Recent Advances in Brain Magnetics and Tissue Engineering

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Abstract: *Biomagnetics is an interdisciplinary field where magnetics, biology, and medicine overlap. Three types of biomagnetic approaches to the understanding of the functional organization of the human brain and the effects of intense static magnetic fields on biological systems are reviewed. Transcranial magnetic stimulation and neuromagnetic imaging techniques have opened a new horizon in brain research. The magnetic control and the magnetic orientation of biological cells and tissues have promising applications for tissue engineering.*

TRANSCRANIAL MAGNETIC STIMULATION

Transcranial magnetic stimulation has become an important tool for the study of the functional organization of the human brain. Most of the studies using transcranial magnetic stimulation are related to the mapping of the cerebral cortex. These mapping studies were achieved by a method of localized and vectorial magnetic stimulation using a figure eight coil that the author developed. Transcranial magnetic stimulation is noninvasive and less painful than direct electric stimulation through surface electrodes placed on the head. It is useful not only for measurement and diagnosis but also, for the treatment or potential cure for mental illnesses and central nervous system diseases such as depression and Parkinson's disease.

MAGNETOENCEPHALOGRAPHY

Magnetoencephalography (MEG) has proven to be a useful method for the localization of circumscribed regions of brain activity through noninvasive means. Compared with EEG, MEG is primarily sensitive to intracellular currents that flow tangentially to the scalp surface. These current sources represent pyramidal cell activation in the fissural cortex and can be localized within 1-2 mm accuracy for transient brain events. The inverse problem and modelling of electrical sources in the brain are essential in neuromagnetic imaging. Our research involves the source estimation of MEG activities associated with short-term memory task and mental rotation task using spreading source model estimations.

IMPEDANCE AND NEURONAL CURRENT MR IMAGING

MRI techniques have become important tools in medicine and biology. Conventional MRI, however, produces no information about the electrical properties of the body. New methods to visualize electrical impedance distribution and neuronal current distributions based on MRI techniques have been proposed.

The basic idea of impedance magnetic resonance imaging is to use the shielding effects of induced eddy currents in the body on spin precession. Two types of methods are proposed. One proposed method to visualize the conductivity distribution of living organisms is to use very large flip angles. The method is used to obtain conductivity-enhanced MR images at the given Larmor frequency. Another proposed method is to apply an additional time-varying magnetic field parallel to the main static field Bo. The magnetic field is produced by the third coil, "Bc" coil. The method is used to obtain conductivity-enhanced MR images at an arbitrary frequency.

A new technique to visualize the distribution of neuronal currents in the human brain has been developed. The basic idea of neuronal current imaging is to use a pair of images with positive and negative gradient fields. Neuronal current MR images of human brain activity associated with motor function were obtained.

MAGNETIC FIELDS AND TISSUE ENGINEERING

We investigated the dynamic behavior of water in high gradient magnetic fields. Exposure to an intense magnetic field of 8Tand a field gradient of 50T/m caused the surface of water to be pushed back. This phenomenon was labeled as the 'Moses Effect.' By applying the Moses effect to tissue engineering, we might possibly be able to control the movement of dia-paramagnetic biological materials using strong magnetic fields.

Magnetic orientation of fibrin fibers and collagen has been observed under strong magnetic fields. Exposure to a magnetic field causes parallel orientation of fibrin fibers to the field, whereas, collagen orients perpendicular to the field, partly due to anisotropy and the magnetic susceptibility of the materials. Red blood cells and platelets are also oriented in magnetic fields. Such magnetic orientation may have many potential applications in tissue engineering and medicine.