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

VIDA HODEK-DEMARIN, M.D. AND HANS R. MÜLLER, M.D.

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 in-
dicating that, with high cross-flow between carotid arteries, reversed medial frontal artery flow is less impor-
tant. 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 inter-
nal 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 1937,1 is generally considered a sign of inadequate
collateral circulation through the circle of Willis.2–4

It has been shown, however, using directional
ophthalmic Doppler sonography,7 that reversed oph-
thalmic artery flow can be demonstrated in up to 84%
of patients with cervical internal carotid artery occlu-
sion,4 including patients with considerable cross-flow
between the internal carotid arteries via the circle of
Willis. This percentage, obtained through investi-
gation of medial frontal artery flow, was exceeded in
reports on Doppler investigations of the supra-orbital
artery.5

From this evidence, the lack of cross-flow between
the internal carotids does not seem to be a prerequi-
site 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 cir-
culation had been examined using a standardized tech-
nique 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 sub-
sequently confirmed by either angiography or nec-
opsy, were studied with a standardized Doppler tech-
nique 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 verte-
bro-basilar TIAs or cervical bruises 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 por-
tion of the cranial arteries was visualized by aortic
arch angiography. The series also included 7 ultra-
sonically 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 evalu-
ated 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 in-
strument (Pourcelot, 1971)6 is based on the zero-
crossing principle. It allows recording of pulsatile
velocity curves as well as an approximate mean veloc-
ity analogue.

All patients were supine when examined. Both com-
mon carotid arteries were insonated at an angle of ap-
proximately 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).10 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](http://stroke.ahajournals.org/)

**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.
patients, the correlation between \(dV_m\) and \(V_m\) increased in significance when \(p < 0.01\).

Flow reversal in the med. 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 med. 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 angio-graphical 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 correla-
tion between the mean flow velocity in the homolateral med. frontal artery, as determined with a zero crossing directional ultrasonic flow meter, and the difference between the mean flow velocities in both common carotids. Typically, with low values of side differences in common carotid flow velocity, there was a higher reversed med. 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, med. 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 med. 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 pa-
tients 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 med. 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 med. 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 med. 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 required to find the true explanation of this phenomenon.

References

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V Hodek-Demarin and H R Müller

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