Title: Basic Study on Magnetic Stimulation and its Applications
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Objective: Magnetic stimulation is a noninvasive method for stimulating biological tissue. Recently, many clinical applications using magnetic stimulation have been proposed. In this presentation, the author first presents the principles and applications of magnetic stimulation. The author then shows results from research on magnetic stimulation conducted by his research group. Ongoing research includes computer simulations of current distribution in the human body by a stimulating coil and the development of a navigation system for transcranial magnetic stimulation (TMS).

Simulation of current distribution by magnetic stimulation: According to Faraday’s law of electromagnetics, electric fields can be induced in a volume conductor by a time-varying magnetic field produced by a stimulation coil. Compared to electrical stimulation, a higher intensity is required for the electric current passing into the coil in magnetic stimulation of a neuron. The eddy current produced by magnetic stimulation is broadly distributed in the brain; therefore, it is difficult to know the stimulated point precisely. Using the finite element method (FEM), the author has attempted to simulate the current distribution in the human body.

Various shapes for the coil have been proposed for the focal stimulation of the target neuron. The figure-of-eight coil, which can focus the induced eddy current beneath the central point of the coil, is mostly used as a focal stimulating coil. However, properly locating the stimulating coil over the point to be stimulated is difficult because of its heavy weight and the flexibility of the wire during manipulation of the coil. To overcome the difficulty in manipulating the coil, the author proposed an allocation method for the stimulated site in magnetic stimulation. The proposed method can target the stimulated point in the biological tissue by varying the location of the magnetic substance. An optimization method should be developed for the current distribution, without manipulating the stimulating coil. The eddy current distribution in TMS is induced by the magnetic flux distribution generated by the figure-of-eight coil. By changing the magnetic flux distribution, the magnetic substance can presumably control the eddy current distribution. The proposed method can vary the eddy current distribution in the magnetic stimulation, without manipulating the location of the figure-of-eight coil. A method for controlling the eddy current is proposed for magnetic stimulation using a magnetic substance.

To confirm the validity of the proposed method, a computer simulation of the eddy current distribution using a FEM was performed. The validity of this method was verified by comparison between the current distributions with air-core and magnetic-substance-core coils. The proposed method is useful for finding the optimum position of the stimulated cortical site.
System for estimating stimulated site in TMS: The author also developed a system for estimating the stimulated site in TMS by using a mechanical arm system. Knowing the stimulated brain site in TMS is important for assessing the brain function; however, identifying the stimulated site in TMS is difficult, so the induced electric field is broadly distributed in the brain. We determine the stimulating point by the strength of the electric field. However, the nerve excitation property related to the fiber orientation for the induced electric field must be considered. We propose a novel method considering the nerve excitation property to estimate the stimulated brain site in TMS. Functional magnetic resonance imaging (fMRI) conducted during a motor task reveals the precise location of the motor cortical area. In this study, the cortical area activated during an index and little finger motor task by fMRI was measured and compared with the stimulated site innervating the index and little finger muscles estimated by our method. The validity of our method for estimating the stimulated sites in TMS by fMRI was confirmed.

TMS-navigation system for locomotive rehabilitation: TMS is used for exploring the brain functions and dynamics and for the treatment of neurological disabilities, e.g., Parkinson’s disease. In the commercial navigation system (NBS navigation system, Nexstim Ltd., Finland), a three-dimensional digitizer is required for measuring relative locations of the subject’s head and stimulating coil. The conventional navigation system for TMS cannot be applied for locomotive rehabilitation because the subject’s head must be restrained. We introduce a TMS navigation system for locomotive rehabilitation, comprising a motion capture system and a fixation device for the stimulating coil.

Conclusions: The principles of TMS and its applications were discussed. Results of a computer simulation performed to verify the validity of an allocation method for the stimulated site in TMS using a magnetic substance were then presented. A navigation system for TMS was also proposed. Future work includes the development of a TMS navigation system for locomotive rehabilitation.
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