Chapter 34
Development of Neurorehabilitation Techniques using Transcranial Magnetic Stimulation with Voluntary Muscle Contraction

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ABSTRACT
The objective of this study was to elucidate the mechanism of transcranial magnetic stimulation (TMS) with maximum voluntary muscle contraction (MVC) (used to facilitate motor neuron function), the effects of magnetic stimulation at the foramen magnum level with MVC were tested by recording motor evoked potentials (MEPs) and the maximum muscle force. In addition, changes in regional cerebral blood flow (rCBF) due to TMS to the motor cortex during MVC were assessed using near infrared spectroscopy (NIRS). Three MEPs in the first dorsal interosseus (FDI) muscle elicited by TMS to the motor cortex or foramen magnum stimulation were recorded before and then at 15 minutes intervals for

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INTRODUCTION

Transcranial magnetic stimulation (TMS) is a non-invasive method that allows the stimulation of cortical neurons; the electrical currents in axons stimulated by TMS activate cortical neuron cell bodies via synaptic transmission (Baker, Jalinous, & Freestone, 1985; Baker, 1991). A single TMS can transiently inhibit cortical neuron excitability for 1-5 ms after stimulation or facilitate excitability for 10-15 ms after stimulation (Kujirai et al., 1993). Further robust effects on cortical neuron excitability are achieved by repetitive stimulation of cortical neurons with TMS (rTMS) (Touge, Gerschlager, Cordivari, Brown, & Rothwell, 2001; Ikeguchi et al., 2005). The effects of rTMS on the brain were confirmed in animal experiments and in human studies by measuring regional cerebral blood flow (rCBF) or metabolism and recording electrical brain potentials or motor evoked potentials (MEPs) in voluntary muscles (Fox et al., 1997; Paus et al., 1997, 1998; Siebner et al., 2000).

There has been a great deal of work dedicated to demonstrating the benefits of TMS or rTMS for treating patients with motor disability (Mally, & Stone, 1999; Ikeguchi et al., 2003; Hamada, Ugawa, Tsuji, & The effectiveness of rTMS on Parkinson’s disease study group, 2009). However, the effects of TMS and rTMS on patients have been limited to a very short period after the stimulation and have been too weak to induce sufficient clinical outcomes.

A previous study by Urbach, Berth, & Awiszus (2005) reported that giving three single TMSs combined with the maximum voluntary muscle contraction (MVC) to patients with weakness of thigh muscles transiently (but significantly) increased muscle power. However, the effects of TMS with MVC have never been established, and the mechanism is still unknown. In the present study, we report a method of TMS with MVC that was able to induce more prolonged effects on motor neuron function. Furthermore, we evaluated the effects of magnetic brainstem stimulation at the foramen magnum level during MVC on motor evoked potentials (MEPs) and on muscle force in an attempt to explain the mechanism for how TMS with MVC modulates motor neuron function. In addition, we measured rCBF using near-infrared spectroscopy (NIRS) before and after TMS with MVC, to further explore the mechanism of activation of cortical motor neurons. NIRS is a recently developed non-invasive method for measuring oxygenized (oxy) and deoxygenized (deoxy) hemoglobin (Hb) in the cortex (Holper, Biallas, & Wolf, 2009; Nambu, et al., 2009).

The preliminary results of the present study have been reported previously in the International Symposium on Complex Medical Engineering (CME2009), held April 9-11, 2009 in Arizona (Touge, Urai, & Shimamura, 2009).
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