The Accuracy of Carotid Back Pressure as an Index for Shunt Requirements
A Reappraisal

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JAMES M. MALONE, M.D., AND WESLEY S. MOORE, M.D.

SUMMARY The accuracy of a carotid back pressure obtained to determine the need for an internal shunt has been questioned. Not all patients undergoing carotid endarterectomy require a carotid shunt while clinically significant cerebral ischemia can be prevented by selective use of a carotid shunt. From July 1977 to January 1980, 139 carotid endarterectomies were performed under general anesthesia at normal carbia and blood pressure. Indications for these procedures included stroke with maximum recovery (60); transient ischemic attacks (49); asymptomatic lesions (25); and non-lateralizing symptoms (5). Indications for use of a shunt consisted of previous ipsilateral stroke or an internal carotid artery back pressure of less than 25 mm Hg. All operations were performed under general anesthesia, and before carotid clamping 10,000 units of heparin were administered intravenously. On the basis of these criteria, 70 operations were done with a shunt in place, 60 (86%) of which required shunting because of prior cerebral infarction and 10 (14%) for back pressure less than 25 mm Hg. In 60 other operations, no shunts were used because back pressure was greater than 25 mm Hg; in 34 (49%) unshunted patients, back pressure ranged from 25 to 50 mm Hg.

Two serious complications occurred; 1 death among 122 patients (0.8%) and 1 stroke among 139 operations (0.7%). The death was due to a cholesterol embolus in the cerebral artery in the shunted group and the stroke occurred in the unshunted group. These data continue to support the criteria for selective shunting. Patients without prior cerebral vascular accidents whose back pressure is greater than 25 mm Hg have a simpler operation by avoiding the inconvenience and inherent risk of an internal shunt.

Most patients undergoing carotid endarterectomy can tolerate the period of occlusion necessary to complete the operation without neurologic complications. There are, however, two categories of patients who require an internal shunt; those who have inadequate collateral circulation through the circle of Willis and those with marginal blood flow to a relatively ischemic zone surrounding an area of cerebral infarction. These patients require some form of intraoperative protection to prevent a new ischemic event or extension of an existing infarct. The inability to identify these patients either by their symptoms or the angiographic appearance of their lesions has led to considerable debate concerning the simplest and safest methods of determining the need for intraoperative shunt placement.

The methods currently advocated include carotid back pressure measurements,1-6 local or regional anesthesia with normocarbia,7-14 hypercarbia with induced hypertension10,11 cerebral blood flow determination using 133Xe12-14 and continuous EEG monitoring.15-18 Jugular venous O2 saturation was studied, but not found to be reliable (19). Some investigators, accepting the fact that patients at risk may be difficult to identify, advocate routine shunt placement.20-22

Since our 1969 experience demonstrating that internal carotid artery back pressure of at least 25 mm Hg under local anesthesia provided adequate protection during carotid endarterectomy, we have used this pressure criterion exclusively to assess the adequacy of cerebral collateral blood flow.1 Our later studies showed that patients with a history of previous stroke on the side of the carotid operation were at increased risk during temporary carotid occlusion, and they constitute the only exception to the use of back pressure criteria for employing an intraoperative shunt.3

This report reevaluates use of carotid back pressure measurements in determining the need for a shunt to provide cerebral protection during carotid endarterectomy, and updates our recent 30-month experience with this technique.

Materials and Methods

From July 1977 to January 1980, 139 carotid endarterectomies were performed at the University of Arizona and Tucson Veterans Administration Hospitals. There were 102 men and 20 women aged 43 to 79 years (mean age, 62) of whom 23 were diabetic and 32 hypertensive. After a complete history and physical examination, these patients were screened for major risk factors: diabetes, ischemic heart disease, hypertension, cigarette smoking and hyperlipidemia. Each patient underwent Doppler ophthalmosonometry (OSM) and oculoplethysmography (OPG ZIRA) as a part of their initial evaluation.

Clinical indications for operation were a) stroke with maximum recovery (deficit persisting beyond 24 hours), 60 operations (43%); b) transient ischemic attacks (deficit present for less than 24 hours), 49 operations (35%); c) asymptomatic stenosis, 25 operations (18%); and 3) non-lateralizing symptoms with steno­sis, 5 operations (4%) (table 1).
TABLE 1  Clinical Indication for Operation

<table>
<thead>
<tr>
<th>Indications</th>
<th>No. (%) of operations</th>
</tr>
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<tr>
<td>Stroke with maximum recovery</td>
<td>60 (43)</td>
</tr>
<tr>
<td>Transient ischemic attacks</td>
<td>49 (35)</td>
</tr>
<tr>
<td>Asymptomatic stenosis</td>
<td>25 (18)</td>
</tr>
<tr>
<td>Nonspecific symptoms with stenosis</td>
<td>5 (4)</td>
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Following their noninvasive evaluations, 116 patients underwent 4-vessel arteriography via the femoral route using the Seldinger technique. Intracranial views were obtained for all patients. Six patients remained with classical hemispheric symptoms who were operated on without angiography because they refused the procedure, had underlying chronic renal disease or some other contraindication for using contrast media. A stenosis was regarded as significant if the intraluminal diameter of the internal carotid artery was reduced by 50% or more.

The arteriographic findings listed in table 2 show that 100 vessels had significant stenosis and 40 demonstrated significant ulceration. Carotid endarterectomy was performed under normocarbic general anesthesia with blood pressure maintained at ward levels. The carotid artery was exposed via a vertical incision along the sternomastoid muscle. Each patient received 10,000 units of heparin intravenously prior to carotid clamping. Carotid back pressure was measured routinely with the technique described (fig. 1). In patients who had an internal carotid back pressure of < 25 torr or a history of prior stroke, a Javid shunt was inserted. When the arteriotomy was closed, an arteriogram of the endarterectomized carotid artery was routinely obtained.

Results

One death occurred among the 122 patients (0.8%) and 1 stroke in 139 operations (0.7%). The death resulted from a cholesterol embolus to the middle cerebral artery, presumably dislodged during placement of the shunt. In this instance, the shunt had been inserted because of a previous stroke. He had been found to have an adequate internal carotid back pressure of 78 torr. We presume that the embolus was dislodged during placement of the shunt. The patient who developed a postoperative deficit had not been shunted because his internal carotid back pressure was 41 torr. Postoperatively, he developed expressive dysphasia and had continuing episodes of amaurosis fugax. Although the amaurosis attacks disappeared, he remained dysphasic. It is likely that this patient had an embolic episode, probably resulting from carotid manipulation during mobilization and/or embolization from a residual plaque.

Tables 3 and 4 describe the angiographic appearance of the lesions and group the patients according to the status of their vertebrobasilar and intracranial vessels. Among the 125 operations in which the status of the vertebrobasilar and intracranial vessels were known, 84 had no associated vertebrobasilar or intracranial disease; however, 11 (13%) had an internal carotid back pressure of < 25 torr and required a shunt. Of the 41 operations in which there was associated vertebrobasilar disease, 2 (5%) had internal carotid back pressure of < 25 mm Hg and a shunt was placed.

In the high-risk group of patients who had stenosis with contralateral occlusion, 5 had associated vertebrobasilar or intracranial disease and 1 required a shunt because of a back pressure of < 25 mm Hg. Of the

![Figure 1. Drawing showing technique for measuring internal carotid back pressure. A 22-gauge needle, with the distal third bent at approximately a 60° angle, is inserted into the common carotid artery so that the bent portion of the needle parallels the axis of the vessel. After systemic pressures are monitored and there is evidence of a good hemodynamic interface through the pressure tubing, the common carotid and external carotid arteries are clamped. The residual pressure in the system then reflects the back pressure down the internal carotid artery which should equal the perfusion pressure at the level of the middle cerebral artery.](http://stroke.ahajournals.org/)

<table>
<thead>
<tr>
<th>Arteriographic findings</th>
<th>No. (%) of arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral stenosis</td>
<td>29 (21)</td>
</tr>
<tr>
<td>Stenosis &amp; contralateral occlusion</td>
<td>11 (8)</td>
</tr>
<tr>
<td>Bilateral stenosis</td>
<td>26 (19)</td>
</tr>
<tr>
<td>Unilateral ulceration</td>
<td>25 (18)</td>
</tr>
<tr>
<td>Unilateral stenosis &amp; ulceration</td>
<td>34 (25)</td>
</tr>
<tr>
<td>Bilateral ulceration</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Operations without angiography</td>
<td>6 (4)</td>
</tr>
<tr>
<td>Exploration for total occlusion</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>
removing 6 who had no associated vertebrobasilar or intracranial disease. 1 required a shunt because he had low back pressure.

Case Reports

Case 1

A 64-year-old diabetic man presented with occlusive disease of the lower extremities causing intermittent claudication. At the time of physical examination, a bruit was noted over his left carotid bifurcation. Noninvasive studies suggested the presence of a high-grade stenosis. Selective 4-vessel angiography was performed which demonstrated a high-grade stenosis at the origin of the left internal carotid artery. His right internal carotid artery origin was relatively normal but with a siphon stenosis, and he had a high-grade stenosis of the dominant vertebral artery origin (fig. 2). A prophylactic left carotid thromboendarterectomy was performed, during which the blood PCO₂ was maintained at 40 torr and systemic blood pressure of 150/50; the internal carotid artery back pressure was 30 mm Hg. No shunt was used and the patient’s postoperative course was uncomplicated.

NOTE: This is an example of a patient with multiple extracranial and intracranial occlusive lesions in whom compromise of the collateral cerebral circulation would presumably require a shunt, but despite this angiographic pattern of disease, back pressure measurement demonstrated adequate collateral circulation and the operation could be performed without using an internal shunt.

Case 2

During the course of a routine physical examination, a 76-year-old man in excellent health, was found to have a bruit over the right carotid bifurcation. He was referred to the Vascular Laboratory for evaluation, where he underwent Doppler supraorbital and oculo-plethysmographic tests. Because the test patterns suggested bilateral carotid occlusive disease, cerebral angiography was performed. The arteriograms demonstrated a total occlusion of the left internal carotid artery at its origin, and a high-grade stenosis of the right internal carotid artery combined with an intraluminal filling defect (fig. 3). Inasmuch as this filling defect might have represented a friable thrombus, emergency operation was performed. The internal carotid artery back pressure was measured to be 45 mm Hg. A right carotid endarterectomy was done without a shunt. Upon opening the artery it was noted that there was a high-grade occlusive lesion from an atherosclerotic plaque in addition to a fibrin-platelet thrombus loosely attached to the underlying plaque. An operative arteriogram demonstrated a satisfactory technical result, and the patient’s postoperative course was uncomplicated.

Discussion

Approximately 85–90% of patients undergoing carotid endarterectomy without prior deficit can withstand the temporary period of occlusion required to complete the operation. However, 10–15% (14% in our present series) need to have a shunt to prevent
postoperative neurological complications. Since it is impossible to identify these patients on the basis of their clinical history and the arteriographic appearance of the lesions, routine shunt placement has been advocated, the proponents of which claim that it is safe, if it can be done without undue haste, and it facilitates closure of the arteriotomy. However, an in-laying shunt is somewhat cumbersome, making it difficult to visualize the end point. Moreover, there is danger of dislodging embolic material, elevating an intimal flap or providing a source for thrombus formation. Inasmuch as only 10–15% of patients require shunting, we favor the selective use of an internal shunt.

Included among the various techniques for ascertaining the need for shunt placement is the time-honored use of local or regional anesthesia, which requires occlusion of the carotid vessels for a period of 3 minutes while the patient is told to talk and move all 4 extremities. If any deficit is detected, a shunt is inserted and the operation continued.

The initial studies of Moore and Hall showed that the development of neurologic deficits during carotid occlusion under local anesthesia could be correlated with an internal carotid back pressure less than 25 torr. Patients who had pressures greater than 25 torr withstood carotid occlusion without neurologic sequelae; subsequently this pressure determined the need for shunt placement. These studies were repeated using halothane anesthesia, an agent known to increase regional cerebral blood flow, with similar results. Our later studies have demonstrated that patients with a history of a previous stroke appear to be at increased

Figure 2. A. Left carotid arteriogram, lateral projection, demonstrating a high-grade stenosis of the origin of the internal carotid artery with moderate disease involving the carotid siphon. B. AP view of the left carotid bifurcation providing another perspective of the high-grade stenosis involving the origin of the left internal carotid artery. C. Right vertebral artery orifice showing that the caliber of that vessel is small. D. Origin of the larger left vertebral artery showing a tight stenosis. E. Right carotid arteriogram demonstrating a high-grade stenosis in the distal portion of the siphon.
risk during temporary carotid occlusion and required the routine use of shunt. These patients constitute the only exception to the use of back pressure criteria for determining whether an indwelling shunt is needed during endarterectomy.

Jugular venous oxygen saturation and lactate levels have been found to be unreliable indicators, inasmuch as they are often unaltered by clamping even in the presence of regional ischemia. In addition, they reflect average oxygenation of the entire brain, or at best in one hemisphere, and are incapable of detecting regional disturbances in oxygenation.

Continuous intraoperative EEG monitoring has received increased attention as a means of assessing the need for a shunt. Callow has reported a 9% incidence of ischemic EEG patients which were immediately altered by use of a shunt. Utilizing EEG monitoring to determine the need for a shunt, he reported a 3.2% incidence of neurological deficit and 1% mortality rate in 399 carotid endarterectomies. We have not applied this technique because it involves cumbersome equipment as well as the presence of a neurologist to interpret the tracings during operation. Moreover, the EEG tracing is affected by anesthetic agents, bradycardia, and hypotension, and we do not know how much the cerebral metabolic regional oxygen requirements
must be reduced before EEG changes occur. Furthermore, the exact relationship between EEG changes and development of neurologic deficit has not been established. Experimentally, in the squirrel monkey, Sundt and Michenfelder have shown that the prolonged ischemic electrocorticographic changes produced by acute occlusion of the middle cerebral artery does not necessarily cause cerebral infarction and improvement occurs after flow is restored, depending on the length of ischemia.

One criticism of the use of back pressure measurements by the proponents of EEG monitoring has been the fact that ischemic EEG changes occur in the presence of high back pressure. It may be that these are patients who previously suffered a stroke, a group known to have increased incidence of intraoperative EEG abnormalities and a higher risk of postoperative temporary exacerbation of any existing neurological deficit. We postulate that in this group there is an area of a relative ischemia surrounding the infarct that is perfused through collateral vessels with a high resistance and therefore such patients are at greater risk during carotid occlusion.

Cerebral blood flow measurements using $^{133}$Xe have not been widely used because they are subject to considerable variability, are difficult to perform under operative conditions, may miss focal areas of ischemia, and show poor correlation with back pressure measurements.

We maintain that routine shunt placement is unnecessary and continue to use an internal carotid back pressure of 25 mm Hg pressure as a guide to shunt insertion. Inasmuch as we are dealing with a closed system, it does indeed provide a true reflection of collateral perfusion pressure. The objection that it may not reflect the pressure in the intracerebral vessels has not been substantiated. In their study of patients with intracranial aneurysms, Bakay and Sweet were un-
able to demonstrate any significant drop in pressure between the intracranial and cervical branches of the internal carotid artery. When the carotid was occluded in the neck, the percent of pressure drop in the internal carotid and its accessible branches was the same, providing further evidence that the back pressure measured in the cervical carotid correlated with the pressure in the intracranial vessels. Their series reinforces our belief that neither the clinical history nor arteriographic pattern of the lesions can be used to predict the need for a shunt. Although we routinely obtain intracranial views at the time of cerebral angiography to exclude the presence of concomitant arteriovenous malformation, intracranial aneurysms or tumors, they have not been helpful in deciding whether or not to use a shunt. Even in those high-risk patients with significant stenosis and contralateral occlusion, the decision to place a shunt was based solely on a history of prior stroke and on back pressure measurements. The additional presence of vertebrobasilar or intracranial disease in this group of patients increased the need for shunting from only 16% to 20%.

The combined use of back pressure measurements in selecting patients for shunt placement and the continued use of four vessel arteriography subsequent to carotid endarterectomy have minimized technical errors and complications and enable us to provide intraoperative protection to those who require it.

References

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