Development of transcranial magnetic stimulator for treatments of neurological and psychiatric diseases at home

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Transcranial magnetic stimulation (TMS) has been applied to diagnosis of neurological diseases and to basic neuroscience studies since this technique was demonstrated for the first time in 1985. The applications are now extending to cover treatments of neurological and psychiatric diseases such as depression, neuropathic pain, and Parkinson's disease[1)]. A magnetic stimulator for treatment of depression was approved last year in Japan. Previous studies suggest that the therapeutic effects are attributed to neuromodulation caused by repetitive TMS at more than 1 pulses per second. In order to maintain the therapeutic effects, patients have to undergo TMS every day. Such treatment will be widely available if a compact magnetic stimulator which can be installed in patients' home is developed. Improvement of efficiency in producing magnetic fields should be improved for downsizing the stimulator system. In addition, the therapeutic effect is affected by the positioning error of stimulator coil. Our group is developing novel TMS techniques including highly efficient stimulator coil and a coil with improved robustness against positioning error.

In order to increase the efficiency of inducing electric fields in the brain, we proposed an eccentric figure-eight coil[2)]. As shown in figure 1, the coil consists of a pair of eccentric spirals, and the center of each spiral is shifted toward the middle of the coil. Because the conductor is dense at the middle of the coil, induced electric field increases. This means that the electric field for exciting neurons can be induced with smaller coil currents. Numerical simulations were conducted for optimizing the designing parameters such as inner and outer radii and number of turns. A prototype coil was fabricated based on these optimized parameters. Stimulation of human motor cortex using the prototype coil showed that the neurons were activated with significantly lower coil currents compared with a conventional concentric figure-eight coil. Another study showed that the efficiency is further improved when the eccentric spirals are formed on the surface of a sphere conforming to the surface of the head.

Because the size of stimulating spot for figure-eight coil is as small as 5 mm, precise and reproducible positioning of the coils is necessary for obtaining stable therapeutic effect. This requirement of precision can be reduced if the spot of stimulation is enlarged. We proposed a bowl-shaped coil which exhibit an enlarged distribution of induced field compared with a conventional figure-eight coil[3)]. Coil conductors are aligned in parallel over the target area in the brain. The return conductors are placed above these parallel conductors to form coil loops. Numerical simulations showed that the bowl-shaped coil exhibits an enlarged distribution of induced electric field. One of the technical challenges is larger coil current for stimulating neurons. Improvement of coil design is necessary for balancing the robustness against positioning error and the high efficiency of stimulation.

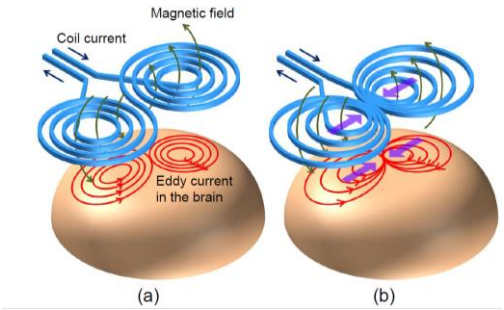

Figure 1 (a) Concentric figure-eight coil and (b) eccentric figure-eight coil[2)].

Reference

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