Intraoperative infrared brain surface blood flow monitoring during superficial temporal artery–middle cerebral artery anastomosis in a patient with moyamoya disease: clinical implication of the gradation value in postoperative clinical course – A case report

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Abstract
Background Superficial temporal artery–middle cerebral artery (STA–MCA) anastomosis is a safe and effective treatment for moyamoya disease. Symptomatic cerebral hyperperfusion is a potential complication of this procedure, especially in adult cases. Accurate diagnosis of postoperative hyperperfusion is important because its treatment is contradictory to that for ischemia. Intraoperative techniques to detect hyperperfusion are still lacking.

Methods We performed intraoperative infrared (IR) brain surface monitoring in a 36-year-old man who underwent left STA–MCA anastomosis.

Findings IR monitoring not only detected the patency of bypass, as also confirmed by conventional Doppler sonography and postoperative magnetic resonance angiography, but also delineated the local brain surface hemodynamics after revascularization. Analysis of gradation value disclosed an abnormal increase in brain surface cerebral blood flow (indirectly indicated as a temperature change) after removal of the temporary clip. The patient suffered from transient right upper extremity numbness and dysarthria due to focal hyperperfusion from postoperative days 2 through 6. Intensive blood pressure control completely relieved his symptoms, and he was discharged without neurologic deficit.

Conclusions Intraoperative brain surface monitoring by IR imaging may be useful to predict cerebral hyperperfusion after revascularization surgery for moyamoya disease. Further evaluation with a larger number of patients is necessary to validate this technique.

Keywords EC–IC bypass · Intraoperative monitoring · Minimally invasive neurosurgery · Neurocritical care

Introduction
Thermography using infrared (IR) imaging is an established technique for studying the surface temperature of human organs. With the advances in IR technology, including detective wavelength, cooling system, filters, as well as data processing methods, intraoperative thermal artery imaging became available. It is a unique method both for morphological evaluation and functional monitoring of superficial vessels [8]. We have developed an IR system with detectable bands located in the range 7–14μm for neurosurgical procedures. In our preliminary experience, we performed intraoperative monitoring of superficial temporal artery–middle cerebral artery (STA–MCA) anastomosis procedures in beagles to determine the patency of
the bypass as well as the hemodynamics within small vessels (up to 0.5mm) and cortical cerebral blood flow (CBF) [4].

Moyamoya disease is a chronic, occlusive cerebrovascular disease with unknown etiology characterized by bilateral steno-occlusive changes at the terminal portion of the internal carotid artery and an abnormal vascular network at the base of the brain. Nearly half of the patients with Moyamoya manifest as ischemic attacks during pediatric period and rest of them manifest both as ischemic and hemorrhagic attacks in adults. Surgical revascularization is believed to be beneficial to prevent cerebral ischemic attacks by improving CBF [2, 3]. STA–MCA anastomosis with or without indirect bypass is generally employed. Conventional modalities suitable for comprehensive, visualized evaluation of the hemodynamics of the entire surgical field have not been available. In addition, intraoperative changes of surface CBF and its correlation with postoperative course are not well understood. We present an adult case of moyamoya patient who underwent intraoperative IR surface CBF monitoring during STA–MCA anastomosis. Intraoperative findings are presented and their implications for postoperative course are discussed.

Case report

A 36-year-old man presented with frequent transient ischemic attack (TIA). Magnetic resonance angiography (MRA) satisfied the diagnostic criteria of moyamoya disease. Preoperative \( N \)-isopropyl-p-[\(^{123}\)I] iodoamphetamine single-photon emission computed tomography (\(^{123}\)I-IMP-SPECT) showed his left CBF and cerebrovascular reserve capacities were markedly impaired, so left bypass surgery was planned.

Intraoperative IR monitoring: After completion of anastomosis, an IRIS V IR imaging system (Sparkling photon Inc., Tokyo, Japan) (Fig. 1), with a high-resolution infrared camera, was set 30cm above brain and surface temperature was continuously monitored during placement and release of the temporary clip. The system has two cameras (IR-band camera and visible-band camera) attached to a head unit with moving arm (whole length = 800mm). IR focal plane array detector (barium strontium titanate; pixel size: \(320 \times 240 \) pixels) shows the area of \(110 \times 82 \) mm using F50 IR lens. IR sensor element’s sensitivity wavelength is 7 to 14\( \mu \)m. The sensor’s recording speed is 30 frames per second and output signal is 8bit (256 gray scale gradation). The range of measuring temperature is confined to 25\(^\circ\)C to 45\(^\circ\)C (1 gradation value = 0.08\(^\circ\)). Visible-band camera has the functions of auto focus and manual zoom. All of the images were stored in the installed computer and recorded with a digital video device. Obtained images were analyzed with imaging software by means of changes in gradation value [5, 6, 9]. Signal processing: To capture the image area that had temperature change, the image processing software “Opmap”, which was originally developed for optical mapping of the cardiac action potential [1, 10], was modified to enable visualization of surface CBF. In the

![Fig. 1 Intraoperative infrared (IR) monitoring by IRIS V IR imaging system disclosed changes in color of bypass to white after temporary occlusion (indicating decrease in temperature) at 0 s compared to that 23 s before, and then changed to black (indicating increase in temperature) after removal of clip at 0 s, indicating presence of blood flow and patency of bypass. The IR images also disclosed that the white blood flow distributed to both distal and proximal direction of M4 at 0.5 s although backward flow seemed to be dominant. Note that the surrounding brain around anastomosis site slightly changed toward black locally indicating significant temperature increase till 5 s after removal of temporary clip (circle). Arrow flow direction, arrowhead site of anastomosis, STA superficial temporal artery, F frontal lobe, P parietal lobe, T temporal lobe](image-url)