

Technique

Application of multichannel near-infrared spectroscopic topography to physiological monitoring of the cortex during cortical mapping: technical case report

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Abstract

Background: Cortical stimulation via a subdural grid electrode (SGE) is one of the most reliable methods for identifying eloquent areas before surgery. However, the physiological conditions of the cortex during stimulation cannot be monitored electrophysiologically because of electrical artifacts. In the present case, we tested whether or not multichannel near-infrared spectroscopy (NIRS) topography, a noninvasive optical imaging technique, is applicable for monitoring the physiological conditions of the stimulated cortex.

Case Description: The patient (a 27-year-old right-handed man) suffered from glioma in the left frontal lobe. For preoperative cortical mapping, SGEs were implanted over the left motor cortex before tumor resection. Employing NIRS topography, we undertook 2 dimensional imaging of the changes in oxyhemoglobin (Oxy-Hb) and deoxyhemoglobin (Deoxy-Hb) concentration during electrical stimulation. Five-hertz stimulation with 5 mA at the left-hand area produced a localized increase in Oxy-Hb and a decrease in Deoxy-Hb, associated with slight twitching of the right hand. In contrast, 50-Hz stimulation produced significant increases in both Oxy-Hb and Deoxy-Hb at the stimulation site, and the area with such cerebral blood oxygenation (CBO) changes propagated beyond the hand area associated with prominent muscle contractions of the right upper extremity, suggesting that 50-Hz stimulation caused epileptic discharge.

Conclusion: Near-infrared spectroscopy topography may represent a useful tool for imaging the degree and extent of the physiological effects of electrical stimulation on the cortex, and permits safe and accurate cortical mapping.

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Keywords:

Cortical mapping; Hemodynamic response; Near-infrared spectroscopy; Oxygen metabolism; Subdural grid electrode

Abbreviations used in this paper: CBO, cerebral blood oxygenation; Deoxy-Hb, deoxyhemoglobin; MRI, magnetic resonance imaging; NIRS, near-infrared spectroscopy; Oxy-Hb, oxyhemoglobin; SGE, subdural grid electrode; Total-Hb, total hemoglobin.

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1. Introduction

Preoperative direct cortical stimulation via a SGE provides the most reliable and precise method currently available that allows the identification of eloquent areas including motor and language areas. The threshold responses at each electrode vary from one stimulation session to the next [3]; however, the physiological conditions and neuronal activities during cortical stimulation

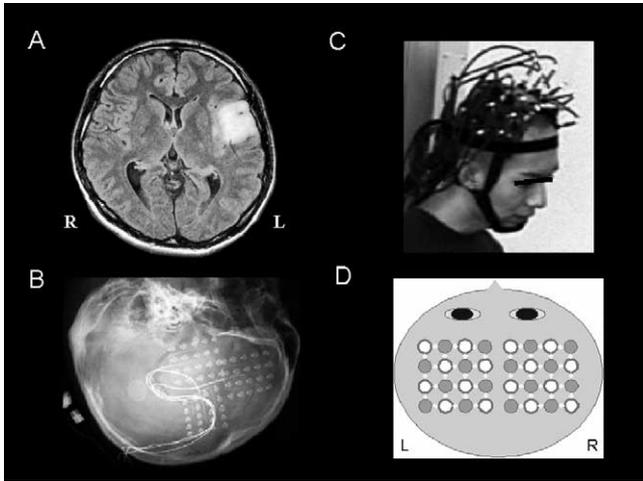


Fig. 1. A: Preoperative MRI on the FLAIR sequence, showing a left frontal low-grade glioma. B: Skull x-ray after implantation of SGEs. C: Recording setting for NIRS topography. D: Arrangement of light-source fibers and detector fibers. The white and gray circles indicate light-source and detectors fibers, respectively.

cannot be accurately monitored electrophysiologically because of electrical artifacts. In the present case, we used multichannel NIRS topography [4,7,8], a noninvasive optical imaging technique, to monitor the CBO changes occurring during cortical stimulation.

2. Case report

2.1. Presentation

The patient was a previously healthy 27-year-old right-handed man who presented with seizures. Conventional MRI revealed a nonenhancing mass within the left frontal lobe (Fig. 1A). To clarify the relation between the tumor and adjacent functional areas, 3 SGEs were implanted chronically over the left motor cortex as well as Broca's area before resection of the tumor (Fig. 1B). Histological analysis after removal of the tumor revealed a grade II astrocytoma.

2.2. Methods

We used an OMM 2000 (Shimadzu, Japan) to undertake 2 dimensional imaging of the changes in concentration of Oxy-Hb, Deoxy-Hb, and total hemoglobin (Total-Hb = Oxy-Hb + Deoxy-Hb) in the activated cortices of the bilateral frontal lobes. This system consists of 16 light-source fibers and 16 detectors resulting in 48 source-detector pairs; each light source has 3 laser diodes with wavelengths of 780, 805, and 830 nm [4]. The optodes for the NIRS topography were placed on the skull to cover the bilateral frontal lobes, including the motor cortex and Broca's area, employing a holder cap to avoid motion-related artifacts; the distance between each optode was 30 mm (Fig. 1C, D).

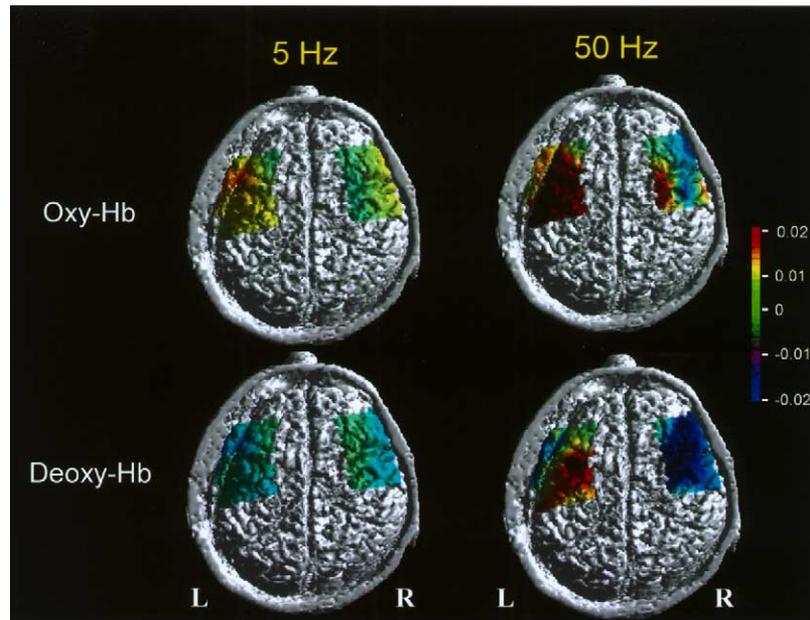


Fig. 2. NIRS topographic maps of changes in Oxy-Hb (upper) and Deoxy-Hb (lower) during stimulation at 5 Hz (left) and at 50 Hz (right) overlaid on anatomical MRI surface images. The 5 and 50 Hz maps were obtained at 6 and 9 seconds after the stimulus onset, respectively. Note that 50-Hz stimulation produced significant rises in both Oxy-Hb and Deoxy-Hb at the stimulation site, and the area with such CBO changes propagated to large areas in the left frontal lobe and partially to the right frontal lobe.

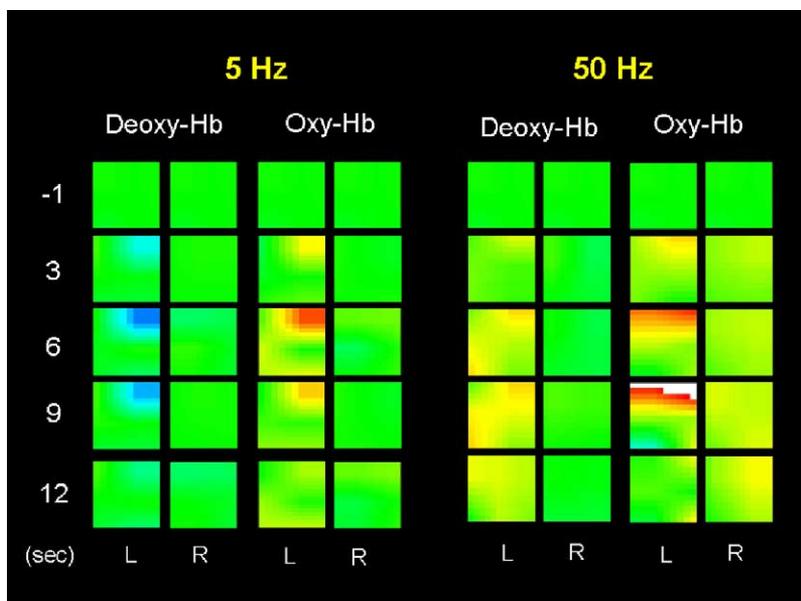


Fig. 3. Chronological changes in topographic maps of Oxy-Hb and Deoxy-Hb during stimulation at 5 Hz (left) and at 50 Hz (right). The times before stimulation (–1 second) and after (3, 6, 9, and 12 seconds) the stimulus onset are indicated on the left.

2.3. Results

Repetitive stimulation of 5 mA at 5 Hz for 5 seconds applied to the hand area of the left motor cortex produced a localized increase in concentration of Oxy-Hb associated with a decrease in Deoxy-Hb (Figs. 2 and 3, left). The peak increase was observed at about 1 second after cessation of the stimulation. During the stimulation, the patient exhibited slight twitching of the right hand. When the stimulus frequency was increased to 50 Hz, the NIRS topography demonstrated significant rises in both Oxy-Hb and Deoxy-Hb at the stimulation site, and the area with such CBO changes had propagated to large areas in the left frontal lobe and partially to the right frontal lobe (Figs. 2 and 3, right). The patient began to exhibit prominent muscle contractions of the right hand and arm at about 5 seconds after the stimulus onset; however, such muscle contractions abated after termination of the stimulation without occurrence of generalized seizures.

3. Discussion

Near-infrared spectroscopy topography is a noninvasive optical technique that can image activated cortices by measuring evoked CBO changes, and has been applied to the diagnosis of epileptic foci [8] or language hemispheric dominance [7]. These findings demonstrate that NIRS topography can be used to obtain evoked CBO maps during electrical stimulation via an SGE. Although NIR light cannot pass through the metal electrodes in the SGE, the results indicate that NIR light did pass through the space between each metal electrode by scattering within the skin and skull bone, leading to successful imaging of the evoked CBO changes.

The evoked CBO changes measured by NIRS reflect changes in the neuronal activity and oxygen metabolism occurring at the recording site [2,4–8]. In the present case, 5-Hz stimulation caused an increase in Oxy-Hb and a decrease in Deoxy-Hb. Similar CBO changes have been observed in the motor cortex during contralateral grasping tasks [2,5], suggesting that the physiological conditions at the stimulated cortex resemble those evoked by a motor task. In contrast, 50-Hz stimulation elicited increases in both Oxy-Hb and Deoxy-Hb. Such CBO changes imply that the oxygen consumption exceeds the oxygen delivery [6], and have been observed in epileptic seizure [1]. These findings suggest that 50-Hz stimulation caused an epileptic discharge in the stimulated cortex; however, further studies are needed to clarify the precise relation between the evoked CBO changes and the electrophysiological activities during cortical stimulation.

4. Conclusion

Near-infrared spectroscopy topography is considered applicable for the monitoring of evoked CBO changes during cortical mapping. Near-infrared spectroscopy topography may represent a useful method for evaluating the degree and extent of the physiological effects of electrical stimulation on the cortex, and permits safe and accurate cortical mapping.

Acknowledgments

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AMA's membership drops for fourth straight year

The American Medical Association continued to get smaller, losing about 5,500 members in 2004, the fourth consecutive year its membership shrank, according to a report to be released at the organization's annual meeting in mid-June. While still the nation's largest doctors' group, the AMA saw its membership drop to 244,530 at the end of 2004, compared with about 250,000 at the end of 2003 and the most recent high of about 294,000 in 1999. Officials detected some good news in the numbers: Membership declined at a 2.5% rate in 2004, less than the 3.7% rate in 2003. The final membership figure for 2004 fell from a mid-year total of about 247,000. Dues revenue fell about \$600,000 to \$48.1 million, meaning the average dues paid was about \$196 per member, compared with the stated annual fee of \$420 for a regular membership.—by *Michael Romano*

—*Daily Dose*, May 29, 2005
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