S6-4: A compact whole-head MEG system for supine position measurement

*Yong-Ho Lee†, Hyukchan Kwon†, Kwon-Kyu Yu†, Jin-Mok Kim†, Kiwoong Kim†
†Korea Research Institute of Standards and Science

We fabricated a whole-head magnetoencephalography (MEG) system for measuring patients in relaxed supine position. In order to realize an economic and practical MEG system, several technical improvements were made. The superconducting quantum interference device (SQUID) is the double relaxation oscillation SQUID (DROS) with large SQUID output voltages which enable compact electronics for SQUID readout and control. The pickup coil is an axial first-order gradiometer with a baseline of 50 mm. To shorten the total length of the gradiometer for longer refill interval of liquid He, the SQUID chip is located just at 10 mm from the distal coil of the gradiometer by using direct bonding of pickup coil wires into the input coil pads. To remove mechanical vibration of the insert, the sensor helmet is fixed directly onto the dewar helmet without mechanical connection to the dewar top. The sensor helmet composed of 4 sections and each section was fixed onto the dewar helmet separately using screws. In this way, the dewar neck diameter could be made smaller than the diameter of helmet sensor array, resulting in low boil rate of liquid He, less than 10 liters per day. The dewar is horizontal type for supine measurement which makes measurement more relaxed for patients, and reduce vibration noise caused by the mechanical movement of the patients. The MEG system has 152 axial gradiometers arranged over the whole cortex. When the MEG system was operated inside a moderately shielded room with 2 layers of permalloy and 1 layer of aluminum, the average noise level of the system is about 3 fT/Hz^{0.5} at 100 Hz. Evoked responses and spontaneous fields were measured successfully using the developed system.

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Symposium 7: MEG (Clinical)

S7-1: MEG for epilepsy surgery in children with intractable epilepsies

*Hiroshi Otsubo†
†The Hospital for Sick Children

This presentation introduces magnetoencephalography (MEG)-guided epilepsy surgery for children with intractable focal epilepsy. Surgical candidacy and decisions on surgical procedure for children with intractable focal epilepsy are based on long-term scalp video EEG (VEEG) results, magnetic resonance imaging (MRI) findings, and the distribution of MEG spike sources. MEG spike sources are classified into cluster, scatter and none. For subset of patients with short history of epilepsy and non-MEG spike source around lesion, we recommend lesionectomy. For most of lesional epilepsy with MEG clusters remote from the eloquent cortex, we perform intraoperative electrocorticography (ECoG) using neuronavigation system. For lesional epilepsy with clusters overlapping the eloquent cortex and non-lesional epilepsy with clusters and/or scatters, we perform extraoperative ECoG (intracranial VEEG). This combination of MEG and intracranial VEEG leads to successful surgical outcome in controlling seizures of challenging paediatric epilepsy patients. MEG is a useful tool in children with intractable localization related epilepsy to determine the surgical candidacy and guide focal cortical resection for optimal epilepsy surgery outcomes.

S7-2: MEG as part of epilepsy surgery planning, Helsinki experience

*Ritva_A Paetau†,‡
†Helsinki University Central Hospital, Department of Paediatric Neurology, Helsinki, Finland ‡Biomag Laboratory, HUSLAB, Hospital District of Helsinki and Uusimaa, Helsinki, Finland

Purpose: To retrospectively analyse the clinical usefulness, ie, the specificity, sensitivity and impact of pre-surgical MEG results with respect of successful epilepsy surgery.Methods: We analysed the result of MEG and of other modalities used in planning of epilepsy surgery, and compared the results with surgery outcome in patients with over 6-month follow-up. Interictal and/or ictal MEG data were recorded with Neuromag-122 or Vectoview (Elekta Neuromag) devices and EEG. Interictal and ictal signals were modelled with multiple single dipoles to discriminate between the early and propagated activity sources.Results: Ninety candidates for epilepsy surgery were included; fifty-five of them had been operated. MEG data in 10/55 patients were not informative: no epileptic activity nor signals (9), major magnetic artefacts (2), insufficient cooperation (1). Of the 45 patients with informative MEG data, epileptic MEG signals of 42 patients were generated inside the surgery area and in three patients, MEG sources were outside the
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resected area. Eleven patients with MEG sources inside surgery area became not completely seizure-free, five of them had palliative surgery (callosotomy or multiple subpial transections), all with worthwhile outcome. The calculated sensitivity of MEG to predict seizure freedom after surgery was 0.70, and the specificity was 0.15. In our center, the use of MEG in presurgery planning is steadily increasing during 1995 through 2007. Conclusion: Introduction of MEG analysis has enabled tailored surgical procedures without decreasing the overall surgery results, and clinical epileptologists are increasingly trusting the method.

S7-3: Coherence analysis of brain activity associated with Tinnitus

*SM Bowyer1,2, MD Seidman1, JE Moran1, KM Mason1, Q Jiang1,2, K Elisevich1, J Zhang2, N Tepley1

1 Henry Ford Hospital 2 Wayne State University

Tinnitus is ringing or buzzing or any sound perceived to be coming from the head or ears without an external sound source. Although no cure for tinnitus exists there are many treatments most of which provide only limited relief. The primary purpose of this study was to determine if MEG can detect cortical activity correlated with severity or location of tinnitus. Coherence is a measure of synchronization between brain regions. Synchronized activity within a neuronal network is determined by the strength of network connections. How well two or more brain regions are connected can be determined by measuring the coherence between these regions. We collected spontaneous MEG from patients with tinnitus and control subjects. MEG data were collected at 508Hz from 0.1-100 Hz for 10 minutes then digitally filtered 1-50 Hz. All subjects wore ear plugs to eliminate outside sounds. Subjects keep their eyes open and fixated on point on the ceiling of the room. Tinnitus patients with unilateral tinnitus participated in this study. In these subjects MEG imaging showed highly coherent brain activity in the auditory cortex, contralateral to their perceived tinnitus. The control subjects had MEG coherence maps that displayed multiple brain areas active but no particular areas were found that were highly coherent during their 10 minute scan. We determined that specific cortical areas in the auditory cortex, which may be responsible for tinnitus, are detectable using coherence mapping of the MEG signals. MEG can provide a technique that enables us to detect cortical neuronal activity that will be useful both in the diagnosis of tinnitus as well as the detection of improvements in the symptoms of tinnitus from different treatments. The main outcome of this study will be to establish an effective clinically diagnostic tool for the detection and severity of tinnitus. Research supported by NIH/NINDS Grant RO1-NS30914.

S7-4: Multi-modal studies of vascular, psychiatric and sensory-motor diseases of the brain

*GL Romani1, S. Della Penna1, M. Caulo1, C. Briganti1, R. Franciotti1, G. Mollo1, F. Notturno1, G. Perrucci1, G. Sepede1, A. Salone1, G. Tamburro1, A. Uncini2, V. Pizzella1

1 DCSB and ITAB, University of Chieti, Italy 2 DON- University of Chieti, Chieti, Italy

We report on three multimodal (MEG-fMRI) clinical studies recently started in our institute. First, a patient with AVM in the right calcaneous fissure studied during a visual stimulation paradigm (flickering bars). In conditions such as vascular malformations, in which neurovascular coupling may be abnormal, the information provided by fMRI may be incomplete. The observed BOLD signal was absent in the affected visual cortex whereas MEG data revealed bioelectrical activity with different timing and spatial pattern as compared to the normal hemisphere. Second, we compared a group of schizophrenic patients with controls by monitoring working memory during a 3-level N-back (button press) task. No significant performance difference was found between groups. fMRI and MEG results in the control group indicated activation of PP (visual attention) and PF (working memory) areas. For 1-back left DLPFC peaked earlier than right DLPFC during 2-back (higher difficulty). Preliminary results on patients indicate different patterns and timing of activity for PP and PF areas. BOLD signal in DLPFC was larger than in controls. MEG results suggested an earlier recruitment of right DLPFC in 1-and 2-back tasks, with a prolonged activity up to the same latency of controls. Finally, MEG and fMRI integration was used to study patients with different types of motoneuronal degenerative disease. All the subjects performed a force controlled motor task with each hand. Both fMRI and MEG were recorded using a block-design paradigm. Preliminary results demonstrate similar patterns of activations in patients with lower motor neuron disease and controls suggesting that this impairment may not trigger cortical reorganization.
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S7-5: Focus localization using MEG/EEG frequency analysis
*Stefan Rampp1, Martin Kaltenhaeuser1, Hermann Stefan1
1Epilepsy Center (ZEE), Department of Neurology, University Hospital

The detection of epileptiform discharges in magneto- and electroencephalography recordings (MEG/EEG) is a crucial part in diagnosing epilepsy. Thorough electrophysiologic evaluation yields information that allows for tailored surgical therapy in many cases, and thus improves treatment outcome. In recent years, the existence of oscillations in slow (2-6Hz) and fast frequency bands (>60-80Hz) has been demonstrated in the animal and human brain. It was shown that these oscillations are associated with epileptic network function. Analysis of this activity might provide valuable information for localization of epileptic networks and understanding of their dynamics. While initial research concentrated on the investigation of these basic mechanisms, clinical applications, especially the diagnostic value beyond the information yielded by well-known patterns such as epileptic transients, are increasingly coming into focus. While investigations regarding pathological high frequency activity have mostly been performed using intracerebral depth electrodes and subdural EEG, magnetoencephalography (MEG) and surface EEG might offer non-invasive alternatives. However, small and highly localized signal generating neuronal populations and consequently very low signal-to-noise ratios pose difficult problems for these modalities. Nevertheless, new methods for the analysis of oscillations are becoming available and might offer solutions. An overview on the diagnostic value of pathologic oscillations is given. The use of MEG for non-invasive detection and analysis of oscillatory activity in patients with epilepsy is discussed.

Symposium 8: Advances in MCG

S8-1: Clinical Significance of Three-dimensional Spectral Map of Atrial Fibrillation by a 64 Channel Magnetocardiogram
*Kenji Nakai1, Takanori Oka1, Hitoshi Okabayashi1, Junichi Tsuboi1, Akira Suwabe1, Manabu Itoh2, Koichiro Kobayashi3, Masahito Yoshizawa3
1Iwate Medical University  2ICS, Co., Lts., 3Iwate University

As a result of advances in interventional catheter ablation and surgical pulmonary vein (PV) isolation, radical treatments have been performed in patients with atrial fibrillation (AFIB). In the present study, we verified the significance of 3D spectral mapping of atrial fibrillation (AFIB) using 64-channel MCG. The study subjects consisted of 16 patients with valvular heart disease (14 mitral and 2 aortic valves) who had chronic AFIB. Patients had a pre-operative routine examination that included a standard ECG, echocardiography, and a 64-channel MCG. All 16 patients had a surgical PV isolation followed by valvular repair. MCG was acquired for 5 min from each patient. We used a space filter to compose the 3D current density map from the 64-channel MCG data in the B direction. After high-pass filtering, the QRST complexes were subtracted using a template-matched algorithm. Then, we applied a 2048-point Fast-Fourier transform to obtain the power spectrum of the non-averaged 3D 64-channel MCG data. Power spectral analysis allowed automatic determination of the gradient frequency for each point acquired. We created 3D color-coded frequency spectral maps within the heart outline generated by the MCG. Results: At four weeks after surgical PV isolation for AFIB followed by valve repair, 10 patients were restored to sinus rhythm (SR) and 6 patients remained in persistent AFIB. Spectral mapping showed that patients with restored SR after PV isolation had a lower average frequency than patients with persistent AFIB after PV isolation (6.3 ± 0.9 Hz vs. 7.4 ± 0.4 Hz, p=0.02). In addition, the pre-operative 3D spectrum was distributed on the right side heart in patients with persistent AFIB. In conclusion, this study showed that 3D spectral analysis and dominant frequency mapping using the 64-channel MCG can be used to evaluate the pre-operative features of AFIB.