Cerebral Vasodilatory Capacity Mapping Using Technetium-99m-DTPA-HSA SPECT and Acetazolamide in Moyamoya Disease

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A cerebral vasodilatory capacity map, consisting of a $^{99m}$Tc-DTPA-HSA SPECT image obtained after acetazolamide injection minus the baseline image, was produced in a patient with moyamoya disease. The map demonstrated diminished capacity in the posterior region of the right cerebral hemisphere. Subsequently, cerebral infarction occurred in the corresponding area. This observation suggests that regions of low vasodilatory capacity identified by cerebral vasodilatory capacity mapping may be at high risk of ischemic stroke.


Moyamoya disease is a chronic obstructive cerebro-vascular disease characterized by occlusion or stenosis of the distal internal carotid artery and a peculiar vascular network at the base of the brain (1,2). While a large prospective randomized trial has failed to demonstrate the effectiveness of extracranial-intracranial (EC-IC) bypass surgery in preventing ischemic strokes in patients with atherosclerotic arterial disease (3,4), such surgery has been reported to be of value in moyamoya disease (5,6).

Understanding cerebral hemodynamics is thought to be essential in determining indications for vascular reconstruction (7,8). Decreased cerebral blood flow, increased cerebral blood volume (9,10), and reduced reactivity to carbon dioxide (II) have been demonstrated in moyamoya disease. This report describes the imaging of cerebral vasodilatory capacity by cerebral blood volume measurements before and after acetazolamide injection in a patient with the disease.

MATERIALS AND METHODS

Cerebral blood volume was measured by technetium-99m-diethylenetriaminepentaacetic acid human serum albumin ($^{99m}$Tc-DTPA-HSA) and SPECT. A single-head rotating gamma camera (ZLC 7500, Siemens) equipped with a low-energy, all-purpose, parallel-hole collimator interfaced to a minicomputer system (Scintipac 2400, Shimadzu) was used. Ten minutes after the intravenous injection of 740 MBq of $^{99m}$Tc-DTPA-HSA, 64 views were collected for 20 sec each. A series of transaxial images were reconstructed using a Shepp and Logan filter with no attenuation correction. A venous blood sample was obtained at the midpoint of imaging, and its radioactivity was measured with a well counter (ARC-300, Aloka).

Following the completion of the first scanning, 1000 mg of acetazolamide were administered intravenously, and 15 min later the second SPECT was performed by the same method. The patient was kept still in the supine position throughout the serial scanning.

Absolute values of hemispheric cerebral blood volume at baseline and after acetazolamide were calculated at a level 60–72 mm above the orbitomeatal line by the method described previously (12). Regions of interest (ROIs) were placed in the area corresponding to the superficial distribution of the middle cerebral artery.

The second image was corrected for the diminution of radioactivity in blood. A cerebral vasodilatory capacity map, the image after acetazolamide minus the baseline image, was generated.

Cerebral blood flow measurement was performed with the SPECT system 20 min after the injection of 111 MBq of N-isopropyl-$^{123}$I-iodoamphetamine. Sixty-four views were acquired at 30 sec per view. A Butterworth filter was applied prior to reconstruction, and transaxial images were reconstructed using a Shepp and Logan filter and attenuation correction.

CASE REPORT

A 56-yr-old male was admitted to our hospital following an episode of intraventricular hemorrhage to evaluate the underlying etiology. He had had cerebral infarction for 2 yr.

Cerebral angiography revealed severe stenosis of the right internal carotid artery, occlusion of the right middle cerebral artery, occlusion of the left internal carotid artery and hypertrophic collateral vessels at the base of the brain on both sides; he was diagnosed as having moyamoya disease. Magnetic resonance imaging (MRI) showed small infarcts in the left frontal subcortical area and left semioval center. Mild hypoperfusion in the right cerebral hemisphere was noted on the cerebral blood flow image (Fig. 1).

At baseline, increased cerebral blood volume was demonstrated in the right cerebral hemisphere (Fig. 2, left panel: right 5.47 ml/100 g, left 4.92 ml/100 g). Cerebral blood volume was
augmented by acetazolamide injection, and the asymmetry almost disappeared (Fig. 2, center; right 5.94 ml/100 g; left 5.95 ml/100 g). Cerebral vasodilatory capacity mapping revealed diminished capacity in the posterior region of the right cerebral hemisphere (Fig. 2, right).

The indication for vascular reconstruction is controversial in adult-type moyamoya disease with a hemorrhagic event. However, the patient had also suffered ischemic strokes, and bilateral superficial temporal artery-middle cerebral artery anastomosis was planned. MRI and angiography suggested predominant ischemia in the left cerebral hemisphere, and the bypass operation was performed on the left side first. Three days after the first operation, a large low density area appeared on transmission computed tomography (Fig. 3). It was considered to be an infarction in the site corresponding to the low capacity area on cerebral vasodilatory capacity mapping.

**DISCUSSION**

Acetazolamide administered intravenously potently dilates cerebral vessels (13), and increases both cerebral blood flow and cerebral blood volume. Such increases are thought to be smaller in regions where vasodilatation due to decreased cerebral perfusion pressure has already occurred than in healthy regions. Cerebral blood flow measurements before and after acetazolamide injection have been performed to assess cerebral perfusion reserve prior to EC-IC bypass surgery (8). In this examination, the image obtained after acetazolamide is compared to the baseline image, generally by visual inspection, and changes in the distribution are evaluated (14).

In our patient, the cerebrovascular response to acetazolamide was estimated by cerebral blood volume measurements. The radioactivity of 99mTc-DTPA-HSA, a stable blood pool agent (12), reaches its maximum in the brain approximately 10 min after the intravenous administration of acetazolamide, and remains constant for at least 30 min (15). Thus, the image that represents cerebral blood volume augmented by acetazolamide can be acquired with a conventional SPECT system. The second image minus the baseline image directly shows the distribution of vasodilatation caused by acetazolamide. Therefore, the image was referred to as a cerebral vasodilatory capacity map.

Assessment of vasodilatory capacity from the aspect of cerebral blood flow requires two administrations of a radiopharmaceutical and comparison of the two images. Cerebral vasodilatory capacity mapping requires only one injection of a blood pool agent, and can delineate a low capacity area on a single image.

Measurements of cerebral blood flow and cerebral blood volume at baseline are also utilized to estimate perfusion reserve (16,17). In our patient, decreased flow and increased volume were observed in the territory of the right middle cerebral artery, suggesting reduced vasodilatory capacity in the area due to diminished perfusion pressure. Nevertheless, only asymmetry in capacity was disclosed, and it was impossible to estimate the degree of impairment. While the region with diminished vasodilatory capacity is assumed to be vulnerable to an ischemic event, it is possible that a mild decrease with sufficient residuum does not elevate risk. In addition, it is difficult to detect a low capacity area smaller than the cerebral hemisphere on a cerebral blood volume image.

Cerebral blood volume was quantified before and after acetazolamide injection for the present patient. Baseline cerebral blood volume obtained in normal subjects by our
Cerebral vasodilatory capacity mapping showed that there was very little augmentation especially in the posterior region of the right cerebral hemisphere. Subsequent infarction in the region suggests that a defect on cerebral vasodilatory capacity mapping may indicate a high risk for an ischemic stroke. In moyamoya disease, occlusive lesions are demonstrated in both the carotid and vertebrobasilar systems (21). This patient is thought to have impaired posterior circulation with inadequate collateral formation.

Cerebral vasodilatory capacity mapping is a simple procedure that directly represents regional vasodilatory capacity. It may be useful in determining areas susceptible to cerebral infarction.

REFERENCES