Results of extracranial-intracranial arterial bypass for bilateral carotid occlusion

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The results of superficial temporal to middle cerebral artery bypass surgery for bilateral internal carotid artery occlusion were reviewed in 39 patients. Preoperative symptoms included recurrent transient ischemic attacks (TIA's) in 31 patients (80%) and mild or moderate stroke in 15 (29%). Deficits were unilateral in 23 cases and bilateral in 14. Dementia or personality changes were observed in 19 patients (49%). Operative morbidity occurred in six of 39 cases and was neurological in one; the surgical mortality rate was 8% (three of 39 patients), including two cases of cerebral hemorrhage. The outcome was good or excellent (relief of TIA's and reduction of neurological deficit) in 82% of patients over a follow-up period of 3 to 139 months. Five patients had a late postoperative stroke, which occurred in the unoperated hemisphere in each case; one patient had an ipsilateral TIA 6 years after the bypass procedure. These results suggest that an extracranial-intracranial arterial bypass procedure to augment collateral cerebral blood flow can be performed safely in patients with bilateral internal carotid artery occlusion and may be associated with relief of ischemic symptoms. Future studies may document a role for this procedure in the prevention of stroke.

KEY WORDS • extracranial-intracranial bypass • carotid occlusion • stroke • ischemia • arterial anastomosis

PATIENTS with bilateral carotid artery occlusion are at high risk for recurrent transient ischemic attacks (TIA's) or stroke resulting from inadequate cerebrovascular perfusion. Collateral blood flow from the vertebrobasilar and external carotid-ophthalmic circulation may be insufficient, and intermittent or chronic symptoms of focal neurological deficit, dementia, and personality changes may be observed. When a major stroke has not already occurred at the time of carotid artery thrombosis, and when symptoms of cerebrovascular insufficiency are present, an extracranial-intracranial (EC-IC) arterial bypass procedure to augment collateral blood flow may be indicated. The effectiveness of this operation in preventing stroke and TIA's is currently being evaluated in a controlled prospective study, the results of which are not yet available. Because of our extensive experience with this unusual indication, we have reviewed the presenting symptoms, operative complications, and outcome in patients with bilateral carotid artery occlusion who underwent superficial temporal artery to middle cerebral artery (STA-MCA) anastomosis.

Summary of Cases

The records of all patients with bilateral carotid artery occlusion who underwent an EC-IC bypass procedure at the Ralph K. Davies Medical Center between 1972 and 1982 were reviewed retrospectively. The criteria for case selection were a history of TIA's or mild stroke and angiographic evidence of bilateral carotid artery occlusion. The STA-MCA anastomosis was performed using standard surgical techniques. A special effort was made to prevent intraoperative hypotension and to avoid compromising vertebral artery flow by placing the patient's neck in a rotated position. All patients were treated with sulfinpyrazone (Anturane, 100 mg three times daily) before and after surgery. Late follow-up information was obtained by examination in the office or by telephone contact with the patients and their local physicians.

Thirty-nine patients met the clinical and angiographic criteria for inclusion in the study. In most cases, the angiographic evaluation consisted of aortic arch and vertebral artery studies as well as bilateral common
TABLE 1
Neurological presentation of 39 patients with bilateral carotid artery occlusion*

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Cases No.</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>no deficit</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>TIA's</td>
<td>31</td>
<td>80</td>
</tr>
<tr>
<td>reversible incomplete neurological deficit</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>progressive stroke</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>mild stroke</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>moderate stroke</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>severe stroke</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>altered mental status</td>
<td>19</td>
<td>49</td>
</tr>
<tr>
<td>dysphasia</td>
<td>23</td>
<td>59</td>
</tr>
<tr>
<td>motor deficit</td>
<td>25</td>
<td>64</td>
</tr>
<tr>
<td>visual symptoms</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>sensory symptoms</td>
<td>18</td>
<td>46</td>
</tr>
</tbody>
</table>

* TIA = transient ischemic attack.

TABLE 2
Risk factors for stroke in 39 patients with bilateral carotid artery occlusion

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Cases No.</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>age over 55 yrs</td>
<td>29</td>
<td>74</td>
</tr>
<tr>
<td>male sex</td>
<td>31</td>
<td>80</td>
</tr>
<tr>
<td>hypertension</td>
<td>26</td>
<td>67</td>
</tr>
<tr>
<td>heart disease</td>
<td>16</td>
<td>41</td>
</tr>
<tr>
<td>peripheral vascular disease</td>
<td>21</td>
<td>54</td>
</tr>
<tr>
<td>diabetes</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>cigarette smoking</td>
<td>30</td>
<td>77</td>
</tr>
<tr>
<td>hypercholesterolemia</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>hypertriglyceridemia</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>family history of diabetes mellitus, heart disease, hypertension, or stroke</td>
<td>18</td>
<td>46</td>
</tr>
</tbody>
</table>

bilateral symptoms underwent bilateral EC-IC bypass procedures: in three patients, the late occurrence of a mild contralateral stroke prompted the second operation, and, in two, generalized symptoms of dementia, psychomotor retardation, and alternating bilateral TIA's initially suggested the need for staged EC-IC bypass operations in both hemispheres.

Operative Results

Perioperative Morbidity and Mortality

Morbidity and mortality rates within 30 days of operation are summarized in Table 3. The only case of neurological morbidity (temporary dysphasia) resolved within 30 days, before the patient was discharged from the hospital. There were three major and two minor medical complications, all of which responded to treatment. There was no operative cardiac morbidity or mortality in this series. The operative mortality rate was 8% (three patients). One patient died of intestinal obstruction caused by mesenteric vascular occlusion. Two patients died of cerebral hemorrhage, one after an episode of postoperative hypertension following contralateral external carotid endarterectomy 1 week after the EC-IC bypass procedure, and one following restoration of normal blood pressure after an episode of severe cardiogenic hypotension during the bypass procedure. Five patients experienced postoperative TIA’s, which ceased within 30 days after surgery.

Late Follow-Up Review

The mean follow-up period was 49 months (range 3 to 139 months). The effect of the EC-IC bypass procedure on preoperative dysphasia, mental changes, and motor weakness is presented in Table 4. Although a quantitative assessment of neurological function was not performed, comparison of preoperative and post-
TABLE 4
Neurological status after bypass procedure in 36 patients with preoperative deficit

<table>
<thead>
<tr>
<th>Status</th>
<th>Dysphasia</th>
<th>Mental Changes</th>
<th>Motor Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement</td>
<td>18</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>No change or worse*</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>No data</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total cases</td>
<td>23</td>
<td>19</td>
<td>25</td>
</tr>
</tbody>
</table>

* Includes two operative deaths; both patients had deteriorated neurologically.

TABLE 5
Late neurological morbidity and mortality in 36 patients*

<table>
<thead>
<tr>
<th>Event</th>
<th>Cases</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>* TIA = transient ischemic attack.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recurrent TIA's</td>
<td>1</td>
<td>2.8 yrs after bypass (no further recurrence after external carotid endarterectomy)</td>
</tr>
<tr>
<td>stroke (all opposite hemisphere)</td>
<td>4</td>
<td>2 mild strokes (treated with contralateral bypass at 2 yrs &amp; 8 mos, respectively)</td>
</tr>
<tr>
<td>death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cardiac</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>ischemic stroke</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>hypertensive hemorrhage</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>contralateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pneumonia</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>lung cancer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>unknown cause</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>total deaths</td>
<td>12</td>
<td>33.3%</td>
</tr>
</tbody>
</table>

* Does not include two patients who did not return for postoperative evaluation.

† See text for definition of categories.

operative or follow-up examinations indicated that functional capacity improved after STA-MCA anastomosis in 18 of 23 patients with dysphasia and in 20 of 25 patients with motor deficits.

Late neurological morbidity and mortality data in the 36 surviving surgical patients are listed in Table 5. Six patients (16.1%) had a late stroke on the side opposite the bypass; two of these strokes were fatal. Thus, the late contralateral stroke rate was 4%/yr among the 33 patients with an adequate follow-up period. No patient had a late ipsilateral stroke. Three patients developed new contralateral symptoms 5, 24, and 36 months after the initial operation and underwent a second EC-IC bypass procedure. Two of them are in excellent condition 10 and 51 months after the second operation, and the third was asymptomatic until his death from unknown causes 17 months later. One patient had a single recurrent ipsilateral TIA 6 years after the EC-IC bypass procedure; external carotid endarterectomy was performed after repeat angiography showed that a stenosis had developed. No further TIA's have occurred during 19 months of additional follow-up monitoring.

Twelve patients (33.3%) died 2 to 83 months after their bypass operation. One patient died of hypertensive cerebral hemorrhage in the contralateral internal capsule 13 months after surgery, and one died of contralateral ischemic stroke 7 months after surgery. Three patients died of unknown causes other than stroke (22, 26, and 45 months postoperatively). Five patients died of heart disease (3, 10, 18, 32, and 83 months after bypass surgery). One patient died of lung cancer (at 24 months), and one died of pneumonia (at 20 months postoperatively). The neurological status at the time of death was excellent in seven of these patients, good in two, fair in two, and poor in one.

At the time of the most recent follow-up review, 18 surviving patients were available for examination or interview, 16 to 139 months (mean 68 months) after their surgery (Table 6). Thirteen are in excellent condition (reversal of preexisting neurological deficits and no recurrence of TIA's) and have returned to their normal lifestyle; two are in good condition (some mild residual neurological deficits, and no recurrence of TIA's); two are in fair condition (residual moderate neurological deficits and less frequent TIA's). One patient is in poor condition with worsening neurological deficit.

Seven patients were lost to follow-up review. Two were never seen for postoperative evaluation after discharge, although information was obtained by telephone. Five were followed for 3 to 59 months (mean 28.8 months); three were in excellent condition at the latest follow-up visit 6, 29, and 59 months postoperatively, and two were in good condition 3 and 50 months after surgery.

Evaluation of Bypass Patency

The bypass graft was found to be patent by Doppler examination at the last follow-up visit in all patients. Postoperative arteriograms demonstrated patency of

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the graft and bidirectional filling of the MCA branches with contrast material in all survivors of late recurrent stroke or TIA’s.

Discussion

Preoperatively, 80% of the patients with bilateral carotid artery occlusion in our series had TIA’s. Possible mechanisms for TIA’s in such cases include embolization and hypoperfusion; loss of autoregulation, which is present in up to 56% of patients with bilateral carotid occlusion, can also lead to TIA or stroke when systemic blood pressure drops (GM Austin, et al., unpublished data, 1980). Gratzl and Müller recommended measurement of cerebral blood flow in patients with bilateral carotid artery occlusion to clarify the indication for EC-IC bypass surgery.

Extracranial-intracranial bypass surgery has the potential to augment cerebral blood flow beyond the inoperable proximal vascular occlusions in patients with bilateral carotid artery occlusion. Although such patients who present with TIA’s are at increased risk of recurrent TIA’s and stroke, only five of our patients (13%) had ipsilateral TIA’s during the first 30 days after surgery. The recurrence of TIA’s in the early postoperative period may be related to delayed maturation of the bypass graft. Initially, flow through the bypass may be inadequate to relieve hypoperfusion. As the temporal artery and the anastomosis dilate, flow should improve, the likelihood of embolization from the suture line should decrease, and the autoregulatory capacity of the cerebral microcirculation should return to normal. Only one patient had a TIA during the late follow-up period. A new hemodynamically significant lesion of the external carotid artery was considered to be the cause of symptoms in that case.

Patients with multiple extracranial vessel occlusions may have significant neurological deficits. It was not surprising that only three of our patients had no deficit preoperatively. The high incidence of dementia and personality changes in our series may be consistent with the presence of diffuse bilateral impairment of cerebral blood flow. The partial resolution of dementia, dysphasia, and motor deficits in some of our patients postoperatively suggests that these symptoms were caused by hypoperfusion rather than by infarction or coincidental degenerative disease. Increased cerebral blood flow after bypass surgery may have allowed function of previously viable, but inadequately perfused, ischemic tissue to return. Thus, it appears that surgical revascularization may restore function in patients with bilateral carotid artery occlusion by reversing diffuse partial ischemia.

Because bilateral carotid artery occlusion may be clinically indistinguishable from occlusion of the common carotid, external carotid, or middle cerebral arteries or their branches, the decision to perform EC-IC bypass surgery must be made only after angiographic evaluation of the entire cerebral circulation. Staged bilateral operations were successful when indicated in this series. The nondominant hemisphere was considered the safe initial operative site in patients with bilateral symptoms. More than one-third of our patients had bilateral symptoms preoperatively, and half of them showed clinical improvement after unilateral operation. This result may be attributed to overall increases in cerebral perfusion by augmentation of previously marginal collateral flow. In the three patients who needed a second EC-IC bypass operation because of recurrent symptoms, reduction of flow might have developed as a result of atherosclerotic involvement of collateral channels in the contralateral or posterior circulation.

The occurrence of two fatal perioperative strokes emphasizes the precarious state of the cerebral circulation in patients with bilateral carotid artery occlusion. In one patient, ischemic infarction may have occurred intraoperatively and become hemorrhagic when severe perioperative cardiogenic hypotension was corrected. The death of the other patient, who had a contralateral basal ganglia hemorrhage during an episode of postoperative hypertension after a second procedure for contralateral external carotid endarterectomy 1 week after the EC-IC bypass operation, suggests that perioperative hypertension must also be treated vigorously.

Multiple extracranial occlusions are not limited to the elderly. The mean age of our patients was only 59 years, and Sadun, et al., described a 39-year-old man with arteriosclerotic bilateral carotid artery occlusion. Occlusion of the carotid artery bilaterally may be one result of a generalized atherosclerotic process affecting the coronary arteries and other medium-sized arteries. Heart disease was associated with cerebral ischemia in many of our patients, and more than half also had peripheral vascular disease. Therefore, complications such as the operative death from mesenteric vascular occlusion and the three late cardiac deaths that occurred in our series are to be expected. Although high-risk cardiac patients can undergo EC-IC bypass surgery if careful attention is given to cardiac function, blood volume, and fluid balance, one of our patients died of cerebral hemorrhage after reversal of severe intraoperative hypotension caused by cardiac insufficiency.

In this series, the unoperated hemisphere served as a form of control for the natural history of internal carotid artery occlusion in the same patient. All late TIA’s and ischemic strokes occurred in the contralateral hemisphere, except in one patient who developed ipsilateral external carotid artery stenosis. Thus, the late ipsilateral TIA and stroke rates were negligible and lower than that predicted by natural history studies, even among patients with unilateral internal carotid artery occlusion.

Conclusions

Although operative mortality, non-neurological morbidity, and late contralateral stroke rates were substan-
EC-IC bypass for bilateral carotid occlusion

tial in this high-risk group, our results indicate that
EC-IC arterial bypass surgery is a relatively safe, tech-
nically successful, and potentially effective method of
treating patients with bilateral carotid artery occlusion.
A bilateral operation must be considered in some cases.
Adequate medical management of risk factors is im-
portant to prevent both early and late postoperative
complications.

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