Relationship Between Ophthalmic Artery Blood Flow and Recanalization of Occluded Carotid Artery.
Ultrasonic Doppler Study

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SUMMARY Ophthalmic artery blood flow in 5 patients with internal carotid artery occlusion of sudden onset was monitored by an ultrasonic Doppler flowmeter to investigate the possible relationship to spontaneous recanalization of the occluded artery. The occluded internal carotid arteries of 2 patients were confirmed angiographically to recanalize and the reversed flow of their ophthalmic arteries changed to physiological flow after the recanalization. The ophthalmic artery blood flow remained reversed in 2 patients whose occluded internal carotid arteries did not recanalize on the follow up angiograms. In the other patient, whose ophthalmic artery blood flow was not detected by the ultrasonic Doppler flowmeter in the acute stage, physiological flow through the ophthalmic artery was detected later. The occluded internal carotid artery did not recanalize and this physiological ophthalmic artery blood flow was filled through the circle of Willis.

AN OCCLUDED major cerebral artery spontaneously recanalizes in about 40% of acute patients and the spontaneous recanalization frequently produces hemorrhagic infarction. Recanalization of a cerebral arterial occlusion must be diagnosed precisely not only for determining prognosis by understanding the pathophysiological aspects of the infarcted brain, but also for evaluating the effect of therapy. Although repeated invasive examinations are not recommended, repeated angiograms are necessary to diagnose spontaneous recanalization of the occluded artery.

Recently, the ultrasonic Doppler technique has been increasing in clinical use as a non-invasive diagnostic examination for occlusive lesions in the internal carotid artery and vertebral artery. In the present communication, we used the ultrasonic Doppler to determine whether spontaneous recanalization of internal carotid artery occlusion can be diagnosed non-invasively.

Subjects and Methods
We selected 5 of 35 patients with internal carotid artery occlusion who were admitted to our clinic from January 1976 to October 1977. The subjects all satisfied the following conditions: those who were diagnosed by angiography within 24 hours of stroke onset as internal carotid artery occlusion and those who survived during the acute stage and had follow up angiography from 3 to 6 weeks after onset. Fibrinolytic agents were not used in these patients.

Ultrasound Doppler examinations were performed twice on each subject; the first within 48 hours of stroke onset and the second 3 to 6 weeks after, and almost simultaneously with follow up angiography. Ophthalmic artery blood flow was measured using a bi-directional ultrasonic Doppler flowmeter with dual filter type (EUD-3B, Hitachi Medico, Tokyo). An ultrasonic probe was attached to the skin of the upper eyelid about 10 mm above and lateral to the corneal midpoint and the ultrasonic beam was directed medially to the optic canal to detect ophthalmic artery blood flow (ophthalmic artery Doppler).

The findings of the ophthalmic artery Doppler examination were classified into 4 groups: 1) Physiological flow type with normal response — a pulsatile blood flow signal in a forward direction with normal compression of the ipsilateral common carotid artery causing this signal to cease or dramatically decrease. 2) Physiological flow type with abnormal response — ophthalmic artery blood flow is forward in direction but ipsilateral common carotid artery compression does not block physiological flow signal. 3) Reversed flow type — blood flow signal in the ophthalmic artery reversed in direction. 4) No flow signal type — neither a physiological nor reversed blood flow signal in an ophthalmic artery was detected with the ophthalmic artery Doppler technique.

On the basis of these classifications we tried to analyze the characteristics of the ophthalmic artery Doppler findings in recanalized patients.

Results
Changes of the ophthalmic artery Doppler findings are summarized in Table 1.

Examinations in Acute Stage
Findings of the ophthalmic artery Doppler in the acute state were reversed flow type in 4 patients and no

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<th>Findings of Ophthalmic Artery Doppler Examinations and Follow-up Angiograms in 5 Patients with Internal Carotid Artery Occlusion</th>
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Follow Up Examinations

Reversed flow on the ophthalmic artery Doppler examination changed to physiological flow with a normal response in cases 1 and 2 (fig. 1). A no flow signal type in case 3 changed to physiological flow with abnormal response to carotid compression (fig. 2), but the ophthalmic artery Doppler examinations in cases 4 and 5 were unchanged, that is, reversed flow in both examinations (fig. 2). On the follow up angiograms, the occluded internal carotid arteries recanalized in cases 1 (fig. 3) and 2 and the ophthalmic artery was filled with contrast medium from a physiological route in case 1 but was equivocally filled in case 2. The occluded arteries of the other 3 patients were not recanalized. The follow up contralateral carotid angiogram still showed a faint collateral flow through
an anterior communicating artery in case 3. The physiological blood flow signal in the ophthalmic artery of this patient was interrupted not by ipsilateral common carotid artery compression but by the contralateral one. Consequently this physiological ophthalmic artery blood flow must come through the anterior communicating artery via the contralateral internal carotid artery.

Discussion

Using ultrasonic Doppler technique Müller et al. reported that the blood flow in a medial frontal artery, a branch of the ophthalmic artery was restored to the physiological direction from the reversed one in 4 patients whose stenosed internal carotid arteries were recanalized with endarterectomy. Keller et al. observed that the blood flow in a medial frontal artery was restored to the physiological direction in 5 among 12 patients who had undergone STA-MCA anastomosis for internal carotid artery obstruction. These reports indirectly support the present findings of the ophthalmic artery Doppler examination in patients with spontaneous recanalization. It has not been reported, however, that the ophthalmic artery was monitored with the ultrasonic Doppler before and after spontaneous recanalization of internal carotid artery occlusion.

Hollin and Silverstein reported that spontaneous recanalization of the occluded artery might be produced by peripheral migration and/or dissolution of emboli and we have also proposed this hypothesis. We consider that the changes of the ophthalmic artery Doppler findings from reversed to physiological flow in the recanalized patients were produced by migration and/or dissolution of emboli. In the recanalized patients in this report, the local blood pressure, where an ophthalmic artery branched from the internal carotid artery, might be much lower in the acute stage because embolic fragments might locate in the internal carotid artery between the carotid bifurcation and the origin of an ophthalmic artery. In such a situation, the blood in the external carotid artery territory flows into an internal carotid artery through an ophthalmic artery and then the ophthalmic artery blood flow is reversed. After embolic fragments resolve or migrate to more distal regions, the local blood pressure at the siphon of the internal carotid artery is restored to normal and the blood flow in the ophthalmic artery recovers to the physiological direction.

As we reported previously, the ophthalmic artery flow findings in patients with internal carotid artery occlusion are reversed in direction in many instances but there is also no flow or physiological flow in some. In the patient with internal carotid artery occlusion whose ophthalmic artery Doppler finding is the physiological flow type, the occlusion can be easily diagnosed by the maneuver of common carotid compression when the ophthalmic artery blood flow is filled through the circle of Willis as in case 3. In patients whose ophthalmic artery blood flow is in the physiological direction because of collateral flow through the external carotid artery or the internal carotid artery, that is, the occlusive lesion lodges distal to the origin of the ophthalmic artery, occlusion as well as its recanalization cannot be diagnosed with the ophthalmic artery Doppler examination even utilizing common carotid compression. Further technical improvements will be necessary to diagnose such a case.

The ultrasonic Doppler technique to detect ophthalmic artery blood flow, which was employed in this work, was first reported by Taniguchi et al., but

| Table 2: Ultrasonic Doppler Findings of 69 Ophthalmic Arteries and 69 Medial Frontal Arteries of the 64 Subjects Who Do Not Have Internal Carotid Artery Obstructions |
|---------------------------------|-----------------|-----------------|
| Ultrasonic Doppler findings     | Ophthalmic artery | Medial frontal artery |
| 1. physiological flow type      | 59              | 47              |
| 2. mixed flow type              | 8               | 19              |
| 3. no flow signal type          | 2               | 3               |
| 4. reversed flow type           | 0               | 0               |
| Total                           | 69              | 69              |
has not been used outside Japan. Most workers employ medial frontal artery blood flow detection attaching the ultrasonic probe to the inner canthus near the orbital fissure. We compared these 2 techniques. Ultrasonic Doppler examination of the ophthalmic artery and of the medial frontal artery was performed in 69 paired arteries of 64 control subjects whose internal carotid arteries were all verified angiographically to have no occlusive lesions. The ages of the subjects ranged from 34 to 84 years (65.4 mean). Results of the ultrasonic Doppler findings in table 2 show "mixed flow type" of which ultrasonic Doppler examination gives both physiological and reversed blood flow signals simultaneously. An angiogram of a control subject with the typical mixed flow type is shown in figure 4 in which coiling and tortuosity of the ophthalmic artery is remarkable. We believe this condition is one of the reasons for the mixed flow type. This type, which is troublesome, exists more frequently in the medial frontal artery than in the ophthalmic artery as indicated in table 2. Of 19 subjects whose medial frontal arteries have a mixed flow type, 16 subjects have ophthalmic arteries of physiological flow type. Therefore, it is better to detect the blood flow of an ophthalmic artery than a medial frontal artery in order to decide the real blood flow direction. This is why we adopted the technique of ophthalmic artery blood flow detection. From a practical standpoint, it is best to examine both arteries.

In conclusion, recanalization of an occluded internal carotid artery could be diagnosed by the Doppler on follow up examination of the ophthalmic artery. This technique can be performed frequently because it is non-invasive and has no side effects. We believe that the timing and progress of spontaneous recanalization of occluded arteries will be analyzed in more detail in the future with the use of the ultrasonic Doppler.

References
Relationship between ophthalmic artery blood flow and recanalization of occluded carotid artery. Ultrasonic Doppler study.
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