NOTES ON THE COLLATERAL CEREBRAL CIRCULATION
AS DEMONSTRATED BY CAROTID ANGIOGRAPHY

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When Moniz in 1926 introduced cerebral angiography as a new diagnostic method, it was a contribution of no less value than the cerebral pneumography introduced by Dandy 8 years previously. For the detection of intracranial disorders, and especially for the diagnosis of intracranial neoplasms, these two radiological methods are indispensable to the neurosurgeons of today.

For the full appreciation of carotid angiography, and for the understanding of its diagnostic possibilities and limitations, a fundamental knowledge concerning the carotid circulation under normal and pathological conditions is necessary. A few remarks referring to this point may therefore be appropriate.

While a contrast medium injected into the carotid artery of a corpse readily proceeds to the contralateral hemisphere, as shown by Moniz, this is normally not so in a living person. Under normal circumstances the blood stream through the internal carotid artery on each side proceeds to the homolateral hemisphere, and, if at all, only to a slight degree intermingles with the blood flow from the internal carotid artery on the opposite side.

Partial or total obliteration of the internal carotid artery on one side, with consequent partial or total circulatory arrest, demands a compensatory supply of arterial blood from the patent internal carotid artery in order to prevent symptoms due to cerebral anaemia.

In cases of insufficiency of the communicating arteries many neurosurgeons have seen the development of disastrous clinical conditions, such as hemiplegia or even death, following ligation of the internal carotid artery. Valuable prognostic information in cases of contemplated ligation of the internal carotid artery may be obtained by carotid angiography, which readily discloses to what extent one hemisphere may be supplied by arterial blood from the carotid on the opposite side.

We shall attempt to demonstrate the collateral circulation which is called into activity in cases of obliteration of the internal carotid artery (1) at its beginning near the bifurcation of the common carotid artery; (2) at the point where the internal carotid artery bifurcates into the anterior and middle cerebral arteries; and (3) in cases of hypoplasia of the internal carotid artery. Possible secondary collaterals which may develop in cases of long-standing obliteration of the internal carotid artery will also be discussed.

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Figs. 1 and 2. Case 1. The needle for percutaneous angiography is seen in the left common carotid artery immediately below its bifurcation. Perabrodil has entered the external carotid. The occlusion of the internal carotid is just above the point of bifurcation. There is considerable retrograde filling with perabrodil, probably because it was injected under a pressure higher than arterial pressure and faster than it could be carried away by the arterial blood stream.

Figs. 3 and 4. Case 1. Right carotid angiography. There is satisfactory filling with perabrodil of the branches of both anterior and middle cerebral vessels. The AP view shows that these vessels on the left side are supplied by blood also from the right internal carotid.
All the angiograms shown in this paper were carried out by the percutaneous technique.9

CASE REPORTS

The first case was one of spontaneous obliteration of the internal carotid artery immediately above the bifurcation of the common carotid artery.

Case 1. Marcus M., a 46-year-old man, was admitted on Oct. 10, 1948. On July 27, 1948 he had noticed some motor dysphasia, and about 2 weeks later he experienced a gradual onset of hemiplegia on the right side which developed to such an extent that he finally could move neither arm nor leg. Later some improvement took place.

Angiography disclosed a complete occlusion of the internal carotid artery closely above the carotid bifurcation (Figs. 1 and 2). The perabrodil entered the external carotid artery but no contrast medium was seen in the internal carotid above the occlusion. The contrast was evident in the common carotid nearly down to its very beginning, probably because it was injected more rapidly than the external carotid could take in.

In order to study the intracranial circulation, carotid angiography was also done on the right side (Figs. 3 and 4). The contrast may be seen in the hemispherical vessels on both the right and left sides, where branches of the anterior and the middle cerebral arteries are easily distinguishable.

Normally the intracranial vessels on the side opposite to the injection are seen only after compression of the internal carotid artery on that side, and the filling is usually definitely less than on the injected side. This, however, varies with the technique of the compression and in successful cases the angiograms may be almost equally satisfactory (Fig. 5). The bilateral filling takes place by way of the communicating arteries and is no cause for surprise.7,8

It is of greater interest to note that the contrast medium not only passes over to the opposite side but also descends into the internal carotid on the opposite side, which apparently means a movement of the contrast medium contrary to the normal blood stream. The explanation for this is probably the fact that the comparatively large ophthalmic artery draws a considerable amount of blood, and if the physiological flush of arterial blood to this artery by way of the internal carotid is impeded or interrupted, a corre-
sponding amount of arterial blood bound for the orbit is drawn from above by the alteration of the intravascular pressure.

Such apparently reversed progression of arterial blood containing the contrast medium may also take place in other arteries. Thus in one case we have seen arterial blood containing perabrodil descend into the basilar artery (Figs. 6 and 7). This case is our sole example of bilateral filling with contrast of the posterior cerebral artery by carotid angiography in a material of about 2,800 cases and may deserve to be mentioned separately:

![Image](image_url)

**Figs. 6 and 7. Case 2.** Right carotid angiography resulted in bilateral filling of posterior cerebral arteries with perabrodil. There is retrograde filling of the basilar artery.

**Case 2.** Ruth S., a woman aged 18 years, was admitted on Feb. 3, 1949. For about 4 months she had suffered from generalized headaches and occasional spells during which she said that she could not move the limbs although she did not lose consciousness. She was in an apparently semicomatose state, and carotid angiography was carried out on the right side. The findings were indefinite, but a possible deviation of the anterior cere-

![Image](image_url)

**Fig. 8. Case 2.** While bilateral filling of the posterior cerebral arteries was seen after injection of perabrodil into the right carotid artery, no similar finding was observed after injection into the left carotid.
The collateral cerebral circulation (Fig. 7). The outstanding finding was a bilateral filling with perilodril of both posterior cerebral arteries. There was also filling of the uppermost portion of the basilar artery. The arterial blood containing the contrast medium had descended into the basilar artery for a few cm. contrary to the normal blood stream. No similar finding was obtained by angiography on the left side, which was done a few days later (Fig. 8).

The patient displayed many features suggesting a psychogenic basis for her illness. She was discharged somewhat improved, no certain diagnosis having been made. Her condition had not changed noticeably 1 year later.

The establishment of a collateral circulation in cases of occlusion of the left cerebral artery to the right was observed. The outstanding finding was a bilateral filling with perilodril of both posterior cerebral arteries. There was also filling of the uppermost portion of the basilar artery. The arterial blood containing the contrast medium had descended into the basilar artery for a few cm. contrary to the normal blood stream. No similar finding was obtained by angiography on the left side, which was done a few days later (Fig. 8).

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The establishment of a collateral circulation in cases of occlusion of the internal carotid artery may take place spontaneously even if a considerable part of the arterial supply is intact. For instance, if the blood flow through the middle cerebral artery becomes disconnected from the homolateral internal carotid artery, it seems more expedient for nature to utilize the contralateral carotid system than to develop a collateral system derived from the posterior cerebral artery within the hemisphere that is in need for arterial blood. The following case demonstrates this point.

Case 3. Irma C., a woman 38 years old, was seen in consultation because of continuous headaches. This trouble was dated back to 1938 when she had suffered a head injury followed by unconsciousness for about 1 hour. The headache was predominantly left-sided, was exaggerated by mental or physical strain, and was occasionally associated with paraesthesia of the right arm and leg.

Angiography was performed on the left side (Figs. 9 and 10). The external and
internal carotid arteries were well filled with the contrast medium. However, the anterior or the middle cerebral artery on the left could not be visualized, although the posterior cerebral artery was well filled. The internal carotid artery could be seen all the way from the point where it branches from the common carotid and nearly up to, but not including, the point of its division into the anterior and the middle cerebral branches.

It was suspected that there was an occlusion of the internal carotid artery or its branches at some point above the origin of the posterior cerebral artery. In order to verify this diagnosis, if possible, carotid angiography was performed on the right side. There was bilateral filling with the contrast medium of both the anterior and the middle cerebral arteries (Figs. 11 and 12). Thus, while no blood could enter the left anterior and middle cerebral arteries by way of the left internal carotid artery, blood entered these vessels easily by way of the internal carotid on the opposite side. Although the middle and anterior cerebral arteries on the left side were normal in size and shape, no arterial blood was seen to enter these vessels by anastomoses of the posterior cerebral artery.

The angiographic examination proved that the pathological lesion is localized in the internal carotid artery at a point above the origin of the posterior cerebral artery but below the division of the internal carotid into the anterior and the middle cerebral branches.

The examples related above show that in cases of occlusion of the channels conveying arterial blood to the cerebral hemispheres, no matter at which point the occlusion has taken place, if possible a collateral circulation by way of the circulus Willisii is called into activity in order to take over

Figs. 11 and 12. Case 3. Right carotid angiography. The right anterior and middle cerebral arteries have been filled with the contrast medium. The AP view shows also that spontaneous transgression of blood from the right to the left side has taken place.
the function of the diseased vessels. We shall not venture to discuss whether it takes place on a mechanical base caused by the differences in intravascular pressure, as pointed out by Moniz, or if it is due to autonomic reflexes secondary to metabolic changes caused by the ischaemic cerebral condition, as maintained by Krieg.

Apparently the aid of a collateral intracranial circulation is demanded not only in cases of obliteration of the internal carotid artery, but in all cases of decreased arterial blood supply to the hemisphere, independent of its cause. For instance, in cases of early occluding vascular disease or in the presence of hypoplasia of the carotid artery, the arterial blood from the int-
right internal carotid, this observation being in contradistinction to the finding after injection of perabrodil into the left internal carotid. The left anterior cerebral artery, which was not visible at all on the angiograms after injection of perabrodil into the left internal carotid, was readily filled with the contrast together with the right anterior cerebral artery by the injection of perabrodil into the right internal carotid.

A considerable number of pictures were taken, giving an opportunity to compare the sizes of the right and left internal carotid arteries. The caliber of the artery on the pathological side was definitely (about 30 per cent) smaller than on the healthy side.

**COMMENT**

The cases described above illustrate the collateral circulation that is called into activity when there is partial or complete obstruction of one internal carotid artery. These cases have been reported in detail by Koppang, whose publication deals primarily with the possibilities of a collateral circulation.

The arteriograms show that in such cases blood from the internal carotid artery on the healthy side not only proceeds to the pathological hemisphere by means of the circulus of Willisii, but blood containing the contrast medium may also descend into the internal carotid artery on the pathological side for a longer or shorter distance. Such distribution of the contrast may take place, for instance, in cases of hypoplasia of the internal carotid artery, under which circumstance it must be presumed that there remains a considerable blood flow through the artery in spite of its diminished diameter.

It is difficult to understand how a reversed blood stream could be created just for the moment of the injection of the contrast medium, and it must be assumed that in such cases there is a constant blood flow in caudal direction through the carotid syphon. A possible explanation is that the ophthalmic artery draws a quantity of blood that is larger than the decreased capacity of the internal carotid artery on the diseased side can afford, and that a correspondingly additional volume under such circumstances is mobilised from above.

In cases of bilateral occlusion of the internal carotid arteries, arterial blood may reach the cerebral hemispheres by means of the basilar artery.
That life under such circumstances can be continued with comparatively few symptoms has been shown by an example published from this clinic by Frøvig.¹

In discussing the sources from which arterial blood may reach the cerebral hemispheres, the interesting question of the possible participation of the external carotid artery presents itself. In this connection there should be recalled the existence of preformed anastomoses between the external and the internal carotid arteries, mainly by three ways: (1) Branches from the external maxillary artery are connected with branches of the ophthalmic artery by way of the angular artery. (2) Branches from the ophthalmic artery form connections with branches of the temporal artery by way of the supraorbital artery. (3) Intracranial arterial branches of the middle meningeal artery form anastomoses with branches from both the lachrymal and the nasociliary arteries, which again arise from the ophthalmic artery.

The arteries mentioned above are small vessels of probably limited importance in normal cases. It is doubtful if these arterial branches can take over the blood supply to the brain in more than a negligible way in cases of sudden occlusion of the internal carotid artery. In cases of gradual occlusion it may be a different proposition, and it is possible that these anastomoses by gradual enlargement may become of practical importance, especially in cases of long standing. A case suggesting such possibility has been observed in the neurological department. The details of this case are being prepared for publication by A. Frøvig, but a brief summary may be given here to illustrate the practical consequences these anastomoses may possibly have for the collateral intracranial circulation:

The patient was a 58-year-old man with a right hemiplegia. Angiography was carried out on the left side. The shadows of the internal carotid artery were evident for only a few mm. above the bifurcation. The external carotid artery was completely visible and of normal appearance. The picture that under normal circumstances would be regarded as a phlebogram (that is, exposure after 4 seconds), showed that there was filling with the contrast both of the carotid syphon and of the middle cerebral artery in the Sylvian fissure. The carotid bifurcation was exposed by operation (Dr. Frøvig) and a piece of the internal carotid artery was excised, showing complete obliteration.

The cases depicted above illustrate different forms of occlusion of the internal carotid artery. Such cases have previously been frequently misinterpreted as cases of cerebral thrombosis. From our angiographic experiences we have learned that in cases of gradual or sudden development of hemiplegia the diagnosis of carotid thrombosis should be suspected and angiography, with such possibilities in mind, should not be omitted from the diagnostic procedures.

REFERENCES