Surgical Treatment of Atherosclerotic Occlusive Lesions in Patients with Cerebral Arterial Insufficiency

By E. Stanley Crawford, M.D., Michael E. De Bakey, M.D., William S. Fields, M.D., Denton A. Cooley, M.D., and George C. Morris, Jr., M.D.

Cerebral vascular disease, according to the results of arteriography, may be caused by extracranial arterial lesions in one third of the cases. Observations in 174 cases are described. The results of surgical treatment in 63 patients are presented and evaluated on the basis of restoration of circulation, clinical improvement, and survival. The implications regarding diagnosis and indications and contraindications for surgery are discussed.

It is now well established that cerebral arterial insufficiency may often be caused by atheromatous occlusive lesions located in the extracranial portions of the arteries supplying the brain. Although its incidence has not been accurately determined, more extensive application of arteriography in the study of such patients suggests that this type of occlusion occurs in more than one third of the cases of cerebral arterial insufficiency. While the occlusive process may be variable in its pathologic features, it tends to assume certain characteristic patterns, particularly as to location, with the most frequent sites being at the origins of the internal carotid, innominate, left common carotid, and vertebral arteries. Multiple lesions are frequent, occurring in 40 per cent of the cases. The limitations of collateral circulation imposed by this frequency of multiple arterial involvement, the progressive nature of the occlusive process, and the dismal prognosis resulting from conservative therapy emphasize the desirability of a more direct attack designed to restore normal blood flow and preserve cerebral function.

Fortunately, these lesions are well localized, with the artery being relatively normal both proximal and distal to the occlusion, particularly in the early stages of the disease. These pathologic features of the lesion have led to the application of certain operative procedures that have proved effective in the treatment of similar lesions occurring elsewhere, namely, the aorta, and the iliac, femoral, and popliteal arteries. The well-localized lesion may be removed by endarterectomy. In other instances when the lesion is more extensive, the occlusion may be bypassed with a graft. Following the successful application of this direct surgical approach in a patient with occlusion of the left carotid artery on August 7, 1953, we have employed this form of therapy in the treatment of 88 lesions occurring in patients with cerebral arterial insufficiency, and this report is concerned with an analysis of these cases.

Clinical Material

Arteriographic studies were performed in 174 consecutive patients with the clinical manifestations of ischemia of the brain or upper extremity. Extracranial arterial occlusion was demonstrated in 73 patients (42 per cent). Operation was employed in the treatment of 63 of these patients, and those cases form the basis of this study. The remaining 10 patients are excluded because they had complete occlusion of the internal carotid artery of long duration, which extended well into the intracranial portions of the artery. In the light of experience obtained early, these cases were considered inoperable on the basis of the arteriographic findings.

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SURGERY FOR CEREBRAL ARTERY OCCLUSION

PATHOLOGY

A total of 115 extracranial arterial occlusive lesions occurred in the 63 patients submitted to operation. The limitations of collateral circulation in these cases were emphasized by the presence of multiple lesions in 32 patients (50 per cent). Of the 115 lesions, 88 were explored surgically (table 1). The remainder were considered to be inoperable due to the extent of occlusion or are to be treated later. Circumstances favorable for restoration of circulation were found at exploration of 75 lesions. The unfavorable lesions were all completely obstructive and were located in the internal carotid arteries. The extent of the lesion in the latter cases was apparent in the arteriograms before operation and each was suspected to be inoperable on the basis of the duration of the disease. These cases were treated early in the series when the extent of operability was unknown. In the light of present knowledge, these cases would now be considered inoperable on the basis of the arteriograms and the clinical manifestations of the disease.

The obstruction was due to atherosclerosis in all cases and, when incomplete, was limited to a discrete atheroma near the origin of the involved vessel (fig. 1). Complete obstruction occurring in the more advanced cases was produced by superimposed thrombosis, and the lesions in these patients consisted of the atheroma and thrombus in various stages of organization (fig. 2). Incomplete occlusions were always well localized, with the artery being reasonably normal both proximal and distal to the lesion. Complete occlusions were usually more extensive, and when located in the internal carotid or vertebral arteries, extended well up into the intracranial portion of artery in 75 per cent of the cases. Complete occlusions of the great vessels arising on the aortic arch, although frequently extensive, never extended into the intracranial arterial segments and were always associated with reasonably normal patent vessels outside the skull, both proximal and distal to the obstruction. These pathologic features of the lesion permitted the application of direct operation in all cases of occlusion located in the great vessels arising on the aortic arch regardless of the nature and extent of the lesion. Incomplete occlusions of the internal carotid and vertebral arteries were similarly susceptible to operation. Complete occlusions at the latter levels, however, were rarely operable unless treated soon after occlusion became complete.

TABLE 1.—Oclusive Disease of Innominate, Carotid, Subclavian and Vertebral Arteries

<table>
<thead>
<tr>
<th>Location of Lesion</th>
<th>Complete</th>
<th>Incomplete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal carotid</td>
<td>17</td>
<td>5 5</td>
</tr>
<tr>
<td>Common carotid</td>
<td>6 6 6</td>
<td>3 3 3</td>
</tr>
<tr>
<td>Innominate</td>
<td>4 4 4</td>
<td>4 4 4</td>
</tr>
<tr>
<td>Subelavian</td>
<td>10 10 10</td>
<td>5 5 5</td>
</tr>
<tr>
<td>Vertebral</td>
<td>2 1 1</td>
<td>4 4 2</td>
</tr>
<tr>
<td>Total</td>
<td>39 26 26</td>
<td>49 49 46</td>
</tr>
</tbody>
</table>

CLINICAL MANIFESTATIONS

The ages of these patients ranged from 24 to 71 years, with the highest incidence in the fifth, sixth, and seventh decades. There were 50 men and 13 women in this series of patients. There was no particular correlation between age and sex incidence and the location of the lesion, except that the younger patients had occlusions of the great vessels arising on the aortic arch, and 6 (49 per cent) of the 13 women in this series had lesions at this level. The relatively high incidence of hypertension and heart disease in this form of occlusive disease is similar to that recognized for occlusive disease of the lower extremities. Patients having blood pressures of 150/90 mm. Hg or greater were considered to be hypertensive. On this basis, 26 patients (40 per cent) were found to be hypertensive with little or no relationship in this regard to the location and extent of the lesion. Some form of heart disease, usually previous myocardial infarction,
was found to be present in 19 patients (30 per cent). Associated atherosclerotic occlusions of the aorta and the iliac, femoral, and popliteal arteries were present in only 5 patients (7 per cent).

The clinical manifestations of arterial insufficiency in these patients varied with the location and extent of the occlusive process and for convenience are considered separately.

**INTERNAL CAROTID ARTERY OCCLUSION**

(INCOMPLETE)

Patients with incomplete occlusions of the internal carotid arteries had had one or more attacks of cerebral arterial insufficiency ranging from a brief period of mild weakness or paresthesia to complete hemiplegia with total aphasia. Complete or near complete recovery had occurred in over half of the cases by the time of operation. In 4 patients who had not had previous attacks, persistent complete paralysis occurred, with aphasia in 3. Other neurologic deficits occurring in this group of patients were monocular visual defects, mental obtundity, and headache. Two patients complained of ear noises that occurred synchronously with the pulse.

The physical findings in these patients were limited to the neurologic defect, when present, and certain changes in the carotid arteries. A systolic murmur could be heard under the angle of the jaw in all patients with partial occlusions of the internal carotid arteries, and, as previously indicated, 2 patients heard these murmurs with each heart beat. Two patients with contralateral partial occlusions of the carotid artery developed transient loss of consciousness with carotid compression in the neck. The atheromatous lesion itself could be palpated as a firm mass in the region of origin of the internal carotid in several cases. In most instances, the region of the bifurcation was less flexible than in the normal patient. Pulsations in the neck, throat, and face were normal in patients with partial occlusions at this level, since the external carotid artery remained patent in all cases.

**INTERNAL CAROTID ARTERY OCCLUSION**

(COMPLETE)

The history of illness in patients with complete occlusion of the internal carotid artery was in general considerably longer than in those with partial occlusions. Almost all patients in this series with persistent hemiplegia of long duration were in this group. Persistent neurologic deficits, usually in the form of paralysis, were present in all these cases. The final episode had been preceded by multiple transient attacks in 80 per cent of the cases,

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**Fig. 1** Left. Carotid arteriogram performed before operation. Middle. Photomicrograph. Right. Diagram of specimen removed at operation showing incomplete occlusion of internal carotid artery by discrete atheromata located at origin of artery.
thus indicating the progressive nature of the disease. Peripheral neurologic deficits were demonstrated in all cases and ranged from mild speech or mental impairment to complete hemiplegia, aphasia, or coma. The degree of neurologic impairment was in many respects related both to the duration and extent of the disease. For example, the degree of paralysis was usually greater in patients who had not had previous attacks and in those with bilateral lesions. There were several exceptions, and the most impressive of these occurred in 2 patients who had bilateral complete occlusions of the internal carotid arteries. The neurologic deficits were mild in both of these cases and consisted of recurrent seizures, mental obtundity, minimal speech impairment, and weakness. Paralysis was more complete in the other patients with bilateral lesions, and the third patient in this series with bilateral complete occlusion had severe paralysis and was in coma.

Complete occlusion of the internal carotid artery in the neck was not evident in these patients on clinical grounds; however, it was suggested by the production of syncope by contralateral carotid compression. Carotid pulsations were always present in the neck, and although these were thought to have been diminished in some instances, there was no significant variation from the normal range of pulse volume. Arterial pulsations in the face, throat, and contralateral carotid artery were normal, and there were no bruits unless there was partial occlusion of the ipsilateral external carotid artery.

**Oclusion of Vertebral Arteries**

Patients with vertebral artery occlusions presented the clinical picture previously described as basilar artery thrombosis, which consists of visual (cortical), cerebellar, cranial nerve, and peripheral motor and sensory disturbances. The symptoms were transient in some, but in other cases neurologic defects persisted. The patients who had recovered from their attacks showed no abnormal physical signs. Those with persistent defects showed disturbances in equilibrium, diplopia, bilateral blindness or hemianopsia, and bilateral sensory and motor impairment. The location of the lesion could not be determined in these cases by physical examination alone.

**Oclusions of Great Vessels Arising on Aortic Arch**

The clinical features of occlusive lesions in the great vessels arising on the aortic arch
consist of arterial insufficiency of both the brain and the upper extremities. The majority of patients with lesions of the common carotid arteries had had transient attacks of paralysis, visual disturbances, dizziness, and headache; however, recovery had occurred in all instances. Patients with occlusive lesions of the innominate and subclavian arteries had intermittent claudication of the upper extremities, and 3 of these patients had gangrenous changes of the fingers. Transient mild symptoms of basilar artery insufficiency had occurred in those patients with bilateral subclavian artery occlusion.

The most important finding in patients with lesions at this level was diminished or absent pulses in the neck and upper extremities. Loud systolic murmurs were present in the base of the neck and supravacuicular regions of patients with incomplete occlusions at this level. The combination of cerebral and upper extremity symptoms with pulse changes in the neck and pulse and blood pressure changes in the arms permitted reasonably accurate clinical localization of the lesion. The absence of pulsations indicated complete occlusion, while diminished pulsations or the presence of systolic murmurs in the base of the neck or supravacular region were associated with partial occlusion.

**DIAGNOSIS AND SELECTION OF PATIENTS FOR OPERATION**

A history of transient attacks, presence of systolic murmurs, syncope with unilateral carotid compression, and alterations in the carotid and subclavian pulses was highly suggestive of extracranial arterial occlusion; however, because of the inconsistency of these findings in patients with extracranial lesions, the precise location and extent of the occlusion were determined by special examination. Several types of examination have been employed for this purpose, namely, electroencephalography, ophthalmodynamometry, and arteriography. Abnormal electroencephalographic patterns were observed in patients with extracranial occlusions who had persistent neurologic deficits indicating residual brain damage. The findings in these cases were similar to those produced by intracranial occlusions and, consequently, were of little significance in the localization of the lesion. In many patients with extracranial arterial occlusions, abnormal electrical activity was produced by contralateral carotid artery compression or sudden elevation of the upper part of the body. Unfortunately, these changes were not produced in all patients with these lesions, and although highly significant when present, the precise location and extent of the lesion were not apparent from this examination.

Ophthalmodynamometry is an indirect method of measuring the retinal arterial blood pressure, which is dependent upon normal intracranial blood flow. Under normal circumstances, the major blood supply to the inside of the eye is derived from the ophthalmic artery, which is an intracranial branch of the internal carotid artery. A small part of the intracranial blood flow under normal conditions is provided by the orbital branches of the internal maxillary artery, a major branch of the external carotid artery. The eye, therefore, has an extracranial and an intracranial source of arterial blood flow, both of which are amply connected by collateral channels. The external carotid artery is rarely involved by the occlusive process, and, in our experience, ocular arterial blood flow through these extracranial channels apparently increases as that in the intracranial segment decreases, not only providing normal ocular blood flow but significant collateral blood flow to the cerebrum through the ophthalmic artery. Consequent to the adequacy of this collateral blood flow to the eye, intraocular pressure is frequently normal in patients with extracranial arterial obstruction. For these reasons, this particular method of examination is not entirely reliable. Moreover, the precise location and extent of the lesion is never evident by this method alone.

Arteriography was the most important method of study in these cases. In fact, it
was impossible to determine precisely the location and the extent of the lesion when located in the internal carotid and vertebral arteries by any other method. Although occlusion of the great vessels on the aortic arch could be determined on clinical grounds in many instances, arteriography was essential in some for precise determination of the location and extent of the lesions. The techniques of arteriography vary according to the particular artery involved, and these are discussed separately.

**Angioaortography**

The thoracic aorta and great vessels arising on the aortic arch were visualized, as described by Robb and Steinberg, in patients with arterial insufficiency of the cerebrum and upper extremities, particularly in the presence of murmurs in the base of the neck or diminished pulses in the neck and upper extremities. The procedure is performed under local anesthesia. A Robb-Steinberg cannula is inserted percutaneously into an antecubital vein, and the arm-to-tongue circulation time is determined by injecting 50 ml. of 0.8 per cent Decholin solution. A similar volume of 85 per cent sodium diatrizoate (Hypaque) solution is injected, and roentgenographic exposure is obtained of the chest and lower neck in the left anteroposterior oblique position after delaying an interval equal to the arm-to-tongue circulation time. Good visualization has been obtained by this method, and the occlusive lesions are seen in the great vessels originating near their origin from the aortic arch and extending distally for varying distances. This procedure has been performed in over 250 patients for various lesions (including aneurysms) at this level with no mortality or significant complications.

**Carotid Arteriography**

Bilateral percutaneous carotid arteriograms, as described by Egas Moniz, are performed in all patients with cerebral arterial insufficiency in the regions of the anterior and middle cerebral arteries who do not have the clinical signs associated with lesions in the great vessels arising on the aortic arch. This study is performed as soon as possible after an attack of cerebral arterial insufficiency, and, should neurologic deficits persist, it is undertaken as an emergency examination. The procedure is performed under local anesthesia. A Cournand needle is inserted into one common carotid artery low in the neck. A flexible tube is attached to the needle, and with a 30-ml. syringe, 8 ml. of 50 per cent Hypaque solution are injected. Roentgenographic exposure is obtained of the head and neck in the lateral position during the latter part of the injection. The procedure is then repeated on the opposite side, since bilateral lesions occur in 25 per cent of the cases. This study has been performed in 160 patients without mortality, significant discomfort, or complications. An important consideration in these cases is the fact that the disease process has not advanced as a result of the examination. Incomplete occlusions of the internal carotid artery appeared as defects in the outline of the internal carotid near its origin. When occlusion of the internal carotid artery was complete, the extracranial segment of this vessel did not appear in the roentgenogram. All patients with incomplete occlusions were considered candidates for operation. However, patients with complete occlusions at this level are now considered operable only when the symptoms suggest very recent complete occlusion.

**Vertebral Arteriography**

Bilateral vertebral arteriography is performed in all patients with the clinical manifestations of basilar artery insufficiency. Since the lesions occur in the vertebral arteries near their origin from the subclavian artery, it is necessary to visualize both the subclavian artery and the vertebral artery. The procedure is performed under local anesthesia by inserting a Cournand needle into the subclavian artery in the supraclavicular space. A flexible tube is attached and 20 ml. of 50 per cent Hypaque solution are injected. Roentgenographic exposure is made of the head, neck, and upper thorax, with visualization of the
subclavian, vertebral, and basilar arteries and their branches. This procedure is then repeated on the opposite side in view of the frequency of bilateral lesions. This procedure has now been performed in 30 patients without mortality; however, pneumothorax has occurred in 20 per cent of the patients. This complication has been satisfactorily relieved in all cases by simple aspirations of the chest. Patients with partial occlusions are considered ideal candidates for operation. Complete occlusions are considered inoperable unless a patent distal segment is present in the neck or the occlusion is of recent onset.

**Treatment**

Treatment in these patients was directed toward restoration of a normal pulsatile blood flow to the brain beyond the occlusion to relieve symptoms or prevent further difficulty. Two types of procedures were employed for this purpose, namely, endarterectomy and end-to-side bypass graft. Endarterectomy was employed in the treatment of lesions that were discrete and well localized to a short segment of artery 1 to 2 cm. in length (figs. 3 and 4). The technical application of this procedure varied with the artery involved. For example, internal carotid artery occlusions were removed either through a transverse incision made in the common carotid artery immediately proximal to the origin of the internal carotid or through a longitudinal incision made in the internal carotid artery in the region of the atheromatous obstruction. Because of the small size of the vertebral artery, endarterectomy of this vessel was performed through an incision made in the subclavian artery opposite the origin of the vertebral artery by developing a plane of dissection under the intima of the subclavian artery and extending this dissection into the vertebral artery beyond the occlusion.17 Endarterectomy of the great vessels arising from the aortic arch was performed by longitudinal incision in the involved artery in the region of obstruction.
The more extensive lesions were bypassed with use of a specially designed, flexible knitted Dacron tube.\textsuperscript{17-19} In patients with internal carotid artery occlusions, one end of the tube was sutured to the uninvolved common carotid artery proximal to the lesion and the other end was sutured to the patent segment of internal carotid artery distal to the occlusion (fig. 5). The bypass graft in patients with vertebral artery occlusion extended proximally from the patent subclavian artery to the patent vertebral artery distal to the occlusion. In patients with occlusions of the great vessels arising from the aortic arch, the proximal end of the tube was sutured to the side of the ascending aorta and the other end was sutured to the carotid or subclavian artery distal to the occlusion (fig. 6). In the latter cases, either straight, bifurcated, or even trifurcated tubes were employed, depending upon the number of vessels involved.

In this series of 75 segmental lesions, the obstruction was well localized and endarterectomy was performed in 37. The remaining 38 lesions, being more extensive, were bypassed with a flexible, knitted Dacron tube. Cerebral protection was rarely required during operation. The period of complete arterial occlusion during the procedure ranged from 5 to 30 minutes in these cases. Collateral circulation was sufficient to maintain normal function during this period except in patients submitted to operation for partial occlusion of the internal carotid artery in the presence of complete occlusion on the other side. Patients with this combination of lesions required cerebral protection during operation, and temporary bypass shunts were successfully employed for this purpose. Reductions in blood flow were prevented by elevating the peripheral blood pressure to 200 mm. Hg, with use of a dilute solution of neosynephrine and with injection of the carotid sinus with procaine. Cerebral depression was prevented by the careful administration of such depressant drugs as opiates and barbiturates.
RESULTS

Results of operation were evaluated on the basis of restoration of circulation, improvement or relief of symptoms, and survival. From an anatomic standpoint, proved by arteriography, circulation was restored in the treatment of all 75 segmental lesions except 3, 1 internal carotid artery and 2 vertebral artery occlusions (table 1). Circulation was restored in all cases with occlusion of the great vessels arising from the aortic arch regardless of the extent of the lesion and in all but 1 case with partial occlusion of the internal carotid artery. Circulation was also restored in all but 5 (25 per cent) of the patients selected for operation with complete occlusion of the internal carotid artery, and 3 patients (60 per cent) with occlusion of the vertebral artery. Circulation was not restored in any patient with complete occlusion of the internal carotid artery with persistent paralysis of more than 4 days’ duration, unless operation was directed toward a contralateral partial occlusion. Cerebral circulation was made worse in only 1 case. This patient, treated early in the series, developed a right hemiplegia with aphasia 24 hours following endarterectomy performed by a technic no longer employed in these cases.

Severe cerebral arterial insufficiency manifested by coma and extensive paralysis was present before operation in 3 cases. These patients were submitted to emergency operation, and although circulation was restored in one or more of the occluded arteries, irreversible brain damage with extensive cerebral infarction had already occurred prior to operation and their fatal terminal course was not altered by operation. Death was due to myocardial infarction in 2 patients, 1 submitted to operation for gangrene of the fingers and the other for mental obtundity and recurrent convulsions. Death in the remaining case was due to hemorrhage resulting from infection and disruption of the suture line 10 days following operation.

The remaining 57 patients recovered from operation, and circulation was restored in one or more of the occluded vessels in 47 of the surviving patients. The functional response to treatment in these cases varied according to the location of the lesion and the condition of the patient before operation. Results were evaluated by clinical examination and listed

Fig. 5. Left. Preoperative carotid arteriogram showing partial occlusion of internal carotid artery near its origin. Middle. Arteriogram performed 3 days after operation showing functioning bypass graft. Right. Arteriogram performed 9 months after operation showing normal cerebral circulation through bypass graft and progression of bypassed lesion to complete occlusion.
as worse, no change, significant improvement, or completely well. Persistent residual paralysis (hemiparesis or monoparesis) occurring before operation was improved in 5 cases and completely relieved in 8 patients. Progressive hemiplegia with aphasia of 18 hours’ duration was completely relieved in 1 patient. Residual monocular visual defects (scotoma) were improved in 1 case and completely relieved in 4 patients. Homonymous hemianopsia was improved in 1 patient. Complete relief occurred from other symptoms: aphasia in 5, vertigo in 4, headache in 3, ear noise in 2, syncope in 1, and claudication of the arm in 17 patients. Transient attacks of paralysis (monoplegia or hemiplegia) have not recurred since operation in 13 patients who had completely recovered from such attacks before operation. All patients with lesions of the great vessels arising from the aortic arch were completely relieved and the majority of patients with lesions of the internal carotid or vertebral arteries were either relieved or significantly improved. In those patients in whom functional improvement did not occur, restoration of a pulsatile cerebral blood flow is considered likely to prevent progression of the disease. For example, bilateral internal carotid obstructions, incomplete on one side and complete on the other, were present in 4 of the patients in whom neurologic improvement did not occur following therapy. The neurologic deficit in these cases was of long duration and was due to the lesion producing complete obstruction. Cerebral function in these cases was dependent upon blood flow through the incompletely obstructed artery, since compression of the carotid on this side produced unconsciousness. In view of the progressive nature of the disease, eventual complete obstruction was anticipated; consequently, operation was directed toward the contralateral incomplete occlusion for prophylactic reasons.

The first patient in this series was operated upon a little over 5 years ago, and all cases have been carefully followed since discharge from the hospital with follow-up arteriograms being performed in most patients. The success achieved by operation has been well maintained in all but 4 patients. Death has occurred in 2 patients, one from myocardial infarction and the other from cerebral arterial insufficiency due to acute occlusion of the contralateral internal carotid artery; the one submitted to operation was still patent at autopsy. Recurrent occlusion has occurred in 2 patients with lesions of the internal carotid
artery in one and the left common carotid in the other patient. Endarterectomy had been employed in one and an end-to-side bypass graft had been inserted in the other. Both these cases were treated early in the series with technics no longer considered suitable in these cases.

**Discussion**

These observations in patients with cerebral arterial insufficiency indicating extracranial arterial occlusion in 42 per cent of them and the practical application of operative technics designed to restore normal circulation represent a departure from the usual concepts of the disease and its management. Although these lesions were described during the past century and arteriographic technics have been available for 25 years, cerebral arterial insufficiency resulting from extracranial arterial occlusion was considered rare. The importance and possible frequency of extracranial lesions was again emphasized in 1951 by Fisher.8 The report by Eastcott and associates6 in 1954 of relieving a patient with persistent cerebral arterial insufficiency by endarterectomy stimulated a lively interest in the subject, since this case suggested that direct operative therapy could be as effective in this disease as had been demonstrated in arterial insufficiency of the lower extremities. This interest, maintained by continued successful application of operative therapy, led to a more aggressive approach to the problem and a clearer understanding of the nature and incidence of the disease.

The atherosclerotic lesion is a progressive process that eventually consumes the arterial lumen and produces arterial insufficiency. Therapy not directed toward the lesion itself has become questionable. For example, 20 per cent of the patients in this series of cases were referred for operative treatment because satisfactory anticoagulant therapy had either not improved or not prevented progression of the disease. Moreover, 5 patients developed cerebral arterial insufficiency while their prothrombin times were being maintained at levels less than 10 per cent of normal by Dicumarol administration because of previous myocardial infarction. The successful results obtained by arterial reconstructive operations in the relief of persistent neurologic defects and the prevention of recurrent attacks, particularly in patients in whom anticoagulant therapy had failed, offer considerable hope in the future management of this problem with an otherwise dismal outlook.

The full potential offered by these new concepts may be realized by an aggressive approach. The limitations of diagnosis by clinical means must be taken into consideration and extracranial involvement should be suspected in all patients. Arteriography is essential for accurate diagnosis and should be routinely performed in all patients with cerebral arterial insufficiency. Every effort should be made to diagnose and treat the patient early in the course of the disease to prevent both the development of permanent brain damage and the progression of the disease. Operation for practical purposes may be considered invariably successful in patients with partial occlusions regardless of the extracranial location. The more advanced complete occlusions of the internal carotid and vertebral arteries, on the other hand, are considerably less susceptible to direct therapy unless submitted to operation soon after onset of complete occlusion. Immediate arteriography and operation are therefore necessary, particularly when neurologic signs persist, if the maximum number of these patients is to benefit from the reconstructive technics.

**Summary**

Arteriographic studies have been performed in 174 patients with clinical manifestations of cerebral arterial insufficiency. Extracranial arterial occlusion was demonstrated in 73 patients (42 per cent). Operation has been employed in the treatment of 63 of these patients who were found to have 115 occlusive lesions.

Oclusion of the great vessels arising on the aortic arch was manifested clinically by symptoms of arterial insufficiency of both the cerebrum and upper extremities and diminu-
tion or absence of pulses in the neck or arms. The precise location and extent of occlusion in patients with internal carotid and vertebral artery occlusion was evident only by arteriography.

At operation 75 lesions were found to be segmental in nature with a normal extracranial segment, both proximal and distal to the obstruction. Employing endarterectomy in 37 well-localized lesions and graft bypass in 38 more extensive occlusions, circulation was restored in 72 arteries. From an anatomic standpoint circulation was restored in all cases with lesions in the great vessels arising from the aortic arch, 97 per cent of those with operable lesions of the internal carotid artery, and 60 per cent of those with occlusions of the vertebral artery.

Severe cerebral arterial insufficiency manifested by coma and extensive paralysis was present before operation in 3 of these cases. Although circulation was restored in one or more of the occluded arteries, brain damage was persistent and the patients' fatal terminal courses were unaltered. Death in the remaining cases was due to myocardial infarction in 2 and hemorrhage in 1 case.

The remaining 57 patients recovered and circulation was restored in one or all of the occluded vessels in 47 patients. All patients with lesions of the great vessels arising from the aortic arch were completely relieved and the majority of patients with lesions of the internal carotid and vertebral arteries were either relieved or significantly improved. These patients have been followed up to periods of over 5 years, and the success achieved by operation has been well maintained.

**Addendum**

Since this article was submitted, operation has been employed in the treatment of an additional 61 lesions, making a total of 149. Of this number the internal carotid artery was involved in 93, the common carotid artery in 12, the innominate artery in 14, the subclavian artery in 21, and the vertebral artery in 9. All occlusive lesions involving the common carotid, innominate, and subclavian arteries were segmental in nature, and circulation was restored in all of them. The occlusive lesion was segmental in 83 of the 93 cases involving the internal carotid artery, and circulation was restored in 80. Of the 9 cases with vertebral artery occlusion, operation was successful in 6.

**Summario in Interlingua**

Studios arteriographic eseva effectuate in 174 patientes con manifestationes clinic de insufficientia cerebro-arterial. Extracranial occlusion arterial eseva demonstrate in 73 patientes (42 pro cento). Intervention chirurgic eseva usate in le tractamento de 63 de iste patientes in qui un total de 115 lesiones occlusive eseva constatate.

Occlusion del grande vasos a origine in le arco aortic se manifestava clinicamente in symptomas de insufficientia arterial tanto in le cerebro como etiam in le extremitates superior e in le diminution o le absentia complete de pulsos in collo e bracos. Le precise location e le extension del occlusion in patientes con occlusiones arterial interne carotidic e vertebral eseva evidentiate solmente per arti-erographia.

Eseva constatate al operation que 75 lesions eseva de natura segmental, con normal segmento extracranial tanto proximal como etiam distal con respecto al sito del obstruction. Endarterectomia eseva usate in le casos de 37 lesiones ben localisate, shunting per graf-los in le casos de 38 occlusiones plus extense. Assi le circulation eseva restaurate in 72 artierias. In terminos anatomic: Le circulation eseva restaurate in omne le casos de lesiones del grande vasos a origine in le arco aortic, in 97 pro cento del casos de lesiones operable del interne arteria carotidic, e in 60 pro cento del casos de occlusiones del arteria vertebral.

Sever grados de insufficientia cerebro-arterial, manifeste in coma e extense formas de paralyse, eseva presente ante le operation in 3 de iste casos. Ben que le circulation eseva restaurate in un ol phares del occludite arterias, le injurias cerebral persisteva, e le mortal curso terminal del patientes remaneva sin alteration. Inter le altere casos, morte eseva causate per infarciemento myocardial in 2 e per hemorrhagia in 1.
Le remanente 57 pacientes se restabliva. Le circulation esevase restaurate in un o omne vasos occludite in 47 de illes. Omne le pacientes con lesiones del grande vasos a origine in le arco aortic experienciate un alleviamento complete. Le majoritate del pacientes con lesiones del interne arteria carotidic e del artery vertebral experienciate alleviamento o al minus grados significative de melioration.

Le pacientes remanenac sub observation post-chirurgic durante periodos de usque a 5 annos, e le successo effectuate per le operation es ben mantenite.

REFERENCES

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