Reversed Ophthalmic Artery Flow in Internal Carotid Artery Occlusion. A Re-Appraisal Based on Ultrasonic Doppler Investigations

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SUMMARY In a retrospective study, ultrasonic Doppler findings obtained with directional continuous wave equipment were evaluated in 51 patients in whom subsequently the diagnosis of an internal carotid artery occlusion was confirmed by angiography or autopsy. The evaluation was based on the registration of mean velocity analogues of medial frontal (supratrochlear) and common carotid artery blood flow. Patients referred for stroke 3 weeks or less before the Doppler examination were considered acute; the remaining patients were considered having long-standing carotid artery occlusion. There was flow reversal in the medial frontal artery in 80% of the acute, and in 62% of the chronic group. The percentage of "no flow" curves in the 2 groups were 20 and 21% respectively. Among the chronic patients 18% showed a physiological direction of medial frontal artery flow, but extremely low streaming velocity. There was a linear correlation between the medial frontal artery flow velocities and the side differences of flow velocity in the common carotid arteries in both groups indicating that, with high cross-flow between carotid arteries, reversed medial frontal artery flow is less important. The impact of both the cross-flow between the carotid arteries, and the vertebral basilar collateral on medial frontal artery flow was demonstrated by analyzing angiographical data. Physiological flow direction in the medial frontal artery can be preserved even with a deficient inter-carotid cross-flow if, in addition to internal carotid occlusion, the patient also has an external carotid occlusion on the contralateral side.

DEMONSTRATION of ophthalmic artery collateral circulation in internal carotid artery occlusion, by angiography, first described by Moniz et al. in 1937, is generally considered a sign of inadequate collateral circulation through the circle of Willis.

It has been shown, however, using directional ophthalmic Doppler sonography, that reversed ophthalmic artery flow can be demonstrated in up to 84% of patients with cervical internal carotid artery occlusion, including patients with considerable cross-flow between the internal carotid arteries via the circle of Willis. This percentage, obtained through investigation of medial frontal artery flow, was exceeded in reports on Doppler investigations of the supra-orbital artery.

From this evidence, the lack of cross-flow between the internal carotids does not seem to be a prerequisite for the development of an ophthalmic collateral. Quantitative assessment of both these collaterals might, however, demonstrate a reciprocal correlation of their joint contribution. For this reason, an analysis was made of patients with cervical carotid occlusion in whom both the ophthalmic and carotid artery circulation had been examined using a standardized technique of directional Doppler sonography.

Material

Fifty-one patients with evidence of cerebrovascular disease, in whom the diagnosis of a unilateral internal carotid artery occlusion at the bifurcation was subsequently confirmed by either angiography or necropsy, were studied with a standardized Doppler technique from January 1, 1973 to December 31, 1977. Of the 51 patients, 20 were referred because of a stroke 3 weeks or less before the investigation and believed to have an acute carotid artery occlusion. The majority of the remaining 31 had either carotid system or vertebral-basilar TIAs or cervical bruits which brought them to medical attention.

In 13 patients a unilateral carotid angiogram was done, 9 patients had bilateral carotid angiography, 17 patients had a 4 vessel study, and in 5 the cervical portion of the cranial arteries was visualized by aortic arch angiography. The series also included 7 ultrasonically investigated patients without angiography whose internal carotid artery occlusion was confirmed at postmortem.

Seven of the 20 patients classified as having acute carotid occlusion were examined again after intervals of between 2 months and 2 years, and these were evaluated both in the acute and chronic subgroups.

Methods

A Delalande directional ultrasonic flow detector transmitting a frequency of 4 MHz was used for the Doppler investigations by one of the authors. This instrument (Pourcelot, 1971) is based on the zero-crossing principle. It allows recording of pulsatile velocity curves as well as an approximate mean velocity analogue.

All patients were supine when examined. Both common carotid arteries were insonated at an angle of approximately 40 degrees, with the probe directed toward the bifurcation but with care not to include this area in the sampled section of the vessel. The medial frontal artery was chosen for the ophthalmic Doppler investigation by the technique described by Müller (1971). Doppler curves were recorded on paper using
an Elema 8-channel Mingograph, with a standard calibration of 25 mm = 500 Hz for the common carotid artery and 50 mm = 500 Hz for the medial frontal artery. Pulsatile and mean velocity curves were recorded simultaneously. Measurements of mean velocity (Vm) were made from the paper tracings as seen in figure 1. The values indicated are mm’s of amplitude from the cleanest section of the pulse curve showing the highest voltage. The CORRE program of the IBM Scientific Subroutine Package was used for statistical analysis.

Results

Results of the study are summarized in figures 2 and 3. These figures illustrate the difference in mean velocity of flow in the 2 common carotid arteries (dVmCCA), which was taken as a parameter for the amount of cross-flow from the contralateral carotid artery, and plotted against the mean flow velocity in the medial frontal artery (VmMFA). Figure 2 shows that the majority of values measured in the acute group were as expected: Patients who showed little side difference in mean carotid flow velocity demonstrated higher reversed medial frontal artery flow. Statistical analysis of these data shows a strong linear correlation between the 2 values with a p value of < 0.01. Figure 3 demonstrates the results from 38 patients with long-standing internal carotid artery occlusion. There was a greater spread of the data and a less steep slope of the regression line, yet a linear correlation between dVmCCA and VmMFA was found with a p value of < 0.05. Eighteen percent of the patients with an old internal carotid occlusion showed physiological medial frontal artery flow direction.

In the detailed analysis of the patients shown in figure 3, 2 patients illustrated in the top left hand side of the diagram demonstrating normal direction of medial frontal artery flow had minimal or virtually no difference in flow velocity in the 2 common carotid arteries. This was explained by the findings on angiography that these 2 patients were the only ones in the series who showed, in addition to a contralateral internal carotid stenosis, a total occlusion of the contralateral external carotid artery. Thus, the lack of cross-flow between the 2 carotid arteries presumably was due to the high impedance in the contralateral internal carotid, while the low pressure in the external carotid artery, because of unilateral external carotid artery occlusion, appears to be the explanation for the preserved physiological medial frontal artery flow. When the data were recalculated excluding these 2 pa-

![Figure 1. Typical Doppler findings in a case of right internal carotid artery occlusion. Physiological flow direction is indicated by upward deflection of the pulse curve. a) medial frontal artery, pulsatile; b) medial frontal artery, mean velocity, c) common carotid, pulsatile, d) common carotid, mean velocity.](http://stroke.ahajournals.org/)

![Figure 2. VmMFA (homolateral) and dVmCCA in 20 cases of "acute" internal carotid occlusion, linear correlation p < 0.01. O = homolateral carotid angiography, - = bilateral carotid angiography, · = panangiography, left bar indicating vertebral angiography. Angiographically demonstrated collateral contribution is indicated by filling out the respective semicircles.](http://stroke.ahajournals.org/)

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patients, the correlation between dVmCCA and VmMFA increased in significance when \( p < 0.01 \).

Flow reversal in the medial frontal artery was present in 80% of those patients with stroke onset 3 weeks or less before the investigation and in 62% of those patients classified as having an old occlusion. Zero flow in the medial frontal artery was found in 21% and 20% respectively in the 2 groups. Physiologically directed flow was present only among the patients with an old occlusion where 18% showed this phenomenon. In all 3 patients of this subgroup having had vertebral angiography there was angiological evidence of collateral circulation from the vertebrobasilar system.

**Discussion**

It is shown in this study that in cervical internal carotid artery occlusion there exists a linear correlation between the mean flow velocity in the homolateral medial frontal artery, as determined with a zero crossing directional ultrasonic flow meter, and the differences in common carotid flow velocity in both common carotids. Typically, with low values of side differences in common carotid flow velocity, there was a higher reversed medial frontal artery flow indicating a major contribution from the ophthalmic collateral. On the contrary, with a high common carotid flow velocity side difference, indicating a good intercarotid cross-flow, medial frontal artery flow was nearly zero or even physiologically directed.

In an earlier evaluation of our material, we found that 84% of our patients with cervical occlusion of the internal carotid artery showed reversal of medial frontal artery flow. In the present study, the percentage was 80% of the patients with acute carotid occlusion and 62% of the patients with an old carotid occlusion. There appear to be 2 reasons for this difference. First, there was a difference in technique used for the 2 evaluations. Earlier the material was evaluated based on the pulsatile curve and accepting minimal deflections as indicating flow direction. In the present study, mean velocity was taken as the relevant parameter. Change in technique had the effect that some of the patients who might have been classified as showing reversed flow with the earlier method, are now found to fall into the zero flow group, as the amplitude of the mean velocity curve in these cases was below the noise level. We have also excluded from this study 7 patients with bilateral carotid artery occlusions, all of whom showed reversed flow bilaterally.

In the present study, the difference in percentage of patients with reversal of physiologic blood flow in the medial frontal artery between the patients with acute carotid occlusions (80%) and those with old carotid occlusions (62%) was taken as possibly indicating the development of intracranial collateral circulation to compensate for the carotid occlusion allowing the gradual return in some instances to physiological flow direction in the medial frontal artery. Alternatively, the patients considered as having chronic occlusions in our series may have had a better intracranial collateral even at the time of their first symptoms, preventing reversed medial frontal artery flow in a larger proportion of this group. No evidence is available from our material for the accuracy of either of these hypotheses. Follow up studies are therefore required to find the true explanation of this phenomenon.

**References**

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