Conclusion: This study shows that MEG using LW-MS provides sufficient attenuation of magnetic interference and good SNR to allow accurate detection and localization of single epileptic abnormalities on continuous MEG data. The use of LW-MS, which are cheaper and lighter than conventional MSR, should facilitate the development of MEG in clinical environments.

2-2-10: Magnetoencephalography-directed epilepsy surgery in children: Can invasive intracranial electrode monitoring be avoided?

*Hiroatsu Murakami1, Shigeki Kameyama1, Hiroshi Masuda1, Naka Saito2, Jun Tohyama2, Noriyuki Akasaka2, Akiyoshi Kakita3, Hitoshi Takahashi3

1Department of Neurosurgery, Epilepsy Center, Nishi-Niigata Chuo National Hospital, 2Department of Pediatrics, Epilepsy Center, Nishi-Niigata Chuo National Hospital, 3Department of Pathology, Brain Research Institute, Niigata University

Background: Setting intracranial electrodes and recording electrocorticography (ECoG) has been essential for deciding resection areas in intractable epilepsy. However, recording ECoG is sometimes difficult in children. Magnetoencephalography (MEG) is a powerful tool for detecting epileptic foci, particularly in neocortical intractable epilepsy. The purpose of this study was to investigate whether ECoG can be avoided in children using MEG. Methods: Subjects comprised 5 boys and 3 girls (mean age, 6 years; range, 2-9 years) with lesions who underwent tailored corticectomy based on MEG findings. One child had frontal lobe epilepsy, 4 temporal lobe epilepsy, 2 parietal lobe epilepsy and 1 multilobar epilepsy. Extraoperative ECoG was not performed when patients displayed a lesion on magnetic resonance imaging (MRI) corresponding to a cluster of equivalent current dipoles (ECDs) on MEG. Results: Patients were followed for a mean of 18 months (range, 5-52 months) and evaluated postoperatively (seizure-free, n=7; rare seizures, n=1). Pathological diagnoses were cortical dysplasia (n=3), tuberous sclerosis (n=2), dysembryoplastic neuroepithelial tumor (n=1), astrocytoma (n=1) and polymicrogyria (n=1). Conclusions: These results suggest that ECoG can be skipped if the lesion on MRI corresponds to clustered ECDs on MEG in children.

2-2-11: Interictal Spike Sensitivity Comparison: Beamformed versus Raw MEG

*Stephen E. Robinson1, Gregory L. Barkley1, Norman Tepley1

1Henry Ford Hospital

A well-know property of the linearly constrained minimum-variance (LCMV) beamformer is the improvement in signal-to-noise ratio (SNR) for focal source activity. The LCMV beamformer constructs linear combinations of measurements such that all signal power is minimized, subject to a unity-gain constraint for a specified source. This property is particularly important in the analysis of clinical epilepsy data. We show that the LCMV beamformer uncovers interictal spike activity with high SNR that was hidden in the raw MEG signal. Ten minutes of data were acquired from an epilepsy patient, using a 148-channel whole-head MEG (4-D Neuroimaging) at 508 Hz, in a DC-100 Hz bandpass. During and after collection, it was noted that no interictal spikes were observed. These data were then divided into six 100-second segments. A functional image of excess kurtosis (g2) was computed using a scalar LCMV beamformer with a resolution of 2.5 mm. Virtual sensor (VS) source waveforms were estimated for each local maximum in the g2 image. The VS were compared with the raw MEG signal. The g2 images were nearly identical for all six data segments. The images show a single focus of spike activity near the left central sulcus. Numerous interictal spikes were visible with high SNR in the VS for that location. Subtle deflections were seen in the raw MEG at times corresponding to each VS spike. The SNR of these deflections was not sufficient to be identified as a spike. LCMV beamformer analysis of MEG epilepsy data is much more sensitive than interpretation of the same unprocessed multi-channel MEG. In this example, interictal spikes were seen in VS with a typical SNR of 5:1 over background activity. By comparison, the same spikes had an SNR of less than 0.5:1 in unprocessed MEG. We have shown that the g2 beamformer imaging and visual identification of spikes in VS has much higher sensitivity than the traditional approach to MEG localization. Research supported by NIH/NINDS Grant No. R01-NS30914.

2-2-12: Removing Vagus Nerve Stimulator noise in MEG using SSS and ICA

*Natsuko Mori1, Hesheng Liu1, Naoaki Tanaka1, Steven Stufflebeam1, Seppo Ahlforts1, Matti Hamalainen1

1MGH/HMS/MIT Athinoula A. Martinos Center for Biomedical Imaging

Introduction: Advances in magnetoencephalography (MEG) denoising techniques, such as the Signal-Space Separation method (SSS) and Independent Component Analysis (ICA), have made it possible to include epilepsy patients with vagus nerve stimulator (VNS) in MEG studies. This study evaluates and compares the denoising effect of SSS and ICA on 306-channel MEG data recorded from epileptic patients with VNS. Methods: SSS and ICA were applied to MEG data from six epilepsy patients with VNS, which remained on during the
recordings. The effect of SSS and ICA was examined by comparing the spikes identified from the two datasets processed separately by SSS (MaxFilter, Elekta-Neuromag) and ICA (EEG Lab, UCSD). Using an expansion of the magnetic fields in spherical harmonics, SSS excludes signals originating from sources outside the MEG measurement surface. ICA decomposes the data into multiple components which can be examined visually to identify and eliminate the components attributable to noise.

Results: Both methods attenuated the noise sufficiently to allow identification of interictal spikes from raw data. The epileptic spikes were clearer and more easily identifiable in the data processed with SSS than those produced by ICA. Conclusion: SSS was found to be more efficient than ICA in detecting and removing the artifacts caused by a vagus nerve stimulator. Another advantage of SSS was that it reduced the noise in an automated fashion while ICA required careful visual inspection of the noise components. SSS also increased the overall quality of data by retaining the magnetic field patterns created by the neural current sources only.

2-2-13: MEG findings in schizophrenia-like psychosis of epilepsy after resection of meningioma

*Koji Ikezawa1, Leonides Canuet1, Ryouhei Ishii1, Masao Iwase1, Ryu Kurimoto1, Michiyo Azechi1, Hidetoshi Takahashi1, Takayuki Nakahachi1, Toshiki Yoshimine2, Masatoshi Takeda1

1Department of Psychiatry, Osaka University Graduate School of Medicine, 2Department of Neurosurgery, Osaka University Graduate School of Medicine

Chronic psychosis is an uncommon and serious complication of epilepsy. There are several reports on epilepsy psychosis associated to resection of some types of tumors, in particular ganglioglioma or dysembryoplastic neuroepithelioma involving mesial temporal lobe structures, such as the amygdala and hippocampus. In this study we report on an elderly patient with symptomatic localization-related epilepsy whom was diagnosed with a large, recurrent parasagitall fronto-parietal meningioma in the right hemisphere. Histological evaluation revealed atypical meningioma. After resection of the recurrent tumor, reduction in seizure frequency was greater than 90%. However, the patient developed a schizophrenia-like psychosis, which was characterized by paranoid delusions and persistent auditory hallucinations. Despite antipsychotic medications, the psychotic symptoms did not show improvement. We measured magnetoencephalography (MEG) during the interictal psychotic state after resection of the recurrent tumor. MEG and synthetic aperture magnetometry (SAM) analysis revealed that, as expected, δ activity was found to be increased in a broad area surrounding the tumor. θ activity, however was increased in a restricted area around the lesion involving the right inferior parietal gyrus. The fact that the psychotic symptoms were related to resection of a tumor in extratemporal regions is an interesting finding, which is consistent with those of recent reports indicating involvement of the right parietal lobe, especially the inferior parietal gyrus with the development of psychotic state in epilepsy patients.

2-2-14: Clinical application of automatic detection software for epileptic magnetic activities

*Hiroshi Shigeto1, Koichi Hagihara2, Yuko Somehara1, Tsuyoshi Okamoto3, Jun-ichi Kira2, Shozo Tobimatsu1

1Department of Neurophysiology, Kyushu University, 2Department of Neurology, Kyushu University, 3Digital Organ, Digital Medicine Initiative, Kyushu University

Background: MEG is one of the important devices for evaluation of epilepsy patients to determine where the epileptic activities are arising from. Although there are several software for automatic detection of epileptic magnetic activities, they demand visually confirmation for each wave form of epileptic discharges. In terms of clinical use, the analysis of huge number of magnetic waves is time consuming. Therefore, we applied the automatic detection software to epileptic magnetic activities and studied its feasibility. Method: Epilepsy patients with many apparent epileptic magnetic activities were chosen. A 306 channel MEG was employed (Neuromag, Elekta). Initially, several epileptic magnetic activities were visually selected and the threshold for detecting them was defined. Thereafter, magnetic activities over the defined threshold were detected automatically during all recording time. Single dipole was estimated during selected time windows. Goodness of fit, dipole moment and position of dipoles were examined finally. Estimated dipoles were overlayed on MRI and the locations of them were compared with those of the manually selected epileptic magnetic activities by visual inspection. Results: Magnetic epileptic discharges from 14 epilepsy patients (temporal 8, frontal 2, occipital 1, parietal 1, multi-lobar 2) were analyzed. In all cases, automatically selected dipoles were located in the same area of manually selected dipoles. Dipoles calculated from automatically and manually selected magnetic field were well estimated on the epileptogenic lobe which was expected from the findings of MRI, EEG and semiology. Conclusion: Automatically selected dipoles are well estimated at the same lobe of manually selected dipoles and provide useful information for epilepsy diagnosis.
2-2-15: Effects of 1 Hz Repetitive Transcranial Magnetic Stimulation on Seizure Reduction and Cortical Synchrony measured by MEG

*Jooman Han1,2, June Sic Kim3,4, Chun Kee Chung3,4, Hyang Woon Lee1,2

1Department of Neurology, School of Medicine, Ewha Womans University, 2Ewha Medical Research Institute, 3Department of Neurosurgery, Seoul National University College of Medicine, 4MEG Center, Seoul National University Hospital

Repetitive transcranial magnetic stimulation (rTMS) is able to modulate the excitability of cortical networks. Low frequency rTMS is known to reduce the cortical excitability, which raises the possibility to use this kind of method to control epileptic seizures. In the current study, we have been conducting a clinical trial using 1Hz rTMS delivered to the seizure foci in patients with intractable partial epilepsy. We investigated therapeutic mechanisms of 1Hz rTMS by analyzing the dynamic changes of magnetoencephalographic (MEG) activities from the patient brains.

One Hz rTMS with 110% of resting motor threshold was delivered to the seizure foci for 30 minutes (total 1800 stimuli) during 5 consecutive days. Spontaneous MEG activities were measured before and after the rTMS sessions. Phase-locking values (PLV) between all pairs of channels in each frequency band were calculated. The local PLV was defined as the average values of PLVs between each sensor and the neighboring sensors.

In one patient with right temporal epileptic focus, the maximum decrease of the local PLV in beta frequency band was 4.6% over the stimulated cortical region after rTMS treatment (0.964 vs. 0.919 before and after rTMS, respectively).

Our preliminary data showed that 1Hz rTMS may decrease local cortical synchronization over the stimulated cortical region. These findings can be related to the possible therapeutic mechanism of 1Hz rTMS for patients with intractable partial epilepsy.

2-2-16: MEG source modeling of independent spike foci in temporal lobe epilepsy: comparison with simultaneous scalp-intracranial EEG

*Richard Wennberg1, Taufik Valiante1, Douglas Cheyne1

1University of Toronto

The development of user-friendly computer-assisted mathematical techniques for MEG source modeling or magnetic source imaging has begun to facilitate application of these techniques in the clinical investigation of patients with epilepsy. Accurate MEG localization of interictal epileptiform discharges (spikes) has the potential to improve surgical planning and avoid intracranial EEG monitoring in many patients. Comparisons of modeling results against the gold standard of intracranial EEG provide the optimal tool for clinical validation of localization accuracy and permit assessment of the relative merits of equivalent current dipole and distributed source modeling techniques. We present results obtained in a patient with medically intractable temporal lobe epilepsy investigated with combined scalp EEG/MEG and scalp-intracranial EEG. Intracranial EEG was recorded from 16 subdural and depth electrode contacts implanted in each temporal lobe, sampling mesial, anterior, inferior and lateral temporal surfaces. Discrete scalp EEG spike patterns provided templates to align the MEG and intracranial EEG. Realistic head models and single moving dipole, minimum norm, and sLORETA algorithms were applied to single and averaged (n = 5, 10, 25, 50) spikes obtained from 6 independent foci (a separate anterior, inferior and lateral focus in each temporal lobe). Single spikes from intracranially-identified mesial foci had no corresponding scalp signal. Dipole mapping and, to a lesser extent, distributed modeling, at times suggested significant mesial involvement with anterior or inferior neocortical foci, where in fact none was evident in the intracranial EEG, apart from a lower amplitude field of inverted polarity indicating the opposite side of the intracranial dipole. Distributed modeling techniques presented a more realistic picture of the extended patches of cortex involved in the different spike foci, however, the extent of the modeled sources showed variable degrees of overlap with the intracranial fields.

2-2-17: Magnetoencephalographic analyze of the generalized spike-wave discharges in patients with juvenile absence epilepsy.

*Kotaro Sakurai1, Youji Takeda1, Tsugiko Kurita1, Fumiya Takeuchi2, Hideaki Shiraishi3, Shinji Nakane4, Tsukasa Koyama1

1Department of Psychiatry and Neurology, Hokkaido University School of Medicine, 2Department of Health Science, Hokkaido University School of Medicine, 3Department of Pediatrics, Hokkaido University School of Medicine, 4Division of Magnetoencephalography, Hokkaido University Hospital

Purpose: To examine whether specific cortical regions are activated at the onset and during the propagation of generalized spike-wave discharges (GSWD) in patients with juvenile absence epilepsy (JAE). Methods: Eight GSWD bursts were recorded from four JAE patients with a 204-channel whole-head MEG system. Dynamic statistical parametric maps (dSPM) were constructed to estimate the cortical distribution of GSWD. Results: Several cortical regions were activated at the onset of the GSWD. However, the activated regions were varied between subjects, or even