Angiographic End-Results of Carotid Ligation in the Treatment of Carotid Aneurysm

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ANGIOGRAPHIC follow-up studies on patients with intracranial aneurysms treated by carotid ligation have been confusing.2-8 The posterior circle of Willis and posterior communicating arteries have not been regularly visualized. Only a fraction of the patients reported have had postoperative angiographic studies.

We have made a complete angiographic study of a group of patients who have had cervical carotid ligations, with particular emphasis on filling of the aneurysm via the vertebro-basilar system.

Material and Methods

The study included 20 patients in whom intracranial carotid artery aneurysms were treated by ligation of the carotid artery in the neck. Sixteen aneurysms were at the origin of the posterior communicating artery and 4 at the bifurcation of the internal carotid artery into the anterior and middle cerebral arteries. In each case we tried to demonstrate the cerebral circulation after ligation as completely as possible. In over 100 contrast studies in 20 patients, there was only 1 failure to obtain complete postoperative angiographic studies.

If the right carotid artery had been ligated, left carotid and brachial injections were made. If the left carotid artery had been ligated, the right brachial injection usually proved adequate unless the preoperative study had demonstrated an inadequate vertebral artery on that side,13 in which case right carotid and left brachial injections were made. When the internal carotid artery was patent following common carotid ligation, flow was effected through a vertebral-external carotid anastomosis, demonstrated by a brachial artery injection, rather than cross-filling from the opposite external carotid artery. When postoperative contralateral carotid injection visualized the anterior and middle cerebral arteries bilaterally but failed to fill the aneurysm, a brachial injection often revealed that the posterior communicating artery did supply the aneurysm. In 1 patient we did not attempt a postoperative brachial injection since placement of the needle in either arm caused immediate blanching of the arm and loss of the radial pulse; however, the desired vertebral artery visualization was obtained by reverse right carotid catheterization.

The 1 patient in whom we did not get complete angiographic studies had had a right carotid artery ligation and was known to have an atheromatous narrowing of the left carotid; placement of the needle in this vessel caused an almost instantaneous aphasia and hemiplegia which was completely reversible upon withdrawing the needle. Injection of contrast medium was not carried out in this case.

Several patients in this series had been operated on years before brachial angiography became routine in this clinic. These patients had follow-up brachial angiograms when seen in the course of annual follow-up visits as late as 7 to 10 years after operation. The most recent patients in this series have had routine angiographic re-examination before leaving the hospital.

Clinical Features

Subarachnoid hemorrhage. Three of the 20 patients had had a previous subarachnoid hemorrhage, 8 days, 2 weeks and 1 year earlier. The remaining 17 patients were all admitted because of an initial subarachnoid hemorrhage. The ages of the 20 patients ranged from 16 to 60 years with an average of 43 years.

Symptoms. Fourteen of the 20 patients had premonitory headache varying from 3 days to many years preceding the ictus. One patient had eye and face pain and 3rd nerve palsy for several days preceding his hemorrhage. Three patients had generalized seizures heralding their hemorrhage. Six patients developed 3rd nerve palsy. Two of these had either slight or no improvement, 2 cleared completely shortly after carotid ligation, 1 is presently improving and 1 died before significant follow-up could be obtained.

Twelve patients had initial paralysis varying from an isolated facial palsy to complete hemiplegia. Most of the hemiplegic signs disappeared spontaneously prior to ligation.

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Lt. = Left  
Rt. = Right  
P. Com. = Posterior Communicating  
C.C. = Common Carotid  
Int. Car. = Internal Carotid  
Ext. Car. = External Carotid  
Brach. = Brachial  
Opp. = Opposite  
Bifurc. = Bifurcation
One patient developed a severe hemiparesis 24 hours following arteriography and 10 days after her subarachnoid hemorrhage. The cause of this remains obscure, although she had severe long-standing hypertension with marked cerebro-vascular sclerosis. Her condition subsequently improved, leaving a mild residual hemiparesis and she tolerated a subsequent common carotid and second stage internal carotid ligation uneventfully. 

Complications. Two of the 20 patients developed complications attributed to operation. One of these, after tolerating common carotid ligation, developed aphasia and right hemiparesis 7 days following external carotid ligation and died following a contrast medium sensitivity reaction. The other patient developed a left-sided hemiplegia, hemihypalgiesia, homonymous hemianopsia and difficulty with conjugate gaze 1 day following common carotid ligation. At the time of discharge from the hospital 15 days later, minimal movement of the left fingers represented her only improvement. Within 12 months, she recovered sufficiently to carry on all her usual household duties, in no way incapacitated by a minimal persistent hemiparesis on her non-dominant side.

Follow-up. The 20 patients in this series have been followed for 1 to 10 years. The average is 3.75 years. Eighteen are living and well and 2 are dead. One death was due to sensitivity reaction to the contrast medium in the postoperative period; the other patient died 7 years after common carotid ligation, during a massive subarachnoid hemorrhage from an anterior communicating aneurysm which had not been revealed by the original angiography.

Analysis of Arteriograms

In 10 of our patients, the aneurysm was not visualized postoperatively; in 8 it was considerably reduced in size, and in 2 it remained unchanged.

Brachial arteriography. The importance of the brachial arteriogram is emphasized by the frequency with which it demonstrated the aneurysm postoperatively. In 9 of the 10 patients whose aneurysms were visualized, the lesion filled only through the posterior communicating artery following brachial injection. In only 1 patient in this series did a contralateral carotid injection fill an aneurysm.

In 10 patients, the postoperative brachial arteriogram was carried out from the same side as the ligation. In all of these patients, the vertebral artery was shown to anastomose with the external carotid branches via its muscular branches in the high cervical area and fill the external carotid in retrograde fashion (Fig. 1). Occasional additional contributions from the subclavian collaterals anastomosing with the external carotid were seen. In all patients who only had common carotid ligation, we were able to see the internal carotid filled to a variable degree from the external carotid. The frequency and consistency of this finding points out the importance of this collateral pathway. It has been previously reported that this collateral can flow in the reverse direction, with the external carotid filling the vertebral-basilar system in cases of stenotic or occlusive disease of the proximal vertebral arteries.

Anterior cerebral artery. Collateral filling of the anterior cerebral artery on the ligated side was accomplished in 19 of the 20 patients via the anterior communicating from the contralateral carotid. In 1 patient, there was no cross-filling from the injected carotid, nor was there any contribution from the posterior communicating. This patient, whose aneurysm no longer showed in the postoperative angiogram, suffered a hemiplegia postoperatively. The angiogram also showed a well developed vertebral-external

Fig. 1. (D.S.) Right brachial arteriogram 1 year after right common carotid ligation. Carotid system filled via vertebral-external carotid anastomosis. Aneurysm on internal carotid artery at origin of posterior communicating artery reduced in size from preoperative appearance.
carotid anastomosis which supplied the internal carotid, and the anterior and middle cerebals above the ligated common carotid. The patient made a satisfactory neurologic recovery.

In all of our patients the anterior cerebral artery showed preoperative filling on the side of the aneurysm, normally through the ipsilateral carotid. In 11 of these patients the contralateral carotid filled both anterior cerebals as well. It seems therefore, that preoperative bilateral filling of the anterior cerebals from the side opposite that of the intended ligation is a favorable sign for good collateral circulation. In 3 patients the carotid on the side of the aneurysm filled both anterior cerebals, and 1 of these patients developed hemiplegia. These data confirm previous observations on this point.6

Middle cerebral artery. The middle cerebral, on the other hand, filled collaterally in 9 cases from the contralateral carotid, in 6 from the ipsilateral posterior communicating, in 3 from contributions by both of these vessels, and in 1 case jointly from the ipsilateral posterior communicating and a persistent trigeminal artery. In the 20th patient the previously described vertebral-external
carotid anastomosis supplied the whole carotid system above the ligation.

*Arteriograms of same patients at various stages.* Three patients in this series had more than 1 series of follow-up arteriography. One patient (C. L.) was studied several days after common carotid ligation, again 10 days after external carotid ligation, and finally 9 months after discharge from the hospital. The first postoperative films showed the aneurysm unchanged and supplied primarily by the internal carotid artery which was effectively filled through the vertebral-external carotid anastomosis (Fig. 2). Arteriography following the 2nd stage ligation showed that the aneurysm was much smaller and supplied solely by the posterior communicating artery (Fig. 3). After 9 months there was no marked change.

The 2nd patient (D. S.) was studied several days after common carotid ligation; the aneurysm was unchanged and filled from the

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**Fig. 3. (C.L.)** Right brachial injection following second stage (right external carotid) ligation. Aneurysm markedly reduced in size and filled via posterior communicating artery.

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**Fig. 4. A.** Right carotid arteriogram demonstrating aneurysm and small persistent trigeminal artery (arrow).
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posterior communicating artery. However, after 3 months, arteriography demonstrated a 50 per cent reduction in the size of the aneurysm; it remained unchanged when re-examined a year later.

The 3rd patient (L. J.) had arteriograms 10 days and 3 months after common carotid ligation. Neither postoperative study showed any change in the lesion which filled from the posterior communicating artery.

Long-term follow up. The follow-up study in 6 of this series was made 3 to 10 years after ligation and in 3 of these, the aneurysms had been obliterated. In a 4th patient (C. W.) a small persistent trigeminal artery had been observed in the preoperative x-rays (Fig. 4A). Arteriography 3 years after ligation of the common and external carotid arteries revealed an enormous dilatation of the trigeminal artery, which, with contributions from the posterior communicating artery, was supplying the carotid system. In spite of this, the aneurysm was greatly reduced in size (Figs. 4 B and C). Another patient (E. D.) had arteriography 8 years after a 2-vessel ligation. The original aneurysm was unchanged, filling from the posterior communicating artery, but a large new parasellar carotid aneurysm was clearly demonstrated on the opposite side (Figs. 5, 6 and 7). The 6th patient (T. L.) was admitted with a massive subarachnoid hemorrhage and died after arteriography before surgical intervention. Seven years earlier, he had had a left common carotid ligation for an aneurysm at
Discussion

Björkesten and Troupp\(^1\) studied a group of 19 surgically untreated aneurysm cases and performed \(2^{nd}\) arteriograms after an interval varying from 2 weeks to 10 years. About 50 per cent of the aneurysms had remained unchanged in size while the other 50 per cent had grown larger. It was their impression that aneurysms of the internal carotid artery show a more marked increase in size after bleeding than do aneurysms in other locations. So when we find postoperative shrinkage or obliteration of an aneurysm, we can probably attribute the change to surgical interruption of carotid flow.

We were impressed that of the 10 patients in our series whose aneurysms appeared obliterated, 5 had had only the common carotid ligated; in the other 5 the common carotid plus either the internal or external carotid were ligated. Mount\(^3\) on the other hand concluded that ligation of the internal carotid artery was more successful than that of the common carotid. In an arteriographic study of 21 patients after ligation of the internal carotid artery, Mount and Taveras\(^6\) demonstrated backflow through the ophthalmic artery in all cases. In only 1 of our 20 patients did we observe collateral flow through the ophthalmic artery that filled the carotid syphon. Our findings are more in accord with those of Pitts\(^9\) who found that in
patients with carotid occlusion, filling of the ophthalmic collateral channel from the external carotid artery is indicative of inadequacy of collateral circulation about the circle of Willis. He further noted that these patients had the greatest neurologic disability. In our series, 18 patients have tolerated ligation without sequelae and, with the 1 exception noted, none developed an ophthalmic collateral pathway.

Mount and Taveras,4 in setting up guide lines for therapy of carotid aneurysms, noted that diffuse vasospasm indicated a collateral circulation that was inadequate for carotid ligation. In 8 patients we found angiographic evidence of severe generalized vasospasm on the side of the lesion; only 1 of these failed to tolerate the ligation. In our series there was no constant relationship between the clinical condition of the patients, the extent of demonstrable vasospasm on the arteriograms, and the ability to tolerate ligation.

We encountered 1 patient with a persistent trigeminal artery. Wise and Palubinskas5 described 7 cases of persistent carotid-basilar anastomosis, 2 of which were associated with aneurysms. They cited the low statistical incidence of its presence (0.001 to 1.5 per cent) and emphasized the importance of awareness of the anomaly. When a persistent trigeminal artery is present, the internal carotid artery may be the main source of blood supply to the distal portion of the basilar, superior cerebellar and posterior cerebral arteries. Surgical or spontaneous occlusion of the carotid artery in this situation could cause infarction of the upper brain stem. Furthermore, the possibility of atypical relationships of pressure and flow in the intracranial arteries caused by the anastomosis could alter the efficacy of carotid ligation, or could provide a useful channel of collateral circulation in case of spontaneous occlusion of vertebral, basilar or carotid vessels. In our patient, the trigeminal artery proved to be a useful source of collateral blood flow without jeopardy to the patient.

Some of the findings in long-term arteriographic followup are disturbing. Two of these patients developed aneurysms in secondary locations; one of them fatal. We have little doubt that the hemodynamic alterations caused by the unilateral interruption of carotid flow with consequent increase in contralateral cerebral blood flow and intracarotid pressure contributed to the etiology of the newly-formed aneurysms. The development of apparently iatrogenic aneurysms or enlargement of previously unrecognized aneurysms in 2 of 6 patients re-examined years after carotid ligation, suggests the need for more studies of this kind, especially since these lesions frequently occur in relatively young persons.

Summary and Conclusions

1) The effect of cervical carotid ligation on the angiographic appearance of intracranial carotid aneurysms has been observed in 20 patients at intervals varying from several days to 10 years postoperatively. In 10 patients, the aneurysm was apparently obliterated, in 8 it was considerably reduced in size, and in 2 it remained unchanged.

2) Consistent demonstration of the complete cerebral circulation was accomplished by the use of brachial angiography. The importance of this technique is emphasized by the fact that in 9 of 10 cases it demonstrated that the aneurysm was being filled through the posterior communicating artery. The injection of the opposite carotid artery alone would have failed to disclose the aneurysm.

3) In 10 patients the postoperative brachial angiogram was done on the same side as the ligated carotid and in all of these patients the vertebral artery was shown to anastomose with and fill the ipsilateral external carotid artery. Furthermore, the ipsilateral internal carotid artery filled via this pathway if only the common carotid vessel was ligated. Postoperative reliance on opposite carotid arteriography alone could lead to an inaccurate assessment of this situation.

4) Collateral filling of the anterior cerebral artery on the ligated side was accomplished in 19 patients via the anterior communicating artery from the contralateral carotid artery.

5) In 9 patients the middle cerebral artery filled from the contralateral carotid artery, in 6 from the ipsilateral posterior communicating artery, in 3 from contributions by both of these vessels, and in 1 from the ipsilateral posterior communicating artery and a persistent trigeminal artery. In 1 patient the vertebral-external carotid anastomosis filled the entire ipsilateral carotid system above the ligation.
6) Six patients were studied 3 to 10 years after ligation and 2 of these developed apparently new aneurysms in secondary locations during the intervening years.

7) It is probably worthwhile to do staged carotid ligations since common carotid ligation may be effective and is admittedly safer. Ligation of the internal carotid can always be done at a second stage if retrograde brachial arteriography proves that common carotid ligation alone was ineffective and that the external carotid artery is the important factor contributing to the maintenance of the aneurysm through a collateral system that develops within 7 days.

References