Magnetoencephalography For the Evaluation of Patients with Disorders of Consciousness

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The objective of the talk given at the CRC BESTA Instituto meeting (Milano, September 19, 2011) was to present the potential of magnetoencephalography (MEG) for the evaluation and physiological assessment of patients with disorders of consciousness (DOC).

MEG non-invasively records the magnetic fields generated by the electrical activity of the brain, while EEG records the extracranial electrical potentials generated by neuronal electrical currents. One of the main advantages of MEG and EEG over other non-invasive functional cerebral imaging techniques such as Functional magnetic resonance imaging (fMRI), positron emission tomography (PET and single photon emission tomography (SPECT) is their excellent temporal resolution, which is in the order of the millisecond (M. Hämäläinen, et al. Rev Modern Physics 65, 413-497 (1993). This extraordinary temporal resolution allows the detection of rapid variations in cortical activity reflecting ongoing neurophysiological processes.

Moreover, since MEG usually uses much more sensors than EEG and since magnetic fields, as opposed to electrical currents, suffer minimum attenuation and distortion from the different tissues they have to cross to reach the scalp surface, this technique is considered to have a better spatial resolution than EEG. More precisely, The MEG system

installed at Erasme hospital (Elekta Meuromag) makes use of 306 sensors offering a spatial resolution far superior to the EEG. It is equipped with a light-weight magnetic shield that has been locally validated in terms of abnormal signal detection in the context of epilepsy (X De Tiège at al. Epilepsy Res 82: 227-31. 2008). Due to its optimal compromise between an excellent temporal and a good spatial resolution, MEG is therefore a technique of choice to investigate neurophysiologically relevant phenomena. MEG is used in parallel to structural MRI and coregistration between MEG and MRI data leads to magnetic source imaging (MSI), a methodology that maps physiological processes in the various brain areas. The sources of the signals detected in MEG are post-synaptic potentials at the apical dendrites of cortical pyramidal neurons. Since mainly electrical dipoles that are tangential to the skull will produce a magnetic field detectable outside of the head, radial dipoles are not involved in the MEG signal. As a consequence, MEG records the variation of fissural cortical activity, which represents 2/3 of the activity generated at the cortical surface. The advantages of MEG for cortical activity evaluation has been well documentated in epilepsy and the MEG unit at Erasme (ULB) is presently active in this field (Carrette E, et al. Seizure 20: 414-8. 2011).

A major advantage of MEG for the study of patients with DOC resulting from various neurological causes is that MEG signals are directly related to the actual activity of the neurones. The techniques based on the changes in regional cerebral blood flow for the assessment of regional neuronal activities are indirect, they are based on the assumption that a perfect match is maintained between the neuronal activity and the local blood flow. Among these indirect methods of neuronal assessment, functional magnetic resonance imaging (fMRI), in particular, analyses the local changes in blood flow through the changes in the BOLD signal. Several studies have demonstrated that the BOLD signal — on which this brain mapping is based — is altered in various neurological conditions. Obvioulsy, in the situations of extensive brain lesions resulting in DOC, the persistence of an adequate match between neuronal activity and local BOLD signal is dubious. As a result, the possibility of detecting neuronal responses with fMRI in patients with DOC may be impaired by the fact that the neuronal activity is not reflected by the changes in BOLD signals. The risk exists, therefore, that signs of consciousness might not be detected by indirect techniques based on changes in regional blood flow. As a consequence, when it comes to the detection of signs of

consciousness in patients with overt communication failure, negative results gathered from indirect technologies need to be confirm using methods such as MEG which is the method with the highest resolution and sensitivity among the methods that directly capture signs of neuronal activities in the human brain.

The MEG unit at Erasme Hospital has initiated a project with the Coma Science Group of the ULg .The project involves MEG acquisition in resting state (15 min), electrical median nerve stimulation to allow recruitment of somatosensory secondary cortices and recording of auditory evoked magnetic fields with 1 KHz pure tone, to allow recruitment of auditory secondary cortices.

These studies in DOC patients will be extended at the ULB MEG unit with more elaborated paradigms of brain stimulation and collaboration with BESTA in this matter is expected to enhance clinical and scientific activities in participating centres.

References

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