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Magnetic Stimulation of Sciatic Nerve Using a Millimeter-Sized Coil

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Abstract— **Implantable magnetic stimulation is a technique that is free from the degradation of an implanted stimulator by immune responses in the body, and the optimal size, design, and stimulation intensity of the stimulator have been studied continuously. In this study, we applied magnetic stimulation for peripheral nerves *in-vivo*. We observed that magnetic stimulation using a small coil with a diameter of 4 mm could elicit neuronal responses in the sciatic nerve. These responses were elicited in all subjects when the stimulus intensity was above 5.5 A.**

Clinical Relevance— **Using a stimulator that is small enough to be implanted in the body, neuronal responses were elicited in the sciatic nerve by magnetic stimulation.**

I. Introduction

Implantable magnetic stimulation is a technique that is free from the degradation of an implanted stimulator by immune responses in the body. This stimulation technique has been applied to the brain or peripheral nerve [1, 2]. Especially a study on magnetic stimulation of the sciatic nerve using a coil with a diameter of 10 mm reported to have caused neuronal responses by applying currents with intensities in a range that is typically used in transcranial magnetic stimulation. However, there are limitations that the used coil was about ten times larger than the nerve diameter, and the used current intensity was considerably high, in the order of kA. Thus, we investigated the feasibility of using a smaller coil and lower current to elicit neuronal responses in the sciatic nerve.

II. Methods

A small coil with 4 mm diameter wound around a bobbin-shaped ferrite core was selected as a stimulator. Due to the ferrite core, the coil had an inductance of 1 mH, hundreds of times greater than the inductance of the coils used in the previous study (ca. 5 μH) [2]. Therefore, it could induce strong electric fields with lower currents, even though it was small in size.

First, the minimum stimulus intensity to elicit a neuronal response was estimated using simulation software (Sim4Life V6.0, ZMT, Zurich, Switzerland). The simulation included an electromagnetic analysis model and a computational neuronal model, and thus, it was possible to simulate the neuronal response induced by a stimulator coil.

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Sciatic nerves of Sprague-Dawley rats in the hind limbs were targeted for magnetic stimulation. After exposing the sciatic nerve under anesthesia with isoflurane, a stimulator coil was placed near the sciatic nerve as close as possible. The response to stimulation was determined by the detection of compound muscle action potentials (CMAPs). To detect CMAPs, two needle electrodes were inserted into the tibialis anterior (TA) and gastrocnemius (GC) muscles, respectively.

III. Results & Conclusion

The simulation predicted that an action potential would be elicited in the sciatic nerve when a current pulse of above 3.5 A was applied to the coil and the sciatic nerve was located on the surface of the coil. Thus, it was likely that the required current would increase as the distance between the coil and the nerve increased. In *in-vivo* experiments, CMAPs and twitching were observed simultaneously in all subjects when the stimulus intensity was above 5.5 A. The latency of CMAPs was measured to be 1.5 ms on average, and the CMAPs were observed in both TA and GC muscles.

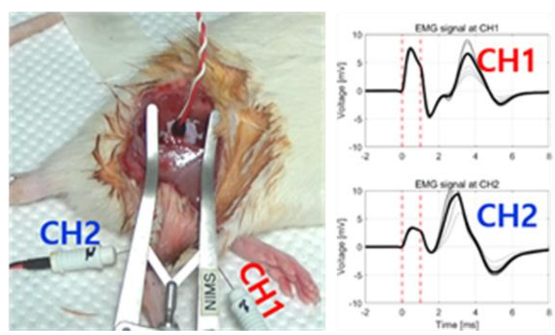

Figure 1. Experimental setup for applying magnetic stimulation to the sciatic nerve (left) and resultant CMAPs in TA (CH1) and GC (CH2) muscles (right).

Using a small-sized coil containing a ferrite core, we observed that the sciatic nerve could be stimulated magnetically with relatively weak current intensity. In the future, we will investigate the stimulation threshold according to the location and orientation of the stimulator, and optimize stimulation protocols.

References

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