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ScienceDirect

Surgical Neurology 71 (2009) 540 – 542

SURGICAL NEUROLOGY

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Technology

Optical topography can predict occurrence of watershed infarction during carotid endarterectomy: technical case report

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Received 23 June 2006; accepted 29 November 2007

Abstract

Background: The major risk of CEA is perioperative stroke. NIRS can detect ischemic changes during CEA; however, possible watershed-type perfusion defects may not be detected by single-channel NIRS occurring at some distance from the light source. In the present case, we tested the usefulness of optical topography (ie, multichannel NIRS, OT) for this purpose.

Case Description: The patient (64-year-old man) exhibited nonsymptomatic 80% stenosis of the right ICA with normal cerebral perfusion. CEA was performed to prevent cerebral infarction. We used single-channel NIRS and OT for monitoring of perfusion changes during CEA. The optodes of OT were placed on the skull to cover the frontal and parietal lobes on the right side, whereas the sensor of the single-channel NIRS was placed on the right forehead. The single-channel NIRS detected no significant perfusion changes during surgery. However, the OT revealed occurrence of watershed-type perfusion defects in the border region between the right middle and posterior cerebral artery supply areas during cross-clamping of the right internal carotid artery. Postoperative MRI showed an ischemic region which corresponded to the area associated with the perfusion defects.

Conclusion: OT could detect watershed-type posterior perfusion defects which the single-channel NIRS failed to detect. OT may represent a useful tool for intraoperative monitoring during CEA.

Keywords: Carotid endarterectomy; Hemodynamic response, Near infrared spectroscopy, Oxygen metabolism, Optical topography, Watershed-type infarction, Cerebral ischemia

1. Introduction

The major risk of CEA is perioperative stroke, which is caused by hypoperfusion during cross-clamping of the ICA and/or emboli arising from the carotid artery [2]. In order to reduce the surgical risk, electrophysiological monitoring, such as electroencephalography and SEP, has been used for the detection of cerebral ischemia during surgery. However, functional evaluation by SEP is restricted in the somatosensory system. In addition, electrophysiological monitoring is easily affected by electrical noise and requires expertise in interpreting the results.

NIRS, an optical technique, is an attractive alternative because it allows noninvasive, continuous measurements of CBO changes with high time resolution and is easy to use. Previous studies provide evidence that NIRS can detect CBO changes caused by cross-clamping of the ICA [4].

Abbreviations: CEA, carotid endarterectomy; CBO, cerebral blood oxygenation; ICA, internal carotid artery; MCA, middle cerebral artery; MRI, magnetic resonance imaging; NIRS, near infrared spectroscopy; Oxy-Hb, oxyhemoglobin; PCA, posterior cerebral artery; Deoxy-Hb, deoxyhemoglobin; rSo_2, regional oxygen saturation; Total-Hb, total hemoglobin; SEP, somatosensory evoked potential; OT, optical topography.

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0090-3019/$ – see front matter
doi:10.1016/j.surneu.2007.11.012

However, possible watershed-type perfusion defects in the border region between the territory of the middle and anterior/posterior cerebral artery during CEA may not be detected by single-channel NIRS. In this letter, we demonstrate the utility of optical topography (ie, multichannel NIRS, OT) for the detection and localization of watershed-type perfusion defects during CEA. OT has been developed for 2-dimensional imaging of neuronal activity in the cortical area by measuring evoked CBO changes during various tasks [5].

2. Case report

2.1. Presentation

The patient (64-year-old man) exhibited nonsymptomatic 80% stenosis of the right ICA on cervical ultrasound sonography. Single photon emission tomography showed normal cerebral perfusion. CEA was performed to prevent cerebral infarction.

3. Methods

We used single-channel NIRS (INVOS 3110A, Somanetics, Troy, MI, USA) and OT (OMM 2000, Shimadzu, Kyoto, Japan) for monitoring of CBO changes during CEA. The INVOS 3110A measures only changes in rSo_2, whereas the OMM 2000 provides 2-dimensional imaging of the changes in concentration of Oxy-Hb, Deoxy-Hb, and Total-Hb (Oxy-Hb + Deoxy-Hb). OMM 2000 consists of 8 light-source fibers and 8 detectors, providing 24 source-detector pairs; each light source has 3 laser diodes with wavelengths of 780, 805, and 830 nm [1]. The sampling time was 100 milliseconds. The optodes were placed on the skull to cover the frontal and parietal lobes (an area measuring 90 × 90 mm^2) on the right side; the distance between optodes was 30 mm. The OT allowed measurements of CBO changes without shaving the hair; it took about 10 minutes for setting system, including pacements of the optodes and calibration of optical intensity. The sensor of the INVOS 3110A was placed on the right forehead. Fig. 1A shows the placement of the optodes (OMM 2000) and the sensor (INVOS 3110A) during surgery. Before NIRS monitoring, we confirmed that both NIRS systems did not interfere with each other by turning one device off and examining the effect on the other.

4. Results

The single-channel NIRS detected no significant changes of the CBO in the right frontal lobe during the course of the surgery. However, the OT revealed rapid decreases of Oxy-Hb and Total-Hb associated with an increase of Deoxy-Hb in the right posterior watershed territory after cross-clamping of

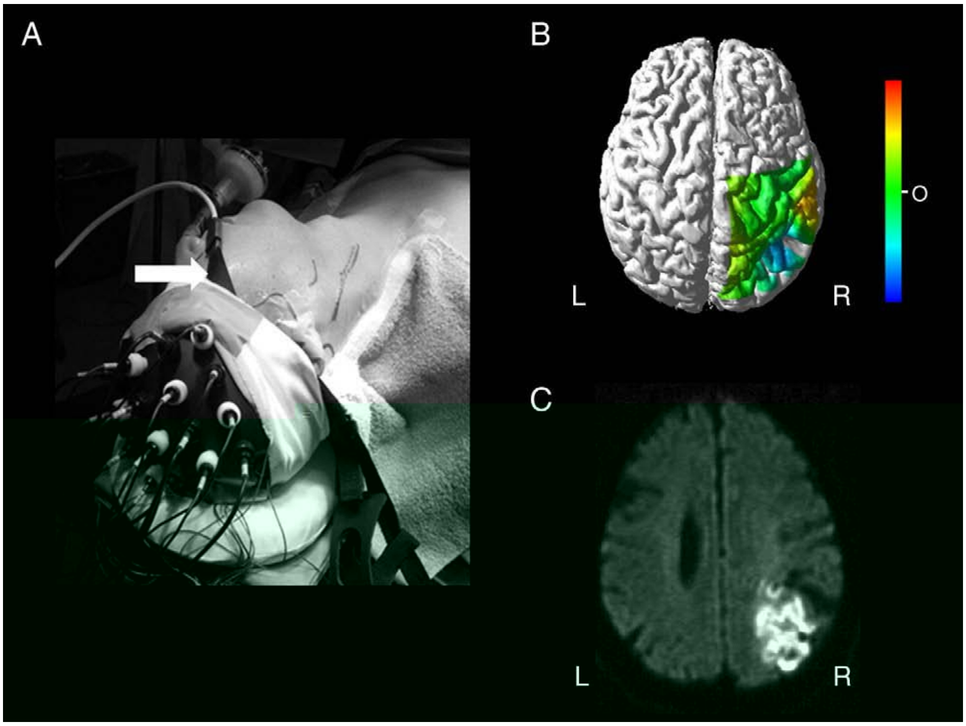

Fig. 1. A: The placement of the optodes (OMM 2000) and the sensor (INVOS 3110A) during surgery. White arrow indicate the sensor of the INVOS 3110A. B: Optical topographic maps demonstrate decreases in Oxy-Hb in the watershed zone between the MCA and PCA on the right side during cross-clamping of the ICA. The maps were overlaid on anatomical MRI surface images. C: Diffusion-weighted MRI shows hight intensity regions corresponding to the area associated with the decrease of Oxy-Hb.

the right ICA (Fig. 1A). This CBO change indicates occurrence of watershed-type perfusion defects in the border region between the right middle and posterior cerebral artery supply areas. To avoid stroke, the systemic blood pressure was raised and volume expanding fluid was administered intravenously; however, these CBO changes continued for approximately 30 min. Diffusion-weighted MRI performed immediately after surgery showed a high-intensity area which corresponded to the region associated with the decrease of Oxy-Hb (Fig. 1B). The patient suffered transient sensory disturbance after surgery.

5. Discussion

This is the first application of OT to monitor hemodynamic changes during CEA. The OT could detect watershed-type posterior perfusion defects which the single-channel NIRS failed to detect. Although OT does not provide rSo_2, previous studies had demonstrated that absolute values of rSo_2 are of little use in interpreting NIRS results, because anatomic variations, such as in skin and skull thickness, affect apparent rSo_2 [4]. It was suggested that a sudden decrease of Oxy-Hb (ie, regional cerebral blood flow) during cross-clamping of the ICA is the closest approximation to a changes of rSo_2 [3]. Indeed, we observed such an abrupt decrease of Oxy-Hb after cross-clamping of the ICA, which resulted in cerebral infarction. Although the present patient suffered stroke during CEA due to insufficient brain protection, it should be emphasized that OT is applicable not only to imaging of neuronal activity but also intraoperative monitoring during CEA.

6. Conclusion

OT could detect watershed-type posterior perfusion defects which the single-channel NIRS failed to detect. OT may represent a useful tool for intraoperative monitoring of perfusion changes during CEA.

Acknowledgments

This work was supported by grants-in-Aid from the Ministry of Education, Culture, Sports, Sciences and Technology of Japan (A12307029, A15209047, C15591553, and a grant for the promotion of industry-university collaboration at Nihon University) and by Hamamatsu Photonics KK (Hamamatsu, Japan).

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