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Biomagnetism in 2004: Introduction

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Biomagnetism is the study of magnetic fields generated by living material. Biomagnetic recordings provide a non-invasive means for obtaining electrophysiological information from the human body. This special issue of Neurology and Clinical Neurophysiology (NCNP) contains a collection of over one hundred papers, illustrating the wide variety of advances being made in the area of biomagnetism. These papers represent a subgroup of those originally presented at Biomag 2004, the 14th International Conference on Biomagnetism, held in Boston in August, 2004. The Proceedings were printed as a book [Halgren, 2004] and distributed at the conference. The authors also had the option to submit their paper to be considered for publication in the NCNP journal. Biomag conferences have been held biennially since 1976 (see Cohen's paper on history in this issue), with the number of participants, close to 650 at Biomag 2004, showing a steady growth over the years. The next conference, Biomag 2006, will be held in Vancouver, Canada.

The most widespread use of biomagnetic measurements today is in functional studies of the brain (magnetoencephalography or MEG) and the heart (magnetocardiography or MCG). MEG and MCG provide information analogous to that obtained from electrical surface potential measurements (electroencephalogram or EEG and electrocardiogram or ECG). Both types of signals, magnetic and electric, are generated by the same electrical sources, usually described in terms of primary currents. However, magnetic signals can provide complementary information to that obtained from surface potential recordings, due to their different sensitivity patterns among the source locations and orientations. In practice, magnetic and electric data are often recorded simultaneously. An important clinical application of MEG is pre-operative evaluation of epileptic patients; examples of other applications include studies of stroke, cognitive deterioration, schizophrenia, and tremor syndromes. MCG is used to detect and evaluate abnormalities in cardiac function, including studies of abnormal heart rhythms, cardiomyopathy, and ischemic heart disease. The noninvasiveness of biomagnetic recordings makes them well suited also for fetal studies. Other applications of biomagnetism include studies of ferromagnetic particles in tissue samples (cytomagnetism) or in the lungs (pneumomagnetism), para- and diamagnetism of the liver, and the gastrointestinal system (e.g., with the help of swallowed magnets).

Biomagnetic instrumentation typically involves arrays of SQUID (Superconducting Quantum Interference Device) sensors, but also novel types of non-SQUID detectors are being developed. Applications of advanced signal processing techniques include, for example, the segregation of fetal and maternal signals. The biomagnetic forward problem involves modeling of the conductivity distribution of the body and calculation of the fields, whereas the inverse problem refers to the task of estimating the sources of the measured field. Sophisticated models and mathematical methods are used for both the forward and the inverse problem, often supported by information obtained with other imaging methods. For forward modeling, principles of quasi-static electromagnetism and detailed anatomical information (as obtained from structural magnetic resonance images) are essential. Inverse modeling, on the other hand, is concerned more about statistics and information theory. Combining information from other functional imaging methods, such as functional MRI, positron emission tomography, and optical imaging, can be valuable for the biomagnetic inverse solutions. In the future, I expect that the focus in biomagnetic data analysis and interpretation will move more from "modeling of the signal sources" to modeling of physiological systems and thereby generating specific hypotheses, for example, about neural networks in the brain, to be tested using biomagnetic measurements.

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REFERENCES

Halgren E, Ahlfors S, Hämäläinen M, Cohen D., editors. Biomag 2004, Proceedings of the 14th International Conference on Biomagnetism. Boston, 2004.