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Research Report

Effect of pulsed magnetic stimulation of the facial nerve on cerebral blood flow

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ABSTRACT

In these experiments we define an effective means of pulsed magnetic stimulation of the facial nerve for the purpose of increasing cerebral blood flow (CBF). In normal anesthetized dog and sheep, a focal magnetic field was directed toward the facial nerve within the temporal bone by placing a 6.5 cm figure-8 stimulation coil over the ear. In an initial set of experiments, CBF was measured by laser Doppler flowmetry and the cerebral vasculature was visualized by angiography. The effect of facial nerve stimulation was found to be dependent on stimulation power, frequency, and the precise positioning of the stimulation coil. Furthermore, an increase in CBF was not observed after direct electrical stimulation in the middle ear space, indicating that non-specific stimulation of the tympanic plexus, an intervening neural structure with vasoactive effects, was not responsible for the increase in CBF after pulsed magnetic stimulation. Subsequent experiments using perfusion MRI demonstrated reproducible increases in CBF throughout the forebrain that manifested bilaterally, albeit with an ipsilateral predominance. These experiments support the development of a non-invasive pulsed magnetic facial nerve stimulator that will increase CBF as a treatment of ischemic stroke.

1. Introduction

Stimulation of the facial nerve with electrical current increases cerebral blood flow (CBF) (D'Alecy and Rose, 1977; Goadsby, 1989, 1990, 1991; Goadsby and Hoskin, 1994; Linder, 1981; Salanga and Waltz, 1973; Sato et al., 1997; Toda et al., 2000a, 2000b). This is a well-known property of the nerve, albeit one that has not been clinically used despite its obvious relevance to the treatment of conditions such as ischemic stroke. We are developing a non-invasive device that activates the

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vasoregulatory components of the facial nerve as the nerve passes through the temporal bone using pulses of magnetic energy, thereby avoiding the need for an invasive approach to the nerve. We expect the facial nerve stimulator will increase CBF in patients with ischemic stroke. As an initial effort toward that end, these experiments were conducted in order to (1) demonstrate that magnetic stimulation of the facial nerve can increase CBF and (2) define effective stimulation parameters by which CBF is increased.

2. Results

2.1. *Magnetic stimulation experiments measuring CBF by laser Doppler flowmetry and angiography*

In the first set of experiments, conducted at the Sutter Research Institute in Sacramento, California, we positioned a 6.5 cm figure-8 magnetic stimulation coil over the ear so that movements of distant muscles innervated by the facial nerve (orbicularis oris, orbicularis oculi, platysma) could be induced ipsilateral to stimulation, confirming activation of the somatic motor portion of the facial nerve as it runs through the temporal bone. On the same side as the stimulator, a laser Doppler flowmetry probe was placed onto the frontal cortex via craniotomy and the common carotid artery was cannulated for digital subtraction angiography (DSA) using an automated pressure-controlled contrast injection system synchronized to the video recording function of the angiography system. These experiments were conducted initially in sheep ($n=6$) with key findings confirmed in dog ($n=5$). No change in blood pressure, heart rate, body temperature, or blood gas analysis was observed either during stimulation or immediately after stimulation (data not shown).

Stimulation of the facial nerve for 5 min was administered and, in response, increases in CBF were repeatedly observed. In our initial stimulation trials, the increase in CBF typically lasted only a few minutes longer than did the stimulation (Fig. 1A) although occasionally prolonged increases in CBF occurred (Fig. 1B,C). In most trials the increase in CBF developed within a few dozen seconds of the onset of stimulation (Fig. 1A,B), although in some trials the effect

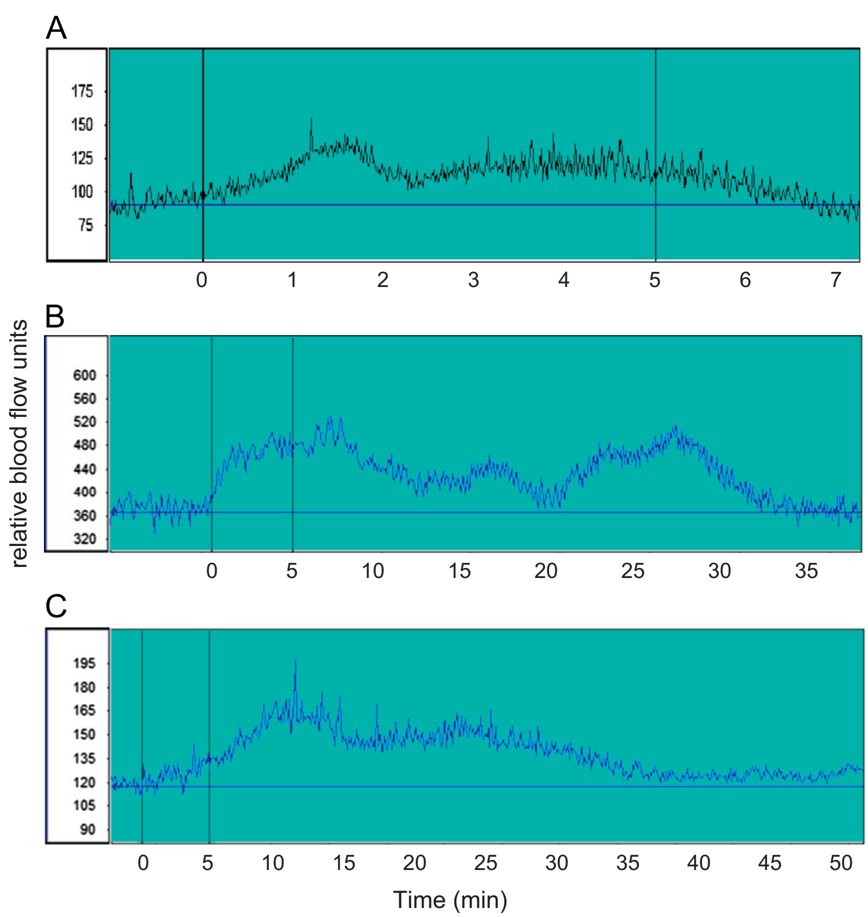

Fig. 1 – Laser Doppler flowmetry measures of relative CBF changes caused by 5 min of pulsed magnetic stimulation of the facial nerve with a figure-8 coil. Stimulation onset and cessation are noted by the position of the vertical lines, and the duration of stimulation in all examples is 5 min. (A) Top: an increase in CBF that occurred rapidly with stimulation onset but that did not persist long past the end of stimulation. (B) Middle: an increase in CBF that occurred rapidly with stimulation onset and that persisted long after the cessation of stimulation. (C) Bottom: an increase in CBF that developed more slowly after stimulation onset and that persisted long after the cessation of stimulation. Stimulation parameters: 10 Hz, 280 μs biphasic pulses of 1.5 T field strength.