Results of Surgical Treatment of Incipient Stroke

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We have approached the question of the desirability of surgical treatment for occlusive cerebrovascular disease with the thought that more than one method of treatment is possible. Two of us (R.G.S. and J.P.W.) with Millikan have reported previously concerning long-term anticoagulant therapy for incipient stroke. Our experience with such medical treatment has been satisfactory enough so that when patients have a condition that clearly indicates a need for anticoagulant therapy, for example, heart disease, but also have significant occlusive cerebrovascular disease, we do not consider them primarily as potential candidates for surgical treatment.

In recent years we have explored the use of surgical treatment of occlusive cerebrovascular disease, particularly in the category of incipient stroke (or focal intermittent cerebrovascular insufficiency). Such patients have transient attacks of focal neurologic symptoms lasting for 5 to 30 minutes and occurring over several weeks or several months; the patient is normal between the episodes. The end result of such transient attacks is often a serious cerebral infarct, although this is not always the case.

The surgical approach to occlusive cerebrovascular disease has been directed to the extracranial cerebral circulation, and most of the reported procedures have been performed on the cervical carotid arteries. A few procedures have been directed to the vertebral arteries near their origin or to the arteries arising from the aortic arch.

Shimizu and Sano were the first to report cases of reconstructive surgery of the internal carotid artery. A thrombus was removed from one of their patients, and the thrombosed portion of the internal carotid artery was resected and replaced with an autologous venous graft in another. It is not clear in their report whether either patient benefited from the procedure or whether circulation was restored.

Eastcott, Pickering, and Rob first reported clearly successful reconstructive operation on the internal carotid artery in a patient having episodes of intermittent focal cerebral ischemia (incipient stroke) in whom arteriography revealed advanced internal carotid stenosis. This patient was relieved of the episodes. Since this report numerous similar reports have been made on various types of surgical procedures for arterial reconstruction. It has been difficult to compare the results of surgical treatment of occlusive cerebrovascular disease obtained by various groups of investigators, not only because of the variable course of cerebral ischemia but also because of the different criteria that are used to evaluate the results of a surgical procedure.

It is our purpose herein to assess a well-defined group of patients—those having incipient stroke or transient ischemic attacks—in whom the results and risks of surgical treatment are easily ascertained. Since data regarding the natural history of patients in this category are incomplete, the results of a comparison of the treated patients with the untreated patients must be interpreted with caution. We are reporting the results of surgical treatment of patients with incipient stroke in either the carotid or vertebral-basilar system. By definition, patients having this condition are neurologically normal between their episodes of transient ischemia and thus all are normal at the time of operation.

Several questions should be answered concerning this kind of experience with surgical patients:
1. Was a definitive surgical procedure accomplished; that is, was the circulation actually restored in the operated artery? If it was not, then the only further clinical consideration is whether the patient suffered harm from the operative procedure.

2. Did the episodes of transient cerebral ischemia stop immediately after the surgical procedure? If not, the operation did not accomplish the anticipated effect.

3. Did the patient, who was normal before the procedure, suffer any degree of cerebral infarction at the time of or shortly after the operation? Since the aim of the treatment is prevention of cerebral infarction, this question is perhaps the most important one.

4. Were there significant local complications of the procedure?

5. Did death occur from any cause during the surgical procedure or in the early postoperative period? It is unreasonable, for example, to exclude operative or postoperative deaths from myocardial infarction, since we can readily assume from necropsy data that a large percentage of patients with high grade cervical atherosclerosis also will have significant coronary artery disease.

Since the primary objective of treatment in this stage of stroke is the prevention of cerebral infarction, the long-term follow-up of patients operated on for incipient stroke requires that we ask similar questions of ourselves. Did the transient ischemic spells stop? How many of the original group of surgically treated patients have had cerebral infarction, regardless of whether it was in the distribution of the operated artery? What is the long-term mortality from cerebral infarction and other causes? It is only by answering such questions that we can assess the role of this form of treatment for occlusive cerebrovascular disease.

Numerous reports have been made on patients operated on for various manifestations and clinical categories of occlusive cerebrovascular disease, but few reports have been made on groups of significant size in which patients were operated on for incipient stroke and thus were normal at the time of the surgical procedure.

Edwards, Gordon, and Rob\textsuperscript{6} reported on 32 patients operated on for all stages of ischemic cerebrovascular disease, and these authors were kind enough to allow us to review their protocols of individual patients. In seven patients with incipient stroke, circulation was successfully restored. Five of these seven patients stopped having transient spells, but mild neurologic deficit developed in two and severe neurologic deficit in one. One patient died and another continued having transient ischemic episodes.

Cameron and Till\textsuperscript{7} reported on carotid endarterectomy performed on three patients who had transient focal cerebral ischemia and in whom arteriography showed evidence of carotid stenosis. Another patient in their group had transient symptoms but with internal carotid occlusion. In this patient "some backflow occurred," but it is not clear that circulation was actually reestablished. All four of these patients apparently did well but two were treated postoperatively with long-term anticoagulant therapy.

Meredith and Rinaldi\textsuperscript{8} reported the cases of six surgical patients who were normal between their cerebral ischemic episodes; in all six a definitive procedure was accomplished. Postoperatively three patients were normal or virtually so; two had a postoperative neurologic deficit and the sixth patient died.

Murphey\textsuperscript{9} reported operations on 38 patients with transitory symptoms. In four patients with occlusions, circulation was not reestablished but the results in these four patients were not separated from those of the other patients. One patient had permanent hemiparesis and two died of coronary occlusion. One patient had asymptomatic thrombosis of the operated artery and six others had transient complications such as temporary paresis of one or more of the extremities or hematomas in the neck. Long-term follow-up of the surviving patients showed that 33 had no further episodes; three patients continued having cerebrovascular insufficiency.
episodes, but in two of them the episodes were not in the distribution of the operated artery.

DeBakey and associates\textsuperscript{10} have reported by far the largest group of patients operated on for incipient stroke. Eighty patients with internal carotid insufficiency had carotid operations and 29 patients with vertebral-basilar insufficiency had surgical procedures on the vertebral arteries. Of the total 109 patients, three patients died, two were made worse, seven continued having some spells, and the remainder were asymptomatic in the early follow-up period. Follow-up of 82 patients for 6 months or longer showed that seven patients had died, three continued to have ischemic episodes to some degree, and the remainder were entirely well. The latter figures apparently do not include the deaths noted in the early postoperative period.

Thompson and Austin\textsuperscript{11} reported operations in 18 patients with transient strokes. Improvement was reported in 14 patients although it is not clear whether all 14 were entirely free from episodes. Two patients were unchanged and continued to have episodes. Two patients were worse; presumably these two had cerebral infarcts although it is not so stated. There were no operative deaths.

Bauer and associates\textsuperscript{12} reported the cases of five patients who had carotid endarterectomies for transient ischemic attacks. One patient died after right hemiplegia developed. Hemiplegia and aphasia developed in another patient. One patient showed mild improvement and two patients showed no change. It is not clear whether the latter three patients continued to have spells of focal cerebral ischemia.

Most investigators have now agreed that operation on internal carotid arteries judged to be occluded is not justified, particularly if the occlusion has been present for more than a few days. In some occluded internal carotid arteries the circulation can be restored to normal by instrumentation through the occluded segment, but this operation is performed at considerable risk of distal embolization. If an occlusion is present near the aortic arch, then the occluded segment usually can be bypassed successfully with a synthetic graft.

Most of the reported operative procedures have been endarterectomies of stenotic regions at or near the bifurcation of the common carotid artery in the neck. It is sometimes difficult to know whether stenosis demonstrated by arteriography actually is sufficient to cause cerebral ischemic symptoms. Crawford and associates\textsuperscript{13} demonstrated that patients estimated to have 50 per cent or more stenosis of an artery had a pressure gradient between points proximal and distal to the stenosis, while those patients with less than 47 per cent stenosis had no pressure gradient.

We have accepted 50 per cent or more stenosis as significant, but since we do not know the mechanism of transient cerebral ischemic episodes, it might be argued that minimal localized atherosclerotic stenosis without a pressure gradient may be just as important if there is a fragile surface on the atheromatous lesion or if there is a varying level of systemic blood pressure.

Results of Surgical Treatment in Incipient Stroke

We have seen 35 patients with incipient stroke associated with a well-defined occluding or stenotic lesion in a cervical artery; in each patient the circulation had been restored to normal by an operative procedure. None of these patients had a neurologic deficit at the time the surgical procedure was performed. In each case surgical treatment was selected as the initial treatment. In these respects these patients were a selected group.

All operative procedures were performed by two of us (P.E.B. and F.H.E.). In 31 patients the operative procedure was endarterectomy of a stenotic lesion in the common carotid or internal carotid artery. Subclavian-vertebral endarterectomy was performed on one patient. In another patient an occluded right common carotid artery was bypassed with a synthetic arterial graft extending from the right subclavian artery to the...
distal portion of the right common carotid artery. In still another patient an occlusion of the proximal segment of the left subelavian artery was bypassed by inserting a synthetic arterial graft between the aorta and the distal portion of the subelavian artery so that the vertebral artery would then receive satisfactory flow. One patient had a graft placed from the aorta to the distal part of the innominate artery in such a way as to bypass an occluded innominate artery.

Shortly after the surgical procedure, 69 per cent or 24 of the patients were normal and had no symptoms of cerebral ischemia. Another 8.5 per cent (three patients) were normal, although the episodes of focal cerebral ischemia for which they had undergone operation recurred within the first 2 weeks. In one of these three patients a clinical diagnosis of postoperative thrombosis of the operated internal carotid artery could be made. In the other two patients there was no indication of any problem at the operative site and one could only conclude that the stenotic lesions that were removed were not the sole cause of the patient’s transient ischemic episodes (table 1). These three patients, who had ischemic episodes after the surgical procedure, have since been put on long-term anticoagulant therapy and the episodes have stopped. Two other operated patients have received long-term anticoagulant therapy after returning to their home physician, but neither had return of neurologic symptoms before or after anticoagulant therapy.

Six patients (17 per cent) had a cerebral infarct at the time of the operative procedure or immediately thereafter. One of these patients died as a result of the infarct and another had a severely incapacitating residual neurologic deficit. Each of the other four patients had only a mild neurologic deficit after recovery from the infarct; in each instance the deficit consisted of slight clumsiness of one upper extremity associated with mildly defective discriminatory sensations. Besides the patient who died from the cerebral infarct, two patients died postoperatively: one patient died from a cerebral hemorrhage, which occurred on the side of the operative procedure 5 days after the operation, and another patient died as a result of a myocardial infarct (table 1).

There has been no morbidity from complications at the operative site. No patient has had a wound infection, hematoma in the neck requiring drainage, or weakness of the tongue from trauma to the hypoglossal nerve during the procedure.

Among our patients in all categories of ischemic cerebrovascular disease who have had cerebral complication from surgical procedures, about 50 per cent of those whose optic fundi were examined before and after the operative procedure have had small shiny embolic fragments in the retinal arterioles on the side of the operation. Although occasionally a fragment is associated with a retinal infarct, most of the fragments apparently cause no significant retinal damage. We have thought it likely that these emboli arose from the operative site at the time of, or shortly after, the operative procedure, and that similar embolic fragments probably account for some of the cerebral infarcts related to the surgical procedure. We have been unable to eliminate the occurrence of occasional retinal emboli by any of our current efforts.

Hollenhorst first noted these shiny embolic fragments. Recently Hollenhorst, Lensink, and one of us (J.P.W.) have found that crystalline cholesterol injected into the

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Table 1

<table>
<thead>
<tr>
<th>Factors</th>
<th>Number</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal patients</td>
<td>24</td>
<td>69</td>
</tr>
<tr>
<td>Episodes recurred</td>
<td>3</td>
<td>8.5</td>
</tr>
<tr>
<td>Cerebral infarct (patient living)</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Mild deficit</td>
<td>4</td>
<td></td>
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<td>Severe deficit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>3</td>
<td>8.5</td>
</tr>
<tr>
<td>Cerebral infarct</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cerebral hemorrhage</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Myocardial infarct</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35</strong></td>
<td><strong>100</strong></td>
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</table>
The carotid circulation of a monkey resulted in many shiny embolic fragments in the retinal arterioles and that these cholesterol crystals appeared similar, if not identical, to the bright plaques that have sometimes been noted in the retinal arterioles of operated patients.

The same 35 patients have now been followed for 6 months to 3½ years. The findings have been compared with those for a group of 40 patients with focal cerebrovascular insufficiency who have not been treated, either medically or surgically (table 2). It should be noted, however, that the untreated group usually did not have arteriography as part of the diagnostic work-up and the follow-up period has been longer. We have found that nearly 25 per cent of patients with inipient stroke who have had arteriograms have not had demonstrable arterial lesions in any of the arteries shown on films. We might assume, therefore, that 25 per cent of the untreated patients were without significant arterial lesions. It is unknown whether such patients have a different prognosis than those patients with demonstrated arterial lesions.

Sixty-six per cent of the surgically treated group (23 patients) and 25 per cent of the untreated patients (10 patients) were normal and had not had spells of cerebral ischemia by the end of the follow-up period (table 2). The 25 per cent of untreated patients who were normal and the additional 25 per cent who continued to have only transient ischemic episodes during the follow-up period are adequate evidence that the symptoms of an inipient stroke do not always terminate in a serious permanent neurologic deficit.

Since the primary aim of treatment is prevention of cerebral infarction, the most important percentages to note are the 17 per cent (four living patients and two who died) of the surgically treated group and the 40 per cent (13 living patients and three who died) of the untreated group who had cerebral infarcts during the period of observation. The results of surgical treatment after long-term follow-up differ little from the immediate postoperative results, which indicates that if the patient’s ischemic episodes are relieved and if no immediate complication follows the surgical procedure, the patient’s prognosis is good.

Summary

Recently we have studied the role of surgical treatment of patients having occlusive cerebrovascular disease, particularly inipient stroke (or focal intermittent cerebrovascular insufficiency). This report concerns 35 patients with inipient stroke in whom circulation was restored to normal by operation on an artery in an attempt to prevent transient ischemic episodes and cerebral infarction.

Since all of the patients were neurologically normal at the time of the surgical procedure, we were concerned primarily with the risk of

Table 2

Circulation Restored after Inipient Stroke: Late Results

<table>
<thead>
<tr>
<th>Factors</th>
<th>Surgical treatment (6 to 42-month follow-up)</th>
<th>No treatment (12 to 60-month follow-up)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Per cent</td>
</tr>
<tr>
<td>Normal patients</td>
<td>23</td>
<td>66</td>
</tr>
<tr>
<td>Episales only</td>
<td>3</td>
<td>8.5</td>
</tr>
<tr>
<td>Cerebral infarct (patient living)</td>
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<td>11</td>
</tr>
<tr>
<td>Mild deficit</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Severe deficit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>5</td>
<td>14.3</td>
</tr>
<tr>
<td>Cerebral infarct</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Cerebral hemorrhage</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Noncerebral</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
<td>100</td>
</tr>
</tbody>
</table>
the procedure, particularly in terms of cerebral infarction. The operative mortality rate was 8.5 per cent (three patients). Six patients (17 per cent) sustained cerebral infarcts. Four of these had mild neurologic deficits, usually consisting of clumsiness and mildly reduced discriminatory sensation in one hand; one had a severe neurologic deficit, and one died. Evidence shows that at least some of these infarcts resulted from emboli arising from the operative site at the time of or shortly after the operation.

The results of long-term follow-up revealed that 66 per cent of the surgically treated patients were normal compared to 25 per cent of a contrast group; and 17 per cent of the treated patients had suffered cerebral infarcts compared to 40 per cent of the contrast group. The long-term results are thus similar to the immediate postoperative results. These findings simply indicate that an operated patient’s prognosis was good over the long term if the cerebral ischemic episodes were relieved and if he sustained no complications from the surgical procedure.

References

Circulation, Volume XXVII, June 1963
Results of Surgical Treatment of Incipient Stroke

JACK P. WHISNANT, ROBERT G. SIEKERT, PHILIP E. BERNATZ and F. HENRY ELLIS, JR.

Circulation. 1963;27:1028-1033
doi: 10.1161/01.CIR.27.6.1028

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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