Carotid ligation for recurrent ischemia due to inaccessible carotid obstruction

Examination of the rationale of this treatment

ROGER W. COUNTEE, M.D., THURAIRASAH VJAYANATHAN, M.D., OTAKAR R. HUBSCHMANN, M.D., AND PAMELA CHAVIS, M.D.

Sections of Neurological Surgery and Neuroradiology, and Department of Ophthalmology, College of Medicine and Dentistry of New Jersey, New Jersey Medical School, Newark, New Jersey

Experiences with a patient with symptomatic obstruction to the carotid artery in its petrous segment are described. In spite of the severe stenosis of this vessel, complete cerebral arteriography demonstrated excellent perfusion of the symptomatic eye and hemisphere and an ample collateral reserve. Funduscopy confirmed the clinical impression that recurrent retinal and hemispheric ischemia in this patient was the result of microembolism rather than intracranial hemodynamic insufficiency. Consequently, extracranial-intracranial (EC-IC) bypass was believed to offer little benefit to this patient. Abrupt ligation of the internal carotid artery in the neck proved to be an effective method for arresting the embolic discharge from this vessel’s inaccessible obstruction, and resulted in prompt and complete relief of ischemic symptoms. It is concluded that identifying the mechanism(s) responsible for recurrent ischemia past uncorrectable carotid obstructions is of paramount importance in order to establish the most appropriate treatment(s). Carotid occlusion is an effective surgical remedy for terminating microembolism from this vessel when it is diseased and incompletely obstructed, and should be considered in selected patients. The importance of angiographic evaluation of naturally occurring EC-IC anastomotic connections in addition to the assessment of intracranial collateral reserves in cases of carotid occlusion is also emphasized.

KEY WORDS • transient ischemia • amaurosis fugax • carotid occlusion • inaccessible carotid obstruction • carotid ligation • extracranial-intracranial bypass

In patients with obstructive carotid artery disease in whom endarterectomy is not technically feasible, extracranial-intracranial (EC-IC) microvascular bypass has become an increasingly popular surgical approach to relieve recurrent symptoms of ipsilateral ischemia.6,28,37,38,41,42 However, a significant number of patients who undergo these procedures will continue to have recurrent ischemic symptoms in spite of a technically successful operation and a patent anastomosis.6,15,24,37,38,42 The need for more clearly defined indications for these operations as well as other surgical procedures designed to relieve recurrent ischemia in such patients has been recognized. In the evaluation of patients seen in our clinic we vigorously attempt to identify the mechanism(s) of recurrent symptoms in each individual patient, and to understand the physiological significance of the various obstructive lesions visualized arteriographically. As a result of this approach, we have often recognized that many patients initially considered as good candidates for EC-IC bypass would, in fact, be better served by alternative operative procedures.6,9

This communication describes our experiences with a patient in whom abrupt ligation of the internal carotid artery (ICA) in the neck proved to be the operation of choice for the relief of recurrent ischemia distal to a severe stenosis of this vessel in its petrous segment. We believe that the merits of this surgical approach to the management of certain situations of
symptomatic inaccessible obstruction of the carotid artery warrant examination.

Case Report

This 56-year-old, right-handed, normotensive truck driver was admitted to the hospital in February, 1979, for complaints of recurrent episodes of transient blindness in the right eye for the previous 8 months. He also reported several fleeting episodes of weakness of his left hand and drooping of the left side of his face. Each of these complaints apparently occurred independently of each other, and typically lasted for only seconds to at most 3 to 5 minutes. The recurrent episodes of monocular blindness, however, were becoming progressively more frequent, and the patient reported as many as 10 to 20 attacks per day for the 3 weeks before his admission, in spite of the institution of aspirin and dipyridamole.

Examination. This generally healthy, slightly obese man was neurologically intact, with normal blood pressures in both arms. Ophthalmological evaluation demonstrated a normal fundus and visual fields and a corrected visual acuity of 20/20 in each eye. Retinal artery pressures determined by Baillart ophthalmodynamometry were 94/40 in the right eye and 104/60 in the left eye. There was no appreciable change in these pressures when measured with the patient supine or sitting. Systolic retinal artery pressures measured by the Gee method of oculoplethysmography were 97 mm Hg in the right eye and 110 mm Hg in the left eye. With percutaneous right common carotid artery compression, these pressures measured 78 mm Hg in the right eye and 108 mm Hg in the left eye, which implied an adequate collateral blood pressure to the right hemisphere.

Computerized tomography (CT) scan, technetium-99 dynamic and static brain scans, chest x-ray film,
Carotid ligation for recurrent ischemia

Fig. 2. Preoperative selective right external carotid angiogram. The orbital branches (arrowheads) of the internal maxillary artery (M) are seen to anastomose with the ophthalmic artery (B). The origins of the external carotid (A), the superficial temporal (ST), and the middle meningeal (MM) arteries are also opacified.

electrocardiogram, hemogram, urinalysis, and serum electrolytes and lipids were all normal.

A selective arteriographic evaluation of the entire cerebrovascular circuit was performed using retrograde femoral catheter technique. Right common carotid injection revealed severe stenosis (more than 90%) of the right ICA in its petrous segment (Fig. 1), with minimal atheromatous changes of the common carotid bifurcation in the neck. There remained, however, good antegrade filling of the intracranial segments of the right ICA and the right middle cerebral artery. The right ophthalmic artery and its orbital branches were normal and were filled in antegrade fashion. Selective right external carotid angiography was performed to estimate the size of the superficial temporal artery branches, but it also revealed good internal maxillary-ophthalmic artery anastomotic connections (Fig. 2). The remainder of the brachiocephalic vessels were completely normal. There was excellent collateral flow to the right ICA distribution from the left carotid artery (Fig. 3), as well as from the vertebrobasilar system via a large right posterior communicating artery (Fig. 4).

From the cerebral and ocular flow patterns demonstrated arteriographically, it seemed that arterial-to-arterial emboli rather than intermittent hypoperfusion through the right ICA was the best explanation for this patient's recurrent ischemic symptoms. This thesis was later confirmed when the patient suddenly experienced complete visual loss in the right eye, and a platelet embolus was visualized in a superior temporal branch of the right central retinal artery. Although vision subsequently improved substantially, the patient was left with a large central scotoma. It was clear at this point that the goals of surgical therapy in this patient should be to protect the right hemisphere and retina from future embolic insults. It was believed that EC-IC microarterial bypass could not be expected to accomplish this goal. Therefore, ICA ligation was subsequently carried out.

Operation. The right common carotid bifurcation was exposed under general endotracheal anesthesia. Normal blood pressures, normothermia, normocapnia, and normovolemia were rigidly maintained throughout the perioperative period. The right ICA was abruptly ligated just above its origin, after the intravenous administration of 2500 units of heparin. The lumen of the common carotid bifurcation was found to be normal when inspected through an arteriotomy incision that had been carried into the external carotid orifice. A temporary common carotid to external carotid shunt was employed. The origin of the ICA was resected so as not to leave a stump, and was incorporated into an angioplastic repair designed to make the external carotid the outflow tract of the common carotid artery. At the completion of the procedure the heparin was not reversed.

Postoperative Course. The patient's postoperative course was totally uneventful, and all ischemic symptoms promptly ceased. Repeat selective arteriography 1 week postoperatively showed excellent filling of the intracranial portion of the right ICA as well as from the vertebrobasilar system. The right ophthalmic artery was enlarged and was amply opacified by the ipsilateral external carotid artery and filled the right intracranial ICA in its supraclinoid and distal cavernous segments in retrograde fashion (Fig. 5). The patient has remained completely free of symptoms and neurologically intact during the 14 months since his operation. His field defect in the right eye has remained unchanged.

Discussion

The goal of EC-IC bypass in patients with symptomatic but inaccessible carotid obstructions is to augment collateral blood flow to areas of neural tissue that are thought to be marginally perfused.6,29,37,38,41,42

J. Neurosurg. / Volume 53 / October, 1980

493
It is assumed that such areas of borderline flow are particularly vulnerable to subtle changes in intracranial hemodynamics which may or may not be accompanied by changes in systemic blood pressure and/or retinal arterial pressures. Transient neuronal dysfunction in this setting is believed to result from intermittent hypoperfusion of these areas of borderline flow. Consequently, the rationale of EC-IC bypass in these situations is in large part predicated upon a nonembolic mechanism of alterations in regional cerebral or retinal blood flow. The wisdom of such a premise, which excludes or diminishes the possible causative role of microembolism in recurrent transient ischemia past severely obstructed or occluded ICA's, must be questioned, however, particularly in the light of recently published experiences. Although Sundt, et al., have theorized that surgically augmented collateral flow enhances the hemisphere's ability to withstand subsequent emboli without consequent infarction, we believe that continued and unabated embolic phenomena may well account for the failure of patent microarterial bypasses to terminate recurrent ischemic symptoms in many of these patients.

In patients with carotid artery obstructions who manifest recurrent retinal ischemia, microembolism is believed to be the most frequent cause. There is evidence that this embolic mechanism is operative even in cases of severe carotid artery stenosis as well as in some cases of completed carotid artery occlusions. The merits of EC-IC bypass in these situations should, therefore, be questioned as well. On the other hand, operations that accomplish the removal of sources of emboli to the ophthalmic artery, either from the common, the internal, and/or the external carotid arteries, have almost routinely enjoyed a high degree of success. It is noteworthy that recurrent ischemia of the eyes and hemispheres may commonly cease after spontaneous occlusion of the offending carotid artery. Although this important feature often seen in the natural course of carotid occlusive disease was recognized by Fisher almost 30 years ago, its significance is frequently overlooked. The efficacy of safely arresting the embolic discharge of a diseased carotid artery in this manner is amply demonstrated by our experiences with this patient. Gee, et al., have reported a similar experience with five of six patients.
Carotid ligation for recurrent ischemia

![Preoperative left vertebral angiograms, anteroposterior (left) and lateral (right) views. Excellent perfusion to the right internal carotid (C) and middle cerebral (MC) arteries via a large right posterior communicating artery is demonstrated. LV = left vertebral artery.](image)

The course and consequences of spontaneous as well as surgical ICA occlusions are variable, and a detailed discussion of this extensive topic exceeds the intent of this report. However, certain conflicts that arise from the various explanations, or the lack of explanations, given to account for the inconsistent outcome of ICA occlusions do warrant further scrutiny. Although an intolerable reduction in blood flow to the ipsilateral hemisphere is a major concern, it is widely appreciated that many of these occlusions will be well tolerated and will remain completely asymptomatic. Moreover, some reports have indicated that cerebral blood flow may actually increase in both hemispheres after an ICA ligation. Clearly, however, the acute and irreversible interruption of blood flow through an ICA is well recognized for its pernicious potential. In the cooperative aneurysm study, the incidence of ischemic neurological deficit after the abrupt ligation of an ICA was 59%. Similarly, morbidity and mortality from cerebral ischemic complications have been reported to be as high as 75% after the abrupt ligation or resection of a carotid artery in patients undergoing head and neck operations. Although graduated occlusion of a carotid artery is generally believed to give an added margin of safety, experiences with this approach have not been uniform. In a series reported from the Mayo Clinic, ischemic complications occurred in 24% of patients after abrupt carotid ligations, and in 38% of patients after gradual occlusions. It is noted that cerebral ischemia may commonly not become manifest in either case until several hours or even several days after the carotid ligation is complete. To date there remains no universally accepted explanation for the cause(s) or the timing of ischemic events consequent to surgical carotid ligations or spontaneous carotid occlusions.

Although it is generally accepted that the functional adequacy of the cerebral collateral circulation is a major determinant of the ultimate outcome of ICA occlusion, it is recognized that this thesis as well may be incomplete. A variety of methods for assessing the functional status of the collateral circuit in a given individual and, thereby, predicting his ability to tolerate the interruption of carotid blood flow have been recommended. The multiplicity of measures that have been advocated, as well as the conflicting claims for and against each, have indicated, however, that none is infallible. Arteriography has proven to be a very accurate method in our experience, as this case demonstrates. In the specific circumstances of the patient in this report, the symptomatic ICA obstruction had already insidiously advanced to an almost complete occlusion, and three alternative sources of collateral blood supply to the ipsilateral carotid distribution had already been recruited. Selective arteriography enabled us to not only identify these
collateral pathways but to quantify their functional adequacy as well (Figs. 2–4). Moreover, Gee’s method of determining collateral hemispheric blood pressure by the simultaneous measurements of bilateral ophthalmic artery pressures during ipsilateral common carotid artery compression gave additional support to our conclusions drawn from the assessment of preoperative arteriograms.\textsuperscript{16,32} From our growing experience with naturally occurring external carotid to intracranial collateral anastomoses, we would emphasize that the circle of Willis need not be the major source of a robust and ample collateral blood supply to the territory of an occluded ICA.\textsuperscript{9}

In patients in whom collateral hemispheric blood flow is believed to be insufficient to tolerate an ICA ligation, surgical augmentation of collateral blood flow with EC-IC bypass has recently been recommended as a prelude to the ICA ligation.\textsuperscript{10,17,23} Although the theoretical benefits of such preocclusion augmentation procedures seem sound, reported experiences have not been uniform.\textsuperscript{15,23} Moreover, the crucial question of whether these augmentation procedures afford a greater degree of safety for abrupt ICA occlusion, which we believe was necessary in the circumstances of our patient, has as yet been incompletely answered.\textsuperscript{10,15,17,23}

In addition to the morphology of available collateral reserves, other variables must come into play in the course of an ICA occlusion and, acting in concert, probably determine the ultimate outcome of the occlusion as regards consequent cerebral ischemia.\textsuperscript{16,26,27} Meticulous attention to various factors during the perioperative period, such as arterial blood gases, intravascular blood volume, systemic blood pressure, and pharmacological agents that affect cerebrovascular responsiveness, which were carefully
Carotid ligation for recurrent ischemia

controlled in our patient, are important elements involved in the success of elective ICA ligations. Likewise, postocclusion events, such as propagating thrombus in the distal ICA and/or postocclusion embolic phenomena, are additional variables that merit attentive perioperative consideration. Since “stagnation thrombus” does not usually propagate beyond the first significant collateral branch of an occluded ICA, preoperative arteriographic quantification of collateral flow to the ICA itself, in addition to the assessment of collateral hemispheric flow, may be useful in estimating the probable limits of anterograde extension of any postocclusion thrombus. Preservation of unobstructed flow through the external carotid artery ipsilateral to the ICA ligation may likewise offer considerable benefit, particularly when preoperative angiograms have demonstrated that this vessel is an important intracranial-ICA collateral (Figs. 2 and 5). Furthermore, we would emphasize that operative maneuvers designed specifically to preclude the possibility of intra- and postoperative microembolism through these important collateral vessels, from atheromatous lesions near their origin and/or from thrombus in residual “stumps” of the occluded ICA’s, are technical considerations of major importance. Perioperative anticoagulant therapy with heparin, a luxury not usually afforded in aneurysm patients but an intraoperative adjunct used in our patient, may indeed offer additional benefits in elective ICA ligations, as Leikensohn, et al., have suggested.

Anticoagulant therapy alone for the management of our patient’s symptoms was recognized as a rational alternative treatment modality and was indeed given due consideration. Although there remains some controversy about the role of anticoagulant drugs in the management of occlusive cerebrovascular disease, there is ample evidence to support the efficacy of this therapeutic modality in the management of transient ischemic attacks. From our own experience, as well as those recently reported by others, we believe that anticoagulant therapy is particularly effective in carefully selected individuals who have appropriately placed arterial lesions demonstrated angiographically and/or in whom there is good presumptive evidence that microembolism is the pathogenetic mechanism responsible for their transient ischemic symptoms. Our enthusiasm for the use of long-term anticoagulant therapy in the treatment of patients with carotid occlusive disease is tempered, however, by the recognition of its significant potential risks. Since the risk of significant complications from anticoagulant therapy is about 10% even in well controlled individuals, and the risk of complications from elective carotid surgery in our hands, both thromboendarterectomy as well as ligation, has been kept below 1%, we have reserved anticoagulation for patients who are either too fragile medically for the rigors of surgery or who decline operation. Moreover, the controversy as to how long the period of risk exists for patients with transient ischemic attacks and, consequently, how long should their anticoagulant therapy be continued are important questions that in our opinion remain incompletely answered. It is for these reasons, as well as because of significant doubts as to the reliability of medical compliance in our particular patient, that surgery was believed to be the most prudent therapeutic course. We conclude that the dynamics responsible for recurrent transient ischemia distal to carotid obstructions are variable. Therefore, attempting to identify the mechanism(s) operative in a particular patient should be a major goal of his evaluation. With improved insights concerning the pathophysiological significance of the various lesions visualized at arteriography, one can more rationally match the individual patient with the most appropriate therapy. When hypoperfusion appears to be the major cause of symptoms, surgical procedures designed to enhance flow through, or around, a carotid obstruction are in order. However, if microembolism is the responsible etiology, termination of embolic phenomena should be the major goal of management. Although anticoagulant therapy has a rational basis and proven efficacy in these specific circumstances, we believe that surgery offers superior benefits, particularly when it can be done with significantly lower risks.

Ligation of a partially patent and diseased carotid artery is an effective and often overlooked surgical method of arresting the embolic discharge from this vessel, and should be considered in carefully selected situations. Abrupt ICA ligation in the specific setting of an already advanced stenosis should be distinguished from other circumstances where this operation is more customarily employed as regards the risks of ischemic complications. In these particular patients alternative collateral pathways are frequently already well established and are, therefore, often more easily identified and more reliably quantified as to their functional adequacy of collateral reserves, and especially the morphology of naturally occurring EC-IC anastomotic connections, is strongly emphasized. Surgical augmentation of collateral cerebral blood flow with EC-IC bypass as a prelude to ICA ligation should be considered when spontaneous collateral flow is determined to be inadequate. Surgical techniques that obviate the possibility of microembolism via collateral routes and rigid control of various physiological parameters during the perioperative period should be recognized as crucial elements in avoiding the untoward effects of ICA ligation. We
believe that aggressive and well reasoned surgical therapy is warranted in these patients when vital visual and neurological function can be protected from the ravages of stroke.

Addendum

Since the initial preparation of this manuscript, we have had occasion to successfully treat another patient in this manner. This second patient had recurrent episodes of postoperative observation. This patient has remained neurologically intact and asymptomatic for the 4-month period of postoperative observation.

References


Carotid ligation for recurrent ischemia


Address reprint requests to: Roger W. Countee, M.D., Section of Neurological Surgery, New Jersey Medical School, 100 Bergen Street, H592, Newark, New Jersey 07103.