrus. On the other hand, it lead us to think about brain plasticity, and the real availability of all the areas implicated if the one of maximal responses is affected by a lesion. Finally, with MR-FOCUSS there is the possibility of studying dynamic sources, which would allow imaging of the propagation of the signal produced by movement in real time.

ACKNOWLEDGEMENT: Research supported by NIH/NINDS Grant RO1-NS30914.

REFERENCES

Beisteiner R, Windischberger C, Lanzenberger R, Edward V, Cunnington R, Erdler M, Gartus A, Streibl B, Moser E, Deecke L. Finger somatotopy in human motor cortex. Neuroimage. 2001 Jun;13(6 Pt 1):1016-26.

Brodal P, Bjaalie JG. Salient anatomicfetures of the cortico-ponto-cerebellar pathway. Prog. Braine Res. 1997; 114:227-249.

Kamada K, et al. Rapid identification of the primary motor area by using magneting resonance axonography. J Neurosurg. 2002; 97 (3): 558-67.

Meyer PT et al. Preoperative Motor System Brain mapping using Positron Emision tomography and statistical parametric mapping: hints of cortical reorganization. J Neurosurg Psychiatry. 2003; 74(4):471-8.

Moran JE, Bowyer SM, Tepley N: Multi-Resolution FOCUSS source imaging of MEG Data. 3rd International Symposium on Noninvasive Functional Source Imaging within the Human Brain and Heart, Biomedizinische Technik 2001; 46, 112-114.

Pedersen JR, Johannsen P, Bak CK, Kofoed B, Saermark K, Gjedde A. Origin of human motor readiness field linked to left middle frontal gyrus by MEG and PET. Neuroimage. 1998; 8(2):214- 20.

Shiffbauer H, el al. Preoperative magnetic source imaging for brain tumor surgery: a quantitative comparison with intraoperative sensory and motor mapping. J Neurosurg. 2002; 97 (6):1933-42.

Woldag H, Waldmann G, Schubert M, et al. Cortical neuromagnetic fields evoked by voluntary and passive hand movements in healthy adults. J. Clinical Neurophysiology 2003; 20:94-101.