Advanced Clinical Magnetocardiogram

Organizer: Hitoshi Horigome, Akihiko Kandori and Doosang Kim

Room: # 105

Date and Time: Tuesday, October4 / 08:30-10:30

In this symposium, we focused on the current status of clinical and experimental MCG study. We invite seven speakers internationally, who will present … 2) overview of current status of clinical magnetocardiography, 3) the efficacy of vector MCG for AF risk stratification, 4) the feasibility of MCG to detect left atrial dysfunction in the patients with paroxysmal AF, … This symposium will show that MCG could have a potential benefit to clarify the pathophysiology and overcome the hurdle of many cardiac diseases.

Speakers:

- **Uwe Schneider** (Univ. Hospital Jena, Germany)
  "Evaluation of autonomic nervous system of the fetus using fetal MCG"

  Fetal autonomic development follows universal principles of maturation like increasing variability, complexity and pattern formation. Autonomic aptitude is mirrored in cardiovascular regulation and the fetal heart rate (fHR) is both the major continuous regulative and access point to understand autonomic maturation. Electrophysiological methods like fetal magnetocardiography enhance the temporal monitoring acuity and enable precise beat-to-beat heart rate variability analysis (fHRV) which is of particular advantage in resolving fast vagal activity and in the analysis of complexity measures. fHR patterns change with increasing gestational age. In addition, rest/activity cycles from about 23 wks GA display progressive synchronization of neuro-behavioral variables as markers of developmental integrity. We applied basic and advanced parameters of linear and non-linear fHRV to conceive a fetal autonomic brain age score (fABAS) and tested the model for robustness between different study populations. fABAS performance depends on temporal resolution of the signal and length of the monitoring interval. During periods of fetal quiescence and active sleep, fABAS is characterized by differential properties with emphasis to confirm either fetal maturation or well-being, respectively. These phenomena qualify for further assessment of functional autonomic brain age and may be explored in clinical situations to help discriminating the impaired from the healthy fetus.

- **Eun-Seok Shin** (Ulsan Univ. Hospital, Korea)
  "Current status and Clinical Application of MCG"

  Although cardiovascular disease (CVD) is a major cause of mortality in humans, its prevention and treatment is challenging as accurate diagnosis is difficult. Moreover, despite the enhancement in coronary artery disease (CAD) or arrhythmic disease, such as non-invasive diagnostic test such as treadmill test, echocardiography, Holter monitoring, computed tomography, and magnetic resonance imaging, accurate diagnosis is still challenging. For this reason, invasive diagnostic tests such as angiography and electrophysiology are inevitable to diagnose CVD and thus the relevant complications are still concerning. Considering the characteristics of CVD, more accurate diagnosis can be made through a function-based diagnostic tool rather than image as a lot of scientific evidence supports this. Magnetocardiography (MCG) presents as an attractive alternative diagnostic tool in CAD and arrhythmias due to its non-invasive, contactless and highly sensitive nature. MCG has an ideal concept, in which it can read the information on the magnetic field that the heart creates on its own, and diagnose CVD without requiring direct patient contact or potential harm including contrast media, any drugs and radiation. Currently, the efficacy of MCG is being verified in ischemic heart disease, arrhythmic disease, and fetal

heart disease, and accordingly its indication is being expanded. The various applications of MCG as a noninvasive strategy for the diagnosis and validate in clinical cardiology seem warranted.

- **Tetsuo Sasano** (Tokyo Medical and Dental Univ., Japan)
"Risk stratification of atrial fibrillation utilizing vector magnetocardiography"

Atrial fibrillation (AF) is the most common arrhythmia. Since AF drastically increases the prevalence of stroke, it's important to predict the occurrence of AF. However, the risk stratification of AF has not been well established.

A growing body of evidence indicated that 2 factors were critical for AF: a triggering activity from the myocardial sleeve surrounding pulmonary vein (PV), and a conduction disturbance in atrium. We tried to evaluate these both factors utilizing vector magnetocardiography (VMCG).

For assessing the triggering activity, we identified the small hump representing the excitation at the PV region. All 107 AF cases showed the hump. On the other hand, the evaluation in 115 healthy subjects revealed 55% of the cases showed hump, but the remaining cases did not.

To evaluate the conduction disturbance in atrium, we pursued the frequency analysis from the waveform obtained at both atrial regions. We established a measurement of fragmentation from the filtered waveform of VMCG recordings. AF cases showed significantly larger number of fragmentation than in healthy subjects.

In summary, VMCG has potential to evaluate the excitation at PV and the conduction disturbance in atrium. The combination of these assessments may be useful for the risk stratification of AF.

- **Ae-Young Her** (Kangwon Nat'l Univ., Korea)
"Magnetocardiography detects left atrial dysfunction in patients with paroxysmal atrial fibrillation: Comparison with healthy subjects"

The aim of this study was to evaluate LA function using MCG in patients with paroxysmal AF and healthy subjects examining possible indices to diagnose PAF.

We enrolled 70 subjects including 26 healthy volunteers and 22 marathon runners who didnot exhibit any cardiac abnormalities with sinus rhythm as controls, and 22 patients with PAF which was documented by conventional or ambulatory EKG between October 2011 and July 2014. Spatiotemporal activation graph in base-apex and left-right direction was reconstructed from the 2D-pseudo currents. Maximum value of current amplitude was measured between end of P wave and beginning of Q wave.

LA pseudo current increase at peak exercise in PAF patients was significantly lower than healthy volunteers and marathon runners ($p<0.001$). The changes of grade of PQ mapping between rest and exercise using spatiotemporal activation graph in PAF patients was smaller increase than healthy volunteers and marathon runners ($p<0.001$). Sensitivity, specificity, and the area under the ROC curve of LA pseudo current increase at peak exercise for differentiating PAF patients from healthy subjects were 77%, 92%, and 0.898.

MCG can provide important information in detecting LA dysfunction in patients with PAF. Therefore, MCG may help in differentiating PAF patients from healthy subjects.

- **Byeongsoo Kim** (Biomagnetik Park GmbH, Germany)
"KE-VMCG: An Alternative Representation of Magnetocardiography Signal for Patient Positioning Offset Robustness and Device Independence"

Current diagnostic methods in magnetocardiography (MCG) are strongly dependent on measurement position and sensor configuration. This is an obstacle to overcome if MCG is to be used in daily clinical routine. We suggest a source space transformation to be used as a standard in MCG. By using direction

and magnitude information obtained by solving the inverse problem, a vector magnetocardiogram (KE-VMCG) is presented. The VMCG is system independent and easy to interpret. We present examples of VMCGs for both axial and tangential gradiometer configurations to show system independence, a feature which is important for joint effort research in MCG. We discuss a method to improve directional resolution and account for physiological variance in the heart position and apex direction of patients. A retrospective study on 98 patients with CAD is done to find diagnostic parameters of the VMCG. We have a brief discussion about the future goal of localizing ischemia and how VMCG might aid in this endeavor.

- **Xiangyan Kong** (Chinese Academy of Sciences, China)
"Recent Progress of MCG System Development and Its Clinical Application in SIMIT"

Recently, SIMIT has development several MCG systems in different environment. According to the different environments, different SQUID gradiometer configurations have been designed and fabricated to suppress the environmental disturbance. Also, we set up the first 36 channel MCG system in China based on voltage-biased SQUID magnetometer. As for the liquid helium evaporation rate, special design of insert has been studied and the optimal insert configurations have been developed to improve the performance of MCG system. Up to now, three four-channel MCG systems have been installed in hospitals for clinical research. Some preliminary clinical results will be reported in this paper. Also, we did several demonstrations on fetal MCG measurements using new developed voltage-biased SQUID magnetometers.

- **Kuniomi Ogata** (Hitachi Ltd., Japan)
"Magnetocardiographic vector loop and its clinical application"

Magnetocardiography (MCG) can record the magnetic fields which are generated from the cardiac electrical current (electromotive forces of the heart). It is possible to evaluate electrophysiological activities in the heart in detail (high spatial resolution) by simultaneous measurements using multi-magnetic sensors. The pseudo 2-dimensional (2-D) electrical currents in the heart (Current arrow map: CAM) is calculated from the magnetic fields. The CAM can visualize the cardiac electrophysiological activities at each sampling time. Maps of this type are providing the basis for a new method of analyzing arrhythmia, ischemic heart disease and heart failure.

When the temporal alteration of the cardiac electrophysiological activities is evaluated by the CAM, we display the time-series CAM imagery and examine the time variation of the amplitude and angle of the CAM. If the time variation of the CAM can be visualized as a single image, it will be possible to easily understand the temporal alteration of the cardiac electrophysiological activities.

Thus, we developed magnetocardiographic vector loops (MVL) which are plotted the maximal and average current vector at each sampling time onto the 2-D plane. We will apply the MVL to analyze the magnetic fields in the patient of the arrhythmia, and demonstrate its clinical values.