Improved Results with Carotid Endarterectomy

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Two hundred ninety patients undergoing carotid endarterectomy were reviewed. From 1968 to 1972, 188 patients had carotid endarterectomy under general anesthesia with use of a shunt and hypercarbia. Stump pressures were not recorded in this group. There were three deaths, three postoperative hemiplegias and two complications of transient limb weakness. From 1973 to 1975, 102 patients were operated on under local anesthesia with systemic Innovar and Sublimaze, normocarbia and intra-operative assessment of stump pressure. In this group there was one death, no hemiplegia, and no complications of transient limb weakness. Twenty of the 102 were shunted either on the basis of stump pressure or the loss of motor ability or consciousness on carotid clamping. Those shunted had stump pressures ranging from 10 to 70 mm Hg with a mean of 20 while those not shunted had stump pressures ranging from 20 to 85 mm Hg with a mean of 53 mm Hg. Five patients lapsed into unconsciousness despite internal carotid stump pressures of 30, 30, 34, 36 and 70 mm Hg respectively, thus requiring intraoperative shunting. This experience seriously questions the reliability of carotid stump pressure as the sole determinant to identify those patients who require intraoperative shunting. We have come full circle, back to operation under local anesthesia, since intraoperative assessment of the patient's motor ability and consciousness alone provide the only absolute criteria for assessing the need for intraoperative shunting. Since the operation can be performed with greater technical efficiency without a shunt and without the potential complications of shunting itself, it behooves the surgeon to have a reliable method of knowing when it is not required.

THE PAST 20 YEARS has seen the emergence of carotid endarterectomy as an increasingly accepted operation for the cure of transient cerebral ischemic attacks and hopefully the avoidance of permanent brain damage or stroke. As with so many surgical advances, the time from its conception to its practical application seems to have spanned an unnecessarily long period. As early as 1914 Hunt[14] wrote "The object of the present study is to emphasize the importance of obstructive lesions of the main arteries of the neck in the causation of softening of the brain and more especially to urge the routine examination of these vessels in all cases presenting cerebral symptoms of vascular origin. In other words, the writer would advocate the same attitude of mind towards this group of cases as towards intermittent claudication, gangrene, and other vascular symptoms of the extremities and never omit a detailed examination of the main arterial stem."

The first successful surgical attempt to reverse transient cerebral ischemia appears to have been performed by Loucks and associates operating at the Peking Union Medical College in Peking, China on February 12, 1936.[17] The patient was a 47-year-old Russian male suffering from intermittent attacks of right hemiplegia and aphasia. At exploration of the left neck, 10 cc of thorium dioxide was injected in the common carotid artery proximal to its bifurcation. A roentgenogram showed that none of the contrast media entered the internal carotid artery. Accordingly a small segment of the internal carotid artery was excised between ligatures. The arterial lumen was filled with grayish material which proved to be organized thrombus. The patient was said to have been dramatically improved by the operation. While the procedure was called an arterectomy after Leriche and was designed to cure what was thought to be spasm of the internal carotid artery, its apparent effectiveness may well have been to remove a source of cerebral emboli.

Fisher in 1951[11] emphasized the relationship between disease of the carotid artery in the neck and cerebrovascular insufficiency. He defined the basic nature of the lesion as atherosclerotic, noted again the occurrence of partial and complete occlusion, and described several syndromes associated with such occusive disease. He observed that in the presence of severe stenosis at the common carotid artery bifurcation, the distal vessels may be entirely free of disease.

The first successful reconstruction of a stenotic internal carotid artery was accomplished by Carrea, Molins, and Murphy[3] in 1951 in Buenos Aires by anastomosing the external carotid artery side to side to the internal carotid distal to the stenotic lesion. Their operation, however, was not reported until 1955.

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Strully and associates[24] in New York on January 23, 1953 correctly diagnosed a patient with thrombosis of the left internal carotid artery and while their attempts to remove the clot were unsuccessful, they demonstrated that direct thromboenterectomy of the carotid bifurcation might be feasible. They stated that an arterial bypass or thromboendarterectomy should be successful if the occlusion is localized and that early diagnosis and removal by thromboendarterectomy could result in reducing cerebral damage and prevent further insult caused by vascular insufficiency. Later on August 7, 1953 DeBakey successfully performed a carotid thromboendarterectomy but did not report it until 22 years later.[8]

On May 19, 1954 Eastcott, Pickering and Rob[9] reported a case that gave the greatest impetus to the development of carotid surgery and for some time later it was thought to be the first case. Their patient was a 66-year-old female who had transient attacks of left amaurosis fugax, aphasia, and contralateral paralysis of the right arm and leg. A direct puncture arteriogram showed what was thought to be an atheromatous obstruction of the origin of the external carotid artery. Operation was carried out under hypothermia of 28°. The external carotid artery was ligated and the obstructed bifurcation was excised and reconstruction was performed by anastomosising the common carotid directly to the internal carotid artery. Occlusion time was 38 minutes and no anticoagulants were employed.

Since these pioneering developments the place of surgery in the treatment of stenotic, occlusive, and ulcerated extracranial carotid vessels has become increasingly recognized as a means of preventing cerebral infarction in many patients.[4] The indications for such surgery have become better defined as have the techniques of operation with the result that morbidity and mortality rates are continually decreasing. However, since any morbidity or mortality while ever so low can be devastating, it behooves us to continually seek safer techniques for operation.

Patients and Methods

We have selected two specific groups of patients operated upon on our teaching vascular service over a seven year period to illustrate our changing concepts in the operative management of carotid endarterectomy which constitutes the primary extracranial surgical procedure for cerebral ischemia.

The review is comprised of 290 carotid endarterectomies. No private patients are included and the operations were performed almost entirely by our resident staff under supervision of the authors. Patient age ranged from 47 to 83 with a mean of 59; 42% were left-sided lesions and 58% right-sided lesions.

From 1968 to 1972 188 carotid endarterectomies were performed under general anesthesia with the use of an internal shunt, 5000 units of heparin, and arterial pressure and gas monitoring with induced hypercarbia. Stump pressures were not recorded in this group. There were three deaths, three post-operative hemiplegias, and two complications of transient limb weakness.

From 1973 to 1975 102 carotid endarterectomies were performed under local anesthesia consisting of premedication with Innovar and local infiltration with 1% xylocaine. Arterial pressure and blood gases were monitored by an intraarterial catheter in the wrist. Normocarbia was maintained and 5000 units of Heparin was given intravenously before crossclamping the carotid vessels. Stump pressures were recorded in this group and an anesthetist was present throughout the procedure to administer oxygen by mask and Sublimaze as necessary for restlessness. In this second group there was one death, no hemiplegia, and no complications of transient limb weakness. Twenty of the 102 patients were shunted with a conventional Javid shunt[15] either on the basis of stump pressure below 25 mm Hg or the loss of motor ability or consciousness on five minutes of trial clamping of the internal carotid artery. Those shunted had stump pressures ranging from ten to 70 mm Hg with a mean of 20 mm Hg while those not shunted had stump pressures ranging from 25 to 85 mm Hg with a mean of 53 mm Hg. Five patients lapsed into unconsciousness despite internal carotid stump pressures of 30, 30, 34, 36, and 70 mm Hg respectively, thus requiring intraoperative shunting.

Discussion

The risk of cerebral ischemia which must accompany crossclamping of the carotid vessels during the performance of endarterectomy appears to effect ten to 20% of patients depending on the extent of involvement of other vessels with the arteriosclerotic process and on variations in the collateral circulation.[1] Some authors feel that rather than try to identify this small but significant per cent of patients, all patients should be cerebrally protected by the use of an indwelling shunt.[15,26]

Most authors[2,7,12,13,20–23] including ourselves, however, feel that the technique of shunting itself has its own complications and therefore it behooves us to seek techniques to identify those patients who do not need shunting. The problems associated with the shunt itself include clotting within the shunt,[22] embolization of clots from within the shunt,[22,23] air introduced through the shunt,[21] dissection of a distal internal carotid artery intimal flap or dislodgement of atherosclerotic material by insertion of the shunt,[23,28] the need for a higher or

more proximal incision in the internal carotid artery to place the shunt above the diseased core, and finally the lack of an operative field unobstructed by the shunt.[23] The studies of Sundt and associates[22] are particularly of interest in regard to thrombus formation within the shunt itself. Between 1970 and 1975 they performed 515 endarterectomies, 183 of which were shunted with a silicone elastomer tube. All of their patients received 50 to 100 mg of heparin before carotid artery clamping and shunt insertion. Examination of the shunts at the end of the procedure during the years of 1970 to 1973 disclosed thrombus routinely within the lumen of the shunt, particularly at the proximal and distal orifices. Use of the scanning microscope showed the clots to consist of a fibrin meshwork containing platelets and red blood cells. On several occasions they documented thrombotic occlusion of the shunt with resultant acute deterioration of the electroencephalographic pattern and reduction of cerebral blood flow as measured by intraarterial injections of Xenon-133. One patient with a shunt in place suffered a permanent neurologic deficit from emboli, possibly arising from the thrombus accumulating within the shunt itself. Because of their experience with thrombosis of silastic shunts despite systemic heparin anticoagulation, in 1973 they switched to the use of TDMAC heparin-treated shunts. They state that they have not had any problems caused by thrombotic occlusion of the shunt nor have they been able to identify any thrombus deposits within the shunt lumens since adopting use of the heparin treated shunt. Certainly closer scrutiny of currently employed shunts should be made, particularly with electron microscopy at the completion of the operative procedure. Their studies would indicate that a shunt certainly should not be used more than once whether coated or not.

Some surgeons have used visual assessment of back bleeding from the open internal carotid artery to assess the need for a shunt, but such observations are certainly empiric and cannot be quantitated or recommended.

Monitoring of the jugular venous oxygen saturation[1,16] has proved to be less reliable than expected, mainly because it is more a reflection of global hemisphere perfusion and interhemispheric mixing of venous blood. This technique of judging whether a shunt is indicated has not stood the test of time and has generally been discarded.

Induced hypertension continues to be recommended by various authors but may be misleading. Its use may be similar to treating shock with vasopressors; the pressure is increased, but with a synchronous increase in vascular resistance, there is no improvement in tissue perfusion. Crawford et al.[6] administered neosynephrine to a patient who developed a convulsion three seconds after temporary occlusion of the internal carotid artery to test its effectiveness in maintaining normal cerebral function. Despite the fact that the mean brachial arterial blood pressure was raised from 105 to 175 mm Hg, the patient developed a second convulsion 45 seconds after occlusion, indicating the ineffectiveness of this agent in supporting the cerebral circulation in this case. Our experience has been that maintenance of P_{CO_2} within normal ranges in the absence of significant hemorrhage has provided adequate blood pressure without the use of pressors. Unsuspected hyperventilation during general anesthesia can markedly lower P_{CO_2} but the resultant decreased cerebral blood flow can be masked by pressor drugs.

Constant monitoring of the electroencephalogram during surgery has been employed by some surgeons[2] to monitor the need for intraoperative shunting. The technique appears to be a reliable guide of cerebral perfusion during carotid occlusion, especially when abnormalities are noted, but it may not be completely reliable when the tracings are normal. The technical aspects of the procedure also are not fool proof and a neurologist is usually required to be in attendance for accurate interpretation of the studies.

Both hypercarbia and hypocarbia have been advocated to enhance total cerebral perfusion during carotid crossclamping. One group of investigators[10] have postulated that there is an actual decrease in regional blood flow to ischemic areas of the brain to the advantage of the contralateral hemisphere with an intracerebral steal when hypercarbia is induced. On this basis they recommended that the safety of carotid crossclamping was enhanced by lowering the P_{CO_2}. While we once believed in induced hypercarbia, we along with most others working in this field feel that the evidence for hypocarbia or hypercarbia is not convincing, whereas the need for maintenance of normal ranges of P_{CO_2} is most important in ensuring optimal cerebral perfusion by way of contralateral extracranial vessels.

Crawford and associates[6] in 1960 first described internal carotid artery (ICA) back pressure or what has commonly become known as the stump pressure. They measured intraarterial blood pressure simultaneously, both proximal and distal to the clamped carotid bifurcation in 17 patients undergoing endarterectomy under local anesthesia. The level of the mean pressure in the proximally clamped internal carotid was correlated both with the development of neurologic deficits and the presence of contralateral internal carotid occlusion. The ICA pressure obtained distal to the region of temporary complete occlusion in these cases they felt represented pressure resulting from collateral blood flow within the cerebrum, since the internal carotid

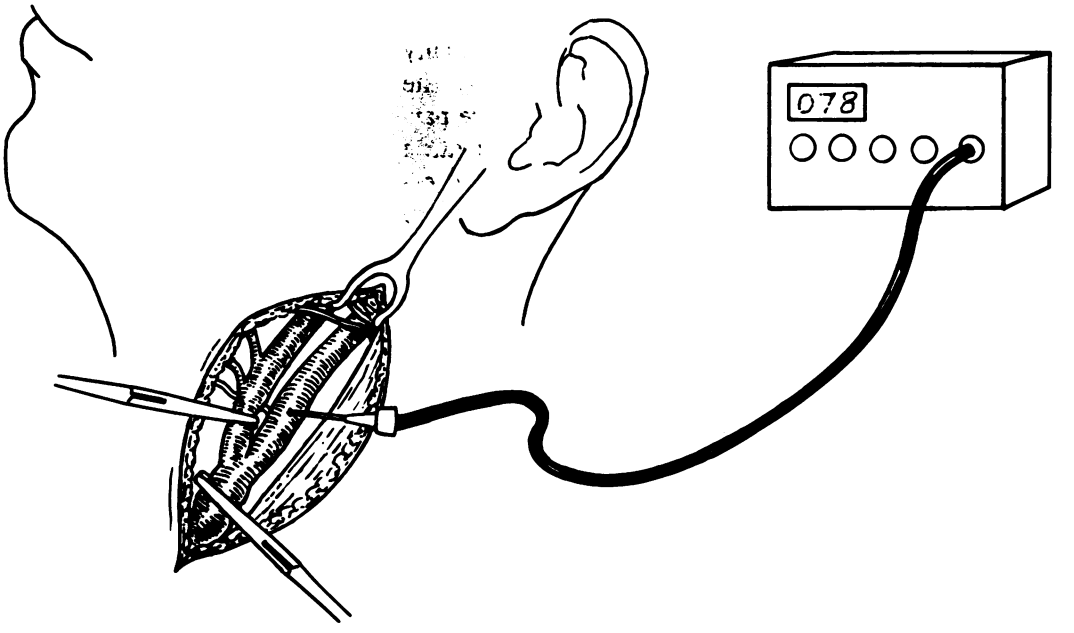

FIG. 1. Shows measurement of the internal carotid artery back pressure or stump pressure after exposure of the carotid bifurcation. The common and external carotid arteries have been clamped.

does not generally have extracranial branches. Three patients with mean stump pressures of 12, 20, and 42 mm Hg all had contralateral internal ICA obstruction and either lost consciousness or had aphasia and motor weakness between three seconds and two minutes of carotid clamping. Stump pressures of the other 14 patients ranged from 40 to 90 mm Hg and were not associated with neurological defect on carotid clamping. The authors stated that additional experience may prove this method to be helpful in the determination of minimal blood flow required during the period of operation.

Moore and associates[20] in 1969 stressed the clinical importance of ICA back pressure and popularized it as the stump pressure (Fig. 1). They operated upon a series of patients under local anesthesia so they could correlate the patients' conscious response to trial arterial occlusion with the level of measured back pressure. They decided on the basis of these studies that a 25 mm Hg stump pressure was the minimum pressure below which a shunt was required and above which the surgeon could clamp the carotid artery with assurance that collateral circulation was adequate. They[21] subsequently stated that patients with back pressures above 25 mm Hg who have had a history of a completed stroke of persistent neurologic deficit on the side of the operation should be shunted in spite of their apparently adequate stump pressures. They stated that the only information that could be gained in a careful analysis of angiographic findings suggests that patients are more likely to require a shunt if they have multiple lesions or contralateral internal carotid occlusion. However, 86% of their patients with contralateral occlusions did not need shunts.

Smith et al.[23] performing carotid endarterectomy under general anesthesia had three patients develop stroke with stump pressures of 25 to 50 mm Hg and one stroke in a patient with a stump pressure over 50 mm Hg. None of these patients were shunted as they were using 25 mm Hg as their criteria for shunting.

Hobson and associates[17] correlated patients' neurological status under local anesthesia with stump pressures and found that three of 22 patients with stump pressures of 70 mm Hg developed deficits during four-minute test occlusions, while two of 25 patients with stump pressures between 25 to 50 mm Hg developed neurological complications. Three of three patients with stump pressures below 25 mm Hg did not tolerate temporary carotid occlusion. They concluded that the ICA back pressure should exceed a range 60 to 70 mm Hg to insure adequacy of collateral cerebral flow if it is being used as the criteria under general anesthesia to select those patients who do not require shunting.

Hays and associates[12] recommended a shunt if stump pressures were below 41 mm Hg but felt shunting was not needed if the stump pressure exceeded 50 mm Hg.

Akl and associates[1] stated that in their opinion a mean stump pressure of over 25 mm Hg, after induction of systemic hypertension, is safe for the performance of endarterectomy without an internal shunt. However, they rarely employed shunts and felt that their morality of 2.5% and the total neurologic complication rate of 7.5% encountered in their series were within the range of complication rates reported by others who either routinely or commonly employed shunts. It may be that variations in P_{CO_2} may account for the apparent discrepancy in the reported critical levels of stump pressure.

When we first performed carotid endarterectomy some 20 years ago, we employed local anesthesia to assess the neurological condition of the patient during the operation. However, we subsequently switched to general anesthesia because of problems associated with operating on a restless, moving patient. Davies and associates[7] in 1972 reported on 219 carotid endarterectomies performed between 1959 and 1970 under local anesthesia. They stated that in their opinion no method of brain monitoring can be as accurate as utilizing the patient's own clinical response. They occlude all three carotid branches for three minutes and have found that those who cannot tolerate the occlusion rapidly become confused, hemiparetic, or unconscious. Sixteen per cent of their patients responded in this fashion and were shunted. The other 84% were not shunted. Once testing had been accomplished, supplemental fentanyl was administered to restless patients. In this series of 219 operations, there was a corrected operative mortality of 2.3%. Only two patients showed late worsening of preexisting neurologic deficit. Hobson and associates in 1974[13] reported a series of 50 carotid endarterectomies performed with the patient awake under regional anesthesia. A four-minute internal carotid artery test occlusion was used to determine the need for shunting. Twenty-one of the patients had an ICA back pressure of 55 to 85 mm Hg. Three of these patients with pressures of 70 mm Hg were unable to tolerate the period of test clamping of the carotid artery and developed neurological deficits during the test occlusion. Twenty-five patients had a mean ICA back pressure varying from 25 to 50 mm Hg. Two patients in this group demonstrated neurological deficits during clamping. A third group of three patients had a mean ICA back pressure below 25 and all were unable to tolerate test clamping of the carotid artery and internal shunting was required. These investigators concluded from their data that if the surgeon wishes to avoid the use of a shunt in the maximum number of patients, the technique of local anesthesia and test occlusion of the internal carotid artery is a reasonable and safe alternative.

Hays et al.[12] stated that they discarded the use of a three-minute test clamping of the internal carotid artery under local anesthesia because the method was found to be not totally reliable since some patients who tolerated three minutes of trial occlusion developed postoperative neurologic deficits with longer periods of operative occlusion. They did not, however, state whether there was evidence of clinical neurological change later during the endarterectomy which would have allowed immediate insertion of a shunt. If there was no discernable cerebral deficit at the completion of the operation under local anesthesia, subsequent neurological changes should not be attributed to the lack of a shunt but rather to thrombosis or late embolization secondary to technical error during the operation.

Several authors refer to a study by Wells and associates[27] in 1963 purporting to show that there is an increased tolerance to cerebral ischemia produced by general anesthesia. It is stated that 20% of patients who had carotid arteries occluded for 30 to 60 seconds without general anesthesia suffered convulsions. However, these occlusions were performed by manual external compression of the neck before any premedicating or anesthetic drugs had been administered and also without knowledge of the patient's P_{CO_2}. We do not think the postulations made by these authors under those conditions are warranted. Our patients come to the operating room with an average preoperative dose of 2 cc of Innovar, calm and relaxed. Xylocaine 1% is administered throughout the operative exposure and also infiltrated into the carotid sinus area. Sublimaze is given in 1 cc supplemental doses during the procedure to keep the patient relaxed but conscious. Each cc of Innovar contains 0.05 mg of fentanyl (a narcotic analgesic with actions qualitatively similar to those of morphine and meperidine) and Droperidol 2.5 mg (a drug that produces marked tranquilization and sedation). The combined effect of these drugs is sometimes referred to as neuroleptanalgesia, characterized by general quiescence, reduced motor activity, and profound analgesia; complete loss of consciousness usually does not occur from the use of Innovar injection alone. Oxygen is administered by mask throughout the procedure. If any neurological deficit is detected during test clamping or later in the procedure, a shunt is immediately inserted. Crossclamping of the carotid vessel is performed only after 5000 units of Heparin have been administered and an intraoperative P_{CO_2} is reported to be within normal limits. Clamping of the carotid vessels is least traumatically performed by using elastomer tapes controlled by a small right angle clamp. The carotid bifurcation must not be palpated or compressed before crossclamping to avoid intraoperative embolization.

In addition to obtaining the ICA back pressure with the distal internal and external carotid arteries clamped, we also test the effect on the stump pressure of opening of the external carotid artery. We reported our experience in 1973[5] on opening the external carotid artery by endarterectomy in 45 patients and pointed out its importance in the surgical management of extracranial cerebrovascular disease. Rich collateral anastomoses exist between the external carotid artery and

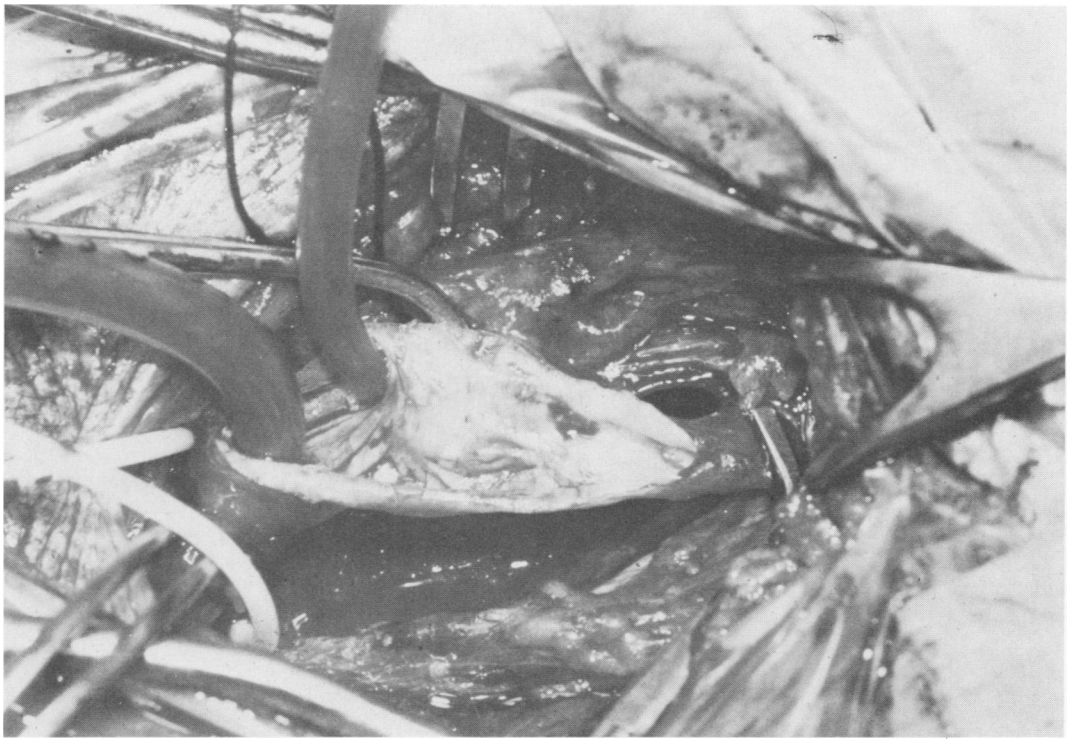

FIG. 2. Shows a Javid shunt used from the common carotid to the external carotid artery. The endarterectomy has been completed and closure is about to be performed. Note the unobstructed view of the internal carotid artery well above the removed disease process.

the intracranial circulation and these anastomoses may account for up to 30% of the intracerebral circulation in cases of bilateral internal carotid occlusion.

Machleder and Barker[18] in 1974 showed that when the external carotid artery was declamped that the ICA stump pressure rose to an average of 13.5 mm Hg in eight patients. This study corroborated our observations that the external carotid collateral circulation may have great importance in the maintenance of total cerebral blood flow and arterial pressure of internal carotid occlusive disease. They suggested that the ischemic effects of common carotid occlusion during endarterectomy of a severely stenotic internal carotid artery may be the result of interference with the crucial external carotid collateral flow rather than diminution of the already compromised internal carotid artery flow. They reported shunting from the common carotid to the external carotid arteries in four patients undergoing carotid endarterectomies. We have also applied this technique and it appears that it may be an attractive alternative method when it has been determined that a shunt is necessary and when one wants to avoid a high incision on the internal carotid (Fig. 2). Its use may be particularly attractive if pressure determinations at the beginning of the procedure show that an open external carotid significantly raises the stump pressure. Finally, it should be noted that a conventional shunt may be inserted from the common carotid to either the internal or external carotid arteries during the actual endarterectomy procedure if neurological ischemia is detected at any time by repeated communication with the conscious patient and assessment also of motor ability. Post-operative hypertension may occur following carotid endarterectomy but appears in our experience to be less common when clinical assessment of cerebral tolerance to crossclamping has been made under conscious operative conditions. Hypertension may well be the body's autonomic response to cerebral oxygen deficit and if the blood pressure is artificially lowered too much under such conditions, the patient may suffer further cerebral ischemia and permanent brain damage or even death. The blood pressure is constantly monitored for several hours postoperatively by arterial catheter and if it exceeds 200 mm Hg, it is artificially titrated down to 200 mm Hg but not lowered artificially ever below 180 mm Hg. Moore[19] reports post-operative stroke which he attributed to excessive lowering of the elevated post-endarterectomy blood pressure.

Conclusion

A comprehensive review of the literature on carotid endarterectomy with special reference to technique of operation plus a review of our experience with two different techniques on a single teaching vascular service has led us to the following conclusions:

1) The operative procedure of carotid endarterectomy without a shunt is technically easier and avoids

possible complications of the intraluminal tube itself. 2) It thus appears unreasonable to subject all patients to a more complicated procedure when only one or two patients in ten require a shunt, particularly if such patients can be reliably identified. 3) Visual assessment of back flow, electroencephalographic monitoring, and venous oxygen saturation determinations are not exact methods for such patient selection. 4) Internal carotid back pressure or stump pressure is a useful intraoperative tool but cannot be depended upon absolutely as a criteria for shunting. 5) The only proven absolute method to assess the safety of carotid endarterectomy without shunting is continuous neurological monitoring of the patient in the conscious state. 6) Carotid endarterectomy can now be performed under local anesthesia without difficulty in almost any patient by adjunct use of Innovar and Sublimaze. 7) Continuous arterial pressures and blood gas determinations are mandatory during and immediately after the procedure. The patient's P_{CO_2} must be in normal ranges before and during crossclamping of the carotid vessels to assure optimal contralateral cerebral perfusion. Extreme postoperative hypertension should be treated but not excessively. 8) When shunts are employed, they should be discarded after each use. It may be advantageous to use shunts coated with heparin or other nonthrombogenic substances. 9) Crossclamping of the carotid vessels is least traumatic if elastomer tapes are used, controlled by small clamps. Crossclamping of the carotid vessels with conventional vascular clamps may be the source of currently unrecognized embolic material. The carotid bifurcation must not be palpated or compressed before crossclamping to avoid intraoperative embolization. 10) Completion angiogram would appear to be helpful in identifying the occasional patient with incomplete operation.

References

1. Akl, B. F., Blakeley, W. R., Lewis, C. E., and Edwards, W. S.: Carotid Endarterectomy: Is a Shunt Necessary? *Am. J. Surg.*, 130:760, 1975.
2. Baker, J., Gluecklich, B., Watson, C. W., et al.: An evaluation of Electroencephalographic Monitoring for Carotid Study. Surgery, 78:787, 1975.
3. Carrea, R., Molins, M., and Murphy, G.: Surgical Treatment of Spontaneous Thrombosis of the Internal Carotid Artery in the Neck: Carotid-carotideal Anastomosis, Report of a Case. Acta. Neurol. Lat. Am., 1:71, 1955.
4. Clauss, R. H., Sanoudas, G. M., Ray, J. F., and Moallem, S.: Carotid Endarterectomy for Cerebrovascular Ischemia. Surg. Gynecol. Obstet., 136:993, 1973.
5. Connolly, J. E. and Stemmer, E. A.: Endarterectomy of the External Carotid Artery. Arch. Surg., 106:799, 1973.
6. Crawford, E. S., DeBakey, M. E., Blaisdell, F. W., et al.: Hemodynamic Alterations in Patients with Cerebral Arterial Insufficiency Before and After Operation. Surgery, 48:76, 1960.
7. Davies, O. G., Jr., Thorburn, J. D., and Powell, P.: Endarterectomy of the Internal Carotid Artery. Calif. Med., 116:15, 1972.
8. DeBakey, M. D.: Successful Carotid Endarterectomy for Vascular Insufficiency. JAMA, 233:1083, 1975.
9. Eastcott, H. H. G., Pickering, G. W., and Rob, C.: Reconstruction of the Internal Carotid Artery in a Patient with Intermittent Attacks of Hemiplegia. Lancet, 2:994, 1954.
10. Ehrenfeld, W. K., Hamilton, F. N., Larson, C. P., Jr., et al.: Effect of CO_2 and systemic hypertension on downstream cerebral arterial pressure during carotid endarterectomy. Surgery, 67:87, 1970.
11. Fisher, M.: Occlusion of the Internal Carotid Artery. Arch. Neurol. Psychiatr., 65:346, 1951.
12. Hays, R. J., Levinson, S. A., and Wylie, E. J.: Intraoperative Measurement of Carotid Back Pressure as a Guide to Operative Management for Carotid Endarterectomy. Surgery, 72:953, 1972.
13. Hobson, R. W., Wright, C. B., Sublett, J. W., et al.: Carotid Artery Back Pressure and Endarterectomy Under Regional Anesthesia. Arch. Surg., 109:682, 1974.
14. Hunt, J. R.: The Role of Carotid Arteries in the Causation of Vascular Lesions of the Brain, with Remarks on Certain Features of the Symptomatology. Am. J. Sci., 147:704, 1914.
15. Javid, H.: Can Surgery Prevent Stroke? Appraisal of Progress in Surgical Therapy. Surgery, 59:1147, 1966.
16. Larson, C. P., Jr., Ehrenfeld, W. K., Wade, J. G. ,and Wylie, E. J.: Jugular Venous Oxygen Saturation as an Index of Adequacy of Cerebral Oxygenation. Surgery, 62:31, 1967.
17. Chao, W. H., Kwan, F. T., Lyman, R. F. and Loucks, H. H.: Thrombosis of the Left Internal Carotid Artery. Arch. Surg., 37:100, 1938.
18. Machleder, H. I. and Barker, W. F.: External Carotid Artery Shunting During Carotid Endarterectomy. Arch. Surg., 108: 785, 1974.
19. Moore, W. S.: Personal Communication.
20. Moore, W. S. and Hall, A. D.: Carotid Artery Back Pressure. A Test of Cerebral Tolerance to Temporary Carotid Occlusion. Arch. Surg., 99:702, 1969.
21. Moore, W. S., Yee, J. M., and Hall, A. D.: Collateral Cerebral Blood Pressure. An Index to Tolerance to Temporary Carotid Occlusion. Arch. Surg., 106:520, 1973.
22. Piepgras, D. G. and Sundt, T. M., Jr.: Clinical and Laboratory Experience with Heparin-Impregnated Silicone Shunts for Carotid Endarterectomy. Ann. Surg., 184:637, 1976.
23. Smith, L. L., Jacobson, J. G., and Hinshaw, D. B.: Correlation of Neurological Complications and Pressure Measurements During Carotid Endarterectomy. Surg. Gynecol. Obstet., 143: 233, 1976.
24. Strully, K. J., Hurwitt, E. S., and Blankenberg, H. W.: Thromboendarterectomy for Thrombosis of the Internal Carotid Artery in the Neck. J. Neurosurg., 10:474, 1953.
25. Thompson, J. E.: The Development of Carotid Artery Surgery. Arch. Surg., 107:643, 1973.
26. Thompson, J. E. and Talkington, C. M.: Carotid Endarterectomy. Ann. Surg., 184:1, 1976.
27. Wells, B. A., Keats, A. S. and Cooley, D. A.: Increased Tolerance to Cerebral Ischemia Produced by General Anesthesia During Temporary Carotid Occlusion. Surgery, 54:216, 1963.
28. Wylie, E. J.: Discussion of Wells et al. Surgery, 54:216, 1963.

Discussion

DR. JESSE E. THOMPSON (Dallas, Texas): I would like to comment about *general* anesthesia for carotid surgery, since this is what we presently use. We previously used local anesthesia, but some years ago switched over to general, and have found it most satisfactory.

One of the chief causes of operative-related strokes is embolization from a necrotic plaque during manipulation of the artery. This