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Published in final edited form as:
Epileptic Disord. 2013 March ; 15(1): 27–31. doi:10.1684/epd.2013.0554.

Sensitivity of scalp 10-20 EEG and Magnetoencephalography for Spike

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Abstract

Although previous studies have investigated spike detectability of electroencephalography (EEG) and magnetoencephalography (MEG) by comparing simultaneously recording, no papers have been published focusing on relationship between spike dipole orientation and the sensitivity of scalp EEG and MEG to the “gold standard” of intracranial recording. We evaluated two patients with focal epilepsy; one with lateral temporal focus and the other with insular focus, who received two simultaneous MEGs, first with scalp EEG based on international 10-20 electrode placement with additional electrodes for anterior temporal regions (10-20 EEG), then with stereotactic EEG. Localization of MEG spike dipoles of the repeated studies was concordant, and all MEG spikes were detected by stereotactic EEG. In the patient with lateral temporal epilepsy (case 1), spike sensitivity of MEG and scalp EEG (to stereotactic EEG) were 55% and 0%, respectively. Of note, in this case MEG spike dipoles were oriented tangentially to scalp surface with tight cluster; the angle of the spike dipole to the vertical line was 3.6 degree. In the patient with insular epilepsy (case 2), spike sensitivity of MEG and 10-20 EEG (to stereotactic EEG) were 83% and 44%, respectively. The angle of the spike dipole to the vertical line was 45.3 degree From the result of case 1, tangential spikes from lateral temporal cortex could be hard to be detected in 10-20 EEG. From the result of case 2, operculum insular sources could be evaluated with MEG. We believe that the findings would be important for interpretation of clinical EEG and MEG.

Keywords

Electroencephalography (EEG); magnetoencephalography; sensitivity; stereotactic EEG

Introduction

Magnetoencephalography (MEG) is a noninvasive technique, which has been known to have better spatial resolution than electroencephalography (EEG). MEG is usually evaluated with simultaneously-recorded scalp EEG, because both modalities play a complimentary role for

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No video data is included in this manuscript

Disclosure: No financial interest is involved in the publication of this manuscript.

spike evaluation (Ebersole &Ebersole, 2011). Recently, it is possible to record and analyze simultaneous intracranial EEG and MEG, in terms of spike detectability (Mikuni et al, 1997; Oishi et al., 2002; Santiuste et al., 2008; Wang et al. 2012).

Previous studies have investigated spike detectability of scalp EEG and MEG by comparing simultaneous recording (Iwasaki et al., 2005). No studies have focused on the relationship between spike dipole orientation and sensitivity of scalp EEG and MEG to the “gold standard” of intracranial recording. Based on our retrospective review of 300 patients in the MEG laboratory in our institution, we identified two patients with focal epilepsy; one with lateral temporal focus and the other with insular focus, who received repeated simultaneous MEGs with initially scalp EEG with international 10-20 electrode placement with additional electrodes for anterior temporal regions (10-20 EEG), and then stereotactic EEG.

Case Presentation

Case 1

A 20-year-old right-handed male began to have seizure from the age of 8. His perinatal and development history were not remarkable. As family history, his father had staring spells during childhood and remitted after 2 years medication. The patient's typical seizures started with an auditory aura followed by either somatosensory seizure of right leg numbness or dialeptic seizure. He sometimes had secondarily generalized tonic-clonic seizures. Seizures occurred 4-9 times/month despite multiple antiepileptic medications. Multiple scalp-EEG monitoring, performed at age of 11, showed spikes in left centro-temporal region interictally and left fronto-temporal onset ictally. As invasive evaluation applying subdural electrocorticography covering left fronto-temporo-parietal region showed multifocal seizure onset around left perisylvian fissure, focal resection surgery was denied. Vagus nerve stimulator was implanted at the age of 12. At age of 20, he was admitted for re-evaluation. Recent EEG showed left fronto-centro-temporo-parietal region as ictal onset, however, no clear interictal spikes. FDG-PET showed subtle hypometabolism involving right frontal operculum, and postictal SPECT showed hypoperfusion involving the right periopercular region. MRI showed Chiari type 1 malformation but was otherwise normal.

Case 2

A 13-year-old right-handed male began to have seizure from the age of 7. His perinatal and early development history as well as family history was not remarkable. His typical seizures started with a somatosensory aura of left arm followed by bilateral asymmetric tonic seizure. He never had secondarily generalized tonic-clonic seizures. Seizures tended to take cluster fashion, the frequency of which was 1-2/ month, although multiple antiepileptic medications had been tried. Previous multiple scalp-EEG monitoring showed spikes in right fronto-temporal region interictally and seizures were confirmed to emerge from the same region. Ictal SPECT showed hyperperfusion in the right anterior/superior insular region and left dorsolateral posterior frontal region. MRI showed stable volume loss in the cerebellar hemispheres but was otherwise normal.

Methods

Simultaneous recordings of MEGs with scalp EEG, as the first study, and stereotactic EEG, as the second study, were performed in a magnetically shielded room for each patient, duration of which was about 40 min. The period from the first study (scalp EEG-MEG) and the second (stereotactic EEG-MEG) was approximately 1.5 month in case 1, and 3.5 months in case 2. For MEG data collection, a whole-head MEG system of 204 planar gradiometers (VectorView; Neuromag, Helsinki, Finland) was used. For scalp EEG, international 10-20 electrode placements with additional electrodes for anterior temporal regions (total number of electrodes was 21) were applied. In case with stereotactic EEG recording, the stereotactic EEG electrodes used consisted of 8-12 cylindrical 2.5 mm long platinum contacts with a diameter of 1.1 mm separated by 5mm (INTEGRA EPILEPSYTM, INTEGRA, NJ, USA). In this study, we focused on four contacts inserted in left superior temporal gyrus in case 1, and another 4 contacts inserted in right periopercular-insular region in case 2 (Fig.1). Electrodes placed in mastoid of the right side (case 1) and the left side (case 2) was used as reference. In this study, spike involvement in a SEEG contact was judged as positive when spike waveform could be identified visually. In all of SEEG spikes, spike involvement was seen in the all 4 SEEG contacts in the both cases. Distance from the patient's nearest brain surface to each contact was as follows; that of contact 1 and 4 in case 1 was 17 mm and 0 mm, and that of contact 1 and 4 in case 2was 17.3 mm and 19.0 mm. In all MEG recordings, we applied continuous movement compensation algorithm during recording. Before analysis, we performed temporally-extended signal space separation algorithm (tSSS) to each data set with a commercial software package, “MaxFilter”, to eliminate magnetic noise. We defined MEG spike as follows: outstanding and distinguishable from background activity (double or larger than background activity in amplitude). For estimation of spike source and orientation, single dipole modeling was applied for MEG signals using spherical head model. We also measured the angle of the spike dipole to the vertical line (Fig. 2).

Results

Fig. 1 shows the representative image of spikes of both cases. Table 1 shows the profile of spikes of both cases. In case 1, stereotactic EEG showed spikes in contacts of left superior temporal gyrus. While all MEG spikes were seen with stereotactic EEG, MEG could show 53% of all stereotactic EEG spikes (sensitivity of MEG = 53%, using stereotactic EEG as gold standard). MEG spike dipoles were estimated on left superior temporal gyrus. In scalp EEG-MEG study, MEG showed spikes whose dipoles were estimated on the same region; left superior temporal gyrus, although scalp EEG failed to show any clear spikes as its correlates (sensitivity of scalp EEG = 0%). Of note, MEG spike dipoles were oriented tangentially to scalp surface with tight manner, and the angle of the spike dipole to the vertical line was 3.6 degree.

In case 2, stereotactic EEG showed spikes in contacts of right insular to peri-insular region. While all MEG spikes were seen with stereotactic EEG, MEG could show 83% of all stereotactic EEG spikes (sensitivity of MEG = 83%). MEG spike dipoles were estimated on right insular to peri-insular region. In scalp EEG-MEG study, MEG could see all scalp EEG spikes and MEG spike dipoles were estimated on the same area; right insular to peri-insular

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region. Scalp EEG showed only 53 % of all MEG spikes (corrected sensitivity of scalp EEG = 44%). The angle of the spike dipole to the vertical line was 45.3 degree.

Discussion

The complementary interpretation of multiple MEG with 10-20 EEG and stereotactic EEG of the two cases clearly indicated that 1) tangential spikes from lateral temporal cortex could be hard to be detected in 10-20 EEG, 2) operculum insular sources could be evaluated with MEG.

All MEG spike dipoles from lateral temporal region (case 1) have characteristic tight cluster with very tangential orientation to scalp; the angle of the spike dipole to the vertical line was 3.6 degree, and with no clear EEG spikes. It is theoretically known that EEG is sensitive to activities from both fissure and gyrus, in contrast that MEG is exclusively sensitive to activities from fissure cortex (Ebersole & Ebersole, 2010). The result seems to provide a curious clinical evidence: spike tangential to scalp could be less apparent or blind to EEG, as shown in our recent study (Kakisaka et al., 2012). For insular spikes (case 2), it is believed that spike detection with MEG would be difficult because of the geometry of this deeply set region (Goldenholz et al., 2009). Recently, Park et al. reported successful spike detection with MEG in 2 cases with lesional insular epilepsy (Park et al., 2011). They speculated that geometrical change due to lesion in insular may relate to their successful MEG recording. However, no clear insular lesion existed in our case. The result of our case 2 not only supports their report in terms of MEG's ability for detecting insular spikes, but also showed that even without a lesion, MEG could still detect insular spike better than we have thought. In contrast to case 1, spike dipole of case 2 had both radial and tangential component (45.6 degree). We believe that this difference of spike orientation, or presence of radial component in case 2, may be related with appearance of epileptic spikes in scalp EEG

On sensitivity of MEG to intracranial recording, Agirre-Arrizubieta et al. reported, from their study applying electrocorticography (ECoG), that all MEG spikes were seen with ECoG, and 56% of all interictal ECoG spikes had a MEG counterpart. They found that spike detectability could be different based on anatomical region; orbitofrontal and interhemispheric regions had highest detectability (>90%) followed by superior frontal, central and lateral temporal (<75%), with the most difficult being mesial temporal spikes (<25%) (Agirre-Arrizubieta et al.; 2009). Santiuste et al. compared spike detectability between stereotactic EEG and MEG in one occipital epilepsy and three mesial temporal epilepsy patients (Santiuste et al., 2008). They reported that 95% of all interictal stereotactic EEG spikes had a MEG counterpart in the occipital case, while only 25 to 60% of all stereotactic EEG spikes had a MEG correlates in the mesial temporal cases (Santiuste et al., 2008). The sensitivity of MEG spike of our case 1 was smaller than that reported by Agirre-Arrizubieta's group (55% vs 73%, respectively). In addition to the difference of electrode type (ECoG vs stereotactic EEG), we assume that various degrees of spike involvement between cases may explain the difference in MEG sensitivity. None of the previous simultaneous ECoG and MEG studies examined MEG's sensitivity to insular spikes. To clarify the capability or limitation of MEG for insular spikes, additional data would be required from a larger study.

Several limitations exist for this study. Firstly, limited period of recording may not show representative spike profile of a patient. In our two cases, all spikes detected with scalp EEG were seen with MEG. However, EEG unique spike may exist (Iwasaki et al., 2005). Secondly, the small sample size of our study will prevent us to reach strong evidence about spike sensitivity amongst the three modalities. Accumulation of cases will be needed to overcome these limitations and strengthen the preliminary evidence gained here.

Acknowledgments

This work was supported in part by the National Institutes of Health under grants R01-EB009048, R01-NS074980, and by the Epilepsy Center of the Cleveland Clinic Neurological Institute.

References

Agirre-Arrizubieta Z, Huiskamp GJ, Ferrier CH, et al. Interictal magnetoencephalography and the irritative zone in the electrocorticogram. Brain. 2009; 132:3060–71. [PubMed: 19498089]

Ebersole JS, Ebersole SM. Combining MEG and EEG source modeling in epilepsy evaluations. J Clin Neurophysiol. 2010; 27:360–71. [PubMed: 21076318]

Iwasaki M, Pestana E, Burgess RC, et al. Detection of epileptiform activity by human interpreters: blinded comparison between electroencephalography and magnetoencephalography. Epilepsia. 2005; 46:59–68. [PubMed: 15660769]

Kakisaka Y, Iwasaki M, Alexopoulos AV, et al. Magnetoencephalography in Fronto-Parietal Opercular Epilepsy. Epilepsy Res. 2012 in press.

Knowlton RC, Elgavish R, Howell J, et al. Magnetic source imaging versus intracranial electroencephalogram in epilepsy surgery: a prospective study. Ann Neurol. 2006; 59:835–42. [PubMed: 16634031]

Mikuni N, Nagamine T, Ikeda A, et al. Simultaneous recording of epileptiform discharges by MEG and subdural electrodes in temporal lobe epilepsy. Neuroimage. 1997; 5:298–306. [PubMed: 9345559]

Oishi M, Otsubo H, Kameyama S, et al. Epileptic spikes: magnetoencephalography versus simultaneous electrocorticography. Epilepsia. 2002; 43:1390–5. [PubMed: 12423390]

Park HM, Nakasato N, Tominaga T. Localization of abnormal discharges causing insular epilepsy by magnetoencephalography. Tohoku J Exp Med. 2012; 226:207–11. [PubMed: 22353789]

Santiuste M, Nowak R, Russi A, et al. Simultaneous magnetoencephalography and intracranial EEG registration: technical and clinical aspects. J Clin Neurophysiol. 2008; 25:331–9. [PubMed: 18997623]

Wang ZI, Jones SE, Ristic AJ, et al. Voxel-based morphometric MRI post-processing in MRI-negative focal cortical dysplasia followed by simultaneously recorded MEG and stereo-EEG. Epilepsy Res. 2012 in press.

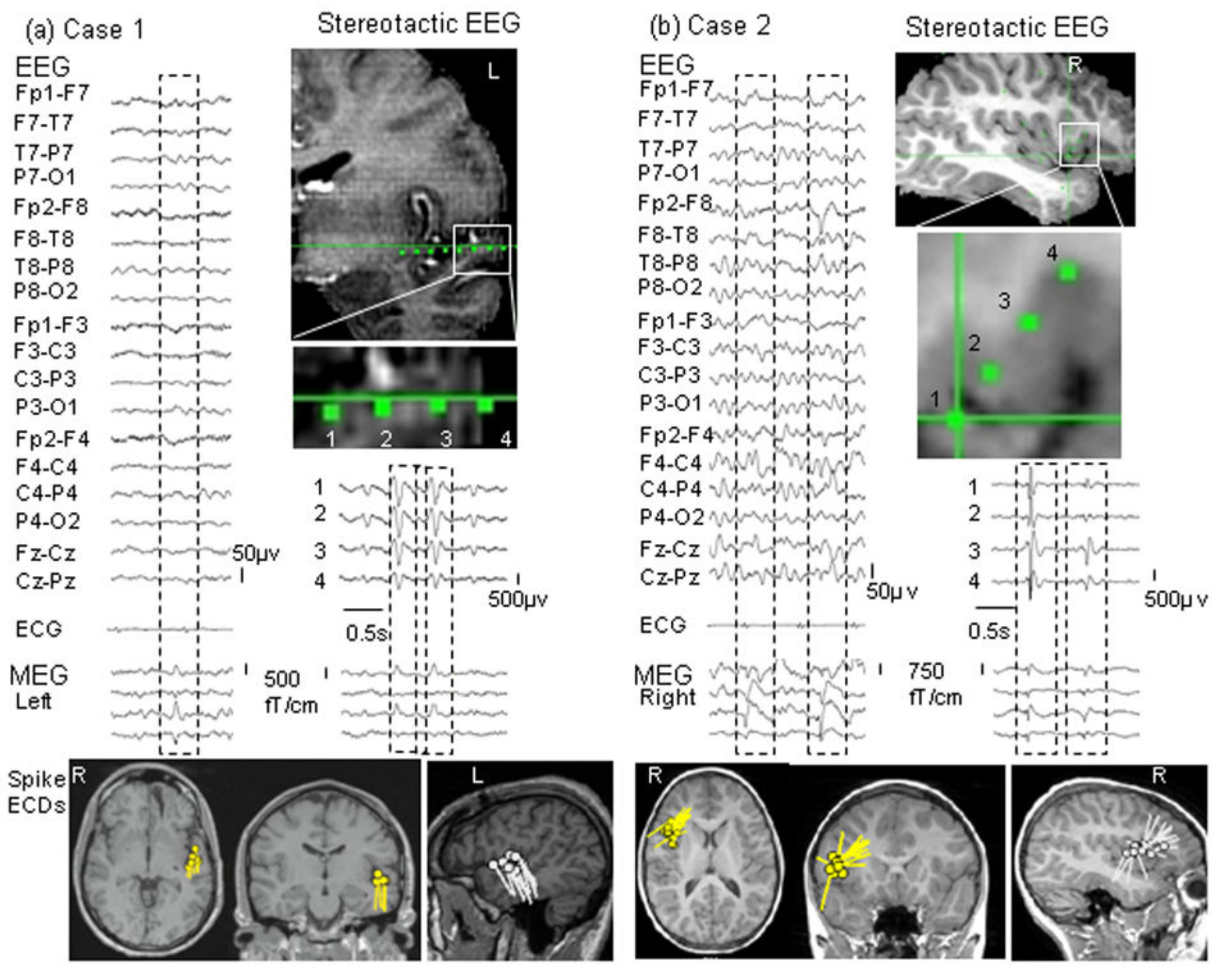

Fig.1.

Representative spikes of scalp electroencephalography (EEG)- magnetoencephalography (MEG) and stereotactic EEG-MEG of the two cases: (a) case 1, (b) case 2.

Upper column: Waveform of representative spike detected in scalp EEG and MEG (left), and stereotactic EEG and MEG (right) with location of interested electrodes (right upper)

Lower column: Axial, coronal, and sagittal MRIs: equivalent current dipole reflects its location (circle) as well as orientation (bar). In both cases, MEG spike dipoles of the repeated studies were anatomically concordant from each other.

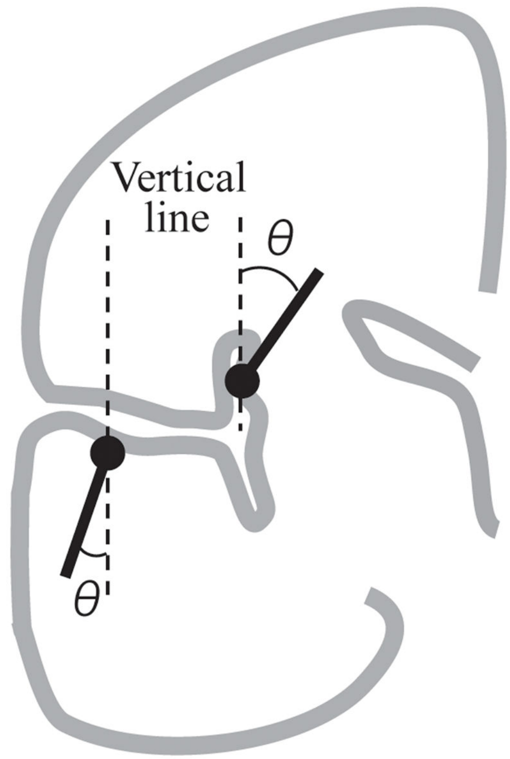

Fig. 2.

Coronal schema showing angle between the spike dipole and vertical line.

Table 1

Key findings of the two cases of multiple MEGs with EEG and SEEG

	Age	Age of Sz onset	Initial Sz symptom	SPK detectability* SEEG : MEG	SPK detectability* MEG : EEG	Are the result of MEG dipole location between the two study concordant?	Sensitivity of SPK with MEG vs EEG (to SEEG)	Angle of the spike dipole to the vertical line (Fig. 1)
Case 1	20	8	Auditory aura, or Diapletic	100% : 55%	100% : 0% (55% : 0%)**	Yes (L superior temporal gyrus)	55%:0%	3.6
Case 2	13	7	L arm somatosensory	100% : 83%	100% : 53% (83% : 44%)**	Yes (R insular to peri-insular)	83%:44%	45.3

Abbreviation; EEG, electroencephalography; MEG, magnetoencephalography, SEEG, stereotactic EEG, SPK, spike, Sz, seizure

* All MEG spikes were seen with SEEG, and all EEG spikes were seen with MEG

** These values were calculated after considering the result of spike detectability of SEEG vs MEG