CAROTID ENDARTERECTOMY has been widely used for 30 years in prevention of ischemic stroke in selected patients. However, the indications for, and the risks and value of the operation are controversial. Indications for this procedure, have been generally agreed to be TIA or minor stroke. The surgical technique, morbidity and mortality rate vary considerably from one institution to another. The perioperative risk of carotid endarterectomy in our hospital is 3.3% and for acute myocardial infarction (AMI) 4.4%. Vascular death occurred with a frequency of 1.7% per year.

Patients and Methods

This prospective study for evaluating possible candidates for carotid endarterectomy, included all the patients with TIA (transient ischemic attack) or IBI (ischemic brain infarction) seen in the Department of Neurology, University of Helsinki from January 1980 to December 1982. During this period 227 patients with TIA or IBI were evaluated, before recommending surgical treatment for prevention of threatened stroke. Patients with severe risk factors may fare better on medical treatment than with surgical intervention.

Carotid Endarterectomy in the Prevention of Ischemic Stroke

The effectiveness and risks of carotid endarterectomy for patients with symptoms other than TIA are even less clear. In this prospective study we have analyzed the risks of carotid endarterectomy in our hospital to obtain information about the factors determining outcome in patients with TIA or minor stroke in connection with carotid endarterectomy.

Outcome of Surgical Treatment of 110 Patients With Transient Ischemic Attack

ANTI MUURONEN, M.D.

SUMMARY Between 1980 and 1982, 227 consecutive patients with transient ischemic attack (TIA) or ischemic brain infarction (IBI) were evaluated as possible candidates for carotid surgery in the Department of Neurology, University of Helsinki. One hundred and ten patients (mean age 58, range 41-72 years) were selected for surgery; 82 of them had had TIA and 28 IBI as the presenting symptom. After a total of 128 operations (84 unilateral and 18 bilateral endarterectomies, and 8 arterial reconstructions), 16 patients selected for surgery; 82 of them had had TIA and 28 IBI as the presenting symptom. After a total of 128 operations (84 unilateral and 18 bilateral endarterectomies, and 8 arterial reconstructions), 16 patients died (6.4%), the deficit was severe and 4 of them (3.6%) died within the first four days after surgery. Ten patients had occlusion of the contralateral internal carotid artery and/or severe hypertension. Five of them suffered ischemic brain infarction after the operation and two died. Operation on an occluded internal carotid artery in 7 patients was complicated by hemiparesis in two patients, one of whom died. Patients with surgical complications more often had severe hypertension (p < .001), total occlusion of the contralateral internal carotid artery, (n.s.) and severe angiographic changes (n.s.) compared with patients without complications. During the follow-up the annual rate for IBI was 3.3% and for acute myocardial infarction (AMI) 4.4%. Vascular death occurred with a frequency of 1.7% per year. The results emphasize that patients with TIA or IBI should be carefully evaluated before recommending surgical treatment for prevention of threatened stroke. Patients with severe risk factors may fare better on medical treatment than with surgical intervention.

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References


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The patients presented in the TIA meetings by the neurologist were classified according to the preoperative risk factors developed by Sundt et al. The definition of criteria for different preoperative risk factors were as follows:

Medical risk factors: The presence of angina pectoris, or of myocardial infarction of less than 6 months’ duration, congestive heart failure, severe arterial hypertension (> 160/110 mm Hg), chronic obstructive pulmonary disease, chronologic age over 70 years, or severe obesity.

Neurologic risk factors: A progressing neurologic deficit, a deficit of less than 24 hours’ duration, frequent daily TIA, or neurologic deficits secondary to multiple cerebral infarctions.

Angiographically defined risk factors: Occlusion of the contralateral ICA (internal carotid artery); stenosis of the ICA in the region of the siphon; extensive involvement of the vessel to be operated on with extension of the plaque greater than 3 cm distally in the ICA or 5 cm proximally in the common carotid artery; bifurcation of the carotid artery at the level of C-2 in conjunction with a short, thick neck; and evidence of a soft thrombus extending from an ulcerative lesion.

Patients at great neurologic risk were not considered suitable for surgery (Sundt’s risk groups 4 and 5) and accordingly were not operated upon.

The patients were examined clinically by the author 1–2 days before surgery to detect new deficits, 5–7 days after the operation, and again one month after surgery to reveal possible new deficits. When there was a surgical complication, the examination was performed immediately postoperatively. All patients were in good condition medically and all were independent in the activities of daily life (ADL). Only two patients had a major deficit prior to operation. In three quarters of the patients, the indication for operation was TIA (including amaurosis fugax) and, in a quarter, IBI with a minor deficit together with an appropriate angiographic lesion at the carotid bifurcation.

All the patients were operated on within 2 months after the initial onset of TIA or IBI but none were operated on within the first 6 months after AMI (acute myocardial infarction). Local anesthesia was used during the endarterectomy. All the patients had ASA and/or dipyridamol postoperatively. At the beginning of 1983 (3–35 months postoperatively), the patients received a questionnaire concerning further TIAs, strokes, myocardial infarctions, working capacity and independence in the activities of daily life. In case of suspected stroke or incomplete information, the patient was contacted by telephone. Complete information was not available in four living patients, but they were known not to have had major complications during the follow-up. The Chi-square test with Yates correction was used in statistical analyses.

Results

Patients and Preoperative Evaluation

The mean age of the 110 patients selected for surgery at the time of their initial TIA or IBI, was 57.9 years (range 41 to 72). Four-fifths of the patients were aged from 50 to 69 years. Patients under 50 and over 70 years represent less than one fifth of the study population. All the patients had had focal neurological symptoms. The majority, 69/82 (84%) of the TIA patients had symptoms related to the internal carotid ar-

<table>
<thead>
<tr>
<th>Grade</th>
<th>Angiographical finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No changes</td>
</tr>
<tr>
<td>1</td>
<td>Slight irregularities</td>
</tr>
<tr>
<td>2</td>
<td>Ulcerative plaques or stenosis less than 25%</td>
</tr>
<tr>
<td>3</td>
<td>25–60% stenosis</td>
</tr>
<tr>
<td>4</td>
<td>Stenosis more than 60%</td>
</tr>
</tbody>
</table>
The majority of the patients also had other risk factors for cardiovascular accidents, only 15 patients of 110 had no other risk factors than TIA or IBI (table 2). By angiography 141 (64%) out of the 220 carotid bifurcations of the 110 patients revealed a stenosis of 25% or more (grade 3 and 4) of the vessel diameter, including 11 total occlusions of the internal carotid artery. The grade of the pathological changes between left and right carotid bifurcation did not differ significantly. Other major angiographical findings were subclavian steal in 9 cases and an aneurysm of the common carotid artery in one patient. Three quarters (106/141) of the patients with grades 3 and 4 changes at the carotid bifurcation were operated on but only one third (14/110) to risk group 1 respectively.

Operative Procedures and Postoperative Complications

Unilateral carotid endarterectomy was performed in 56 TIA and 28 IBI patients. Eighteen patients with TIA were submitted to bilateral carotid endarterectomy. Reconstruction of the subclavian artery was performed in 7 patients with TIA. One patient had reconstruction of the common carotid artery because of an aneurysm. Bilateral carotid endarterectomy was carried out in 18 patients, 9 of whom had bilateral TIA, 6 of whom had persistent TIA after the first operation and 3 because of asymptomatic contralateral disease detected by angiography. There was no difference in frequency of surgery between the left and right carotid bifurcations for patients with changes of grade 3 and 4. The majority (95/120, 79%) of the operated carotid arteries were symptomatic. Attempts to recanalize a totally occluded carotid artery were made in 7 of 11 occlusions (67%).

All 13 patients with vertebrobasilar symptoms initially had carotid endarterectomy but none of them suffered complications in connection with the surgery. None of the eight patients with arterial reconstruction (7 subclavian arteries and one common carotid artery) suffered new deficits.

In total 128 operative procedures were performed in 110 patients. Complications in connection with the surgery in different preoperative categories are shown in table 3. Sixteen out of the 110 patients developed a new neurological deficit in connection with the surgery. The deficit was slight in 9 patients (8%). In 7 patients (6%) the deficit was severe and 4 of them (3.6%) died within the first four days after surgery. All four patients who died suffered leftsided IBI in connection with the surgery, and the ipsilateral carotid artery had been operated on. The cause of death was acute myocardial infarction in one patient and IBI in three patients. All the patients who died had had TIA as a presenting initial symptom. In two of the four patients who died, the disaster occurred in connection with the second operation. Both of the two patients had continued to have TIA as after the first operation. Three of the 4 patients who died had severe arterial hypertension and one of them also had occlusion of the opposite internal carotid artery. Seven TIA patients had occlusion of the contralateral carotid artery and/or severe arterial hypertension and this subgroup suffered three severe strokes and two deaths in connection with the surgery. All the severe complications following surgery in this study occurred in patients with TIA in risk group 3.

There were no deaths or severe new deficits in patients with previous IBI. Only two of the 28 patients with previous IBI initially had new postoperative defi-

### Table 2 Occurrence of Risk Factors in the 110 Patients Operated on

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial hypertension</td>
<td>62 (56.4%)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>22 (20.0%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>15 (13.6%)</td>
</tr>
<tr>
<td>Severe arterial hypertension</td>
<td>7 (6.4%)</td>
</tr>
<tr>
<td>Smoking</td>
<td>56 (50.9%)</td>
</tr>
<tr>
<td>Absence of any of above by history</td>
<td>15 (13.6%)</td>
</tr>
</tbody>
</table>

### Table 3 Perioperative Complications in the Different Risk Groups in the 110 Patients Operated on

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk group</th>
<th>No. of patients</th>
<th>New deficit</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Slight</td>
<td>Severe</td>
</tr>
<tr>
<td>TIA</td>
<td>1</td>
<td>12</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>25</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>45</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>IBI</td>
<td>1</td>
<td>2</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>22</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>9</td>
<td>7</td>
<td>14.5</td>
</tr>
</tbody>
</table>
Only two patients had multiple TIA as the initial symptom combined with grade 4 angiographic changes in the ipsilateral carotid bifurcation. Both of them suffered severe stroke postoperatively. One patient with severe hypertension and occlusion of the contralateral carotid artery suffered severe hemiplegia postoperatively.

The attempt to recanalize an occluded internal carotid artery in 7 TIA patients without neurological deficit was unsuccessful and in one case was complicated by ipsilateral IBI and in an other with IBI and death. Ten patients preoperatively had severe arterial hypertension and/or total occlusion of the contralateral internal carotid artery. In this subgroup five patients (50%) suffered a new neurological deficit and two of them (20%) died. Three of the 10 patients had had IBI as the initial presenting symptom and 7 had had TIA. All the complications mentioned above occurred in TIA patients.

Comparing the histories of the patients with complications to those of the patients who did not suffer perioperative complications there were more patients with severe arterial hypertension (p < .001) and occlusion of the contralateral internal carotid artery (n.s.) in the former group.

The preoperative angiographical studies of the patients with complications more often showed severe changes and total occlusions (n.s.) than did those of patients without complications.

All complications occurred in connection with the surgery. None of the patients had late (up to one month) postoperative complications. None of the patients went through repeat angiography after surgery but four of patients with major postoperative complications had computed tomography of the brain to exclude a brain hemorrhage.

Follow-up Morbidity and Mortality

In a follow-up period of mean 1.7 years fifteen patients experienced further TIA (table 4). Ten patients with TIA as initial symptom continued to have TIA postoperatively and 5 patients with previous IBI had TIA postoperatively. Almost all of these patients (12 of 15) belonged to risk group 3. Six patients suffered IBI (5.7% of the patients at risk) and eight patients AMI (7.7% of the patients at risk), of which three were fatal. One patient died of bronchial carcinoma. All the severe events except two IBI occurred in the group of patients with previous TIA. Patients with previous IBI did well both postoperatively and during the follow-up; they had no severe surgical complications and suffered only two IBI during the follow-up period. The annual rates for IBI and AMI were 4.4% and 3.3%, respectively, during the follow-up period. Deaths from vascular disease occurred with a frequency of 1.7% per year.

Out of the 102 patients alive at the end of the follow-up period 50 patients had a normal working capacity. The reasons for retirement were age in 15 (29%); vascular diseases in 25 (48%); and other diseases in 12 (23%) patients. Of the survivors 92 (90%) were fully independent in ADL, 7 (7%) required assistance, and 3 (3%) were completely disabled.

Discussion

The combined surgical morbidity-mortality of 18.1% in the present study is high, compared with most other series. The best published results include a stroke morbidity of about 3% and a mortality of 1% from surgery. The over-all complication rate in the present study. Our results are comparable with those of Easton and Sherman's study with a combined morbidity-mortality rate of 21% in two community hospitals. Ignoring the slight complications in our patients the combined morbidity-mortality rate decreases to 10% with 6.4% morbidity and 3.6% mortality. The slight neurological deficits after surgery were only noticed upon detailed neurological examination. It can be assumed that most of them would have been passed over in routine clinical examination.

The majority of the complications (14 out of 16) occurred in patients with TIA as the initial symptom. Only two patients with previous IBI had slight new deficits. All the severe deficits (7) occurred in the patients with previous TIA and all these patients belonged to risk group 3. Furthermore, all 4 patients with fatal postoperative complications had also had IBI and belonged to risk group 3. Though others have found a significant difference in postoperative complication rates between the TIA and IBI subgroups, surprisingly, in their studies the IBI patients suffered more complications than the TIA patients.

| Category | Risk group | No. of patients | Morbidity | Mortality | | | | |
|---|---|---|---|---|---|---|---|
| | | | TIA | IBI | AMI | % | | | |
| TIA | | | 1 | 1 | 1 | 25 | | | |
| 78 pat | 1 | | 25 | | | | | |
| | 2 | | 2 | 1 | 4 | 28 | | |
| | 3 | 41 | 7 | 2 | 3 | 31 | | |
| | | | | | | | | |
| IBI | | | 2 | | | | | |
| | 1 | | 2 | | | | | |
| | | | | | | | | |
| 28 pat | | | 4 | | | | | |
| | 2 | | | | | | | |
| | 3 | 22 | 5 | 2 | | 32 | | |
| Total | | | 106 | 15 | 6 | 8 | 27.4 | | |

Note: The table shows the number of new events during the follow-up period in 106 survivors, classified by risk group and symptom category. The percentages are calculated for each category.
The poor results of the present series cannot be explained by neurological risk factors because we excluded patients in the high-risk groups such as neurologically unstable patients or patients with frequent daily TIA or neurological deficit secondary to multiple cerebral infarctions. Only two patients had severe hemiparesis preoperatively and all the patients with previous IBI (28) were operated on after good recovery.

A special high-risk group seems to be the TIA patients with occlusion of the contralateral carotid artery and/or severe hypertension. This group of 7 patients is responsible for 42% (3 of 7) of the new permanent severe postoperative deficits and 50% (2 of 4) of the deaths. Hypertension is a known risk factor for any operation. Occlusion of the contralateral carotid artery has been reported not to increase the risk of complications in endarterectomy but in that series 19 out of 23 patients with occlusion of the contralateral carotid artery had a history of complete stroke. Our patients in this special high risk group had all experienced TIA initially. Only two slight deficits occurred in patients with previous IBI.

Attempts to recanalize 7 occluded internal carotid arteries were unsuccessful and complicated by hemiparesis in two patients, one of whom died. There is no evidence of benefit for patients with this procedure and it should be undertaken only in rare circumstances, if ever.

The follow-up morbidity in our patients after surgery was also relatively high. In the Joint Study there was a stroke morbidity of 4% in a follow-up period of 42 months. Half of the strokes were fatal. In the present study stroke morbidity was 5.7% over 1.7 years and morbidity for myocardial infarction 7.5%. During the follow-up none of our patients died because of IBI but three patients died because of AMI. These findings are consistent with our earlier observations, where TIA patients on conservative therapy died three times more often from AMI than from IBI. In that series we had an annual ischemic stroke rate of only 0.6% and a vascular death rate of 1.3% against 3.3% and 1.7% in the present series.

In a non-randomized study of TIA patients Toole and co-workers reported a high surgical morbidity (22%) and mortality (6%). However, the overall mortality (23% at 4 years) was similar in the medically and surgically treated groups in the patients surviving the initial postoperative period. Whisnant et al. reported good surgical results with a 3% stroke morbidity and under 1% mortality postoperatively, in a series of clearly defined patients who had experienced TIA in one carotid territory and who were submitted to carotid endarterectomy on the side corresponding to the ischemic symptoms. During the follow-up, ischemic stroke occurred at a rate of 2% per year and death rate was 3% per year. Seventy percent of the deaths were due to a cardiac disorder. Fifteen percent of the patients continued to have TIA. In a multi-variable analysis with 17 variables they did not reveal any single factor or combination of factors which could be related to mortality.

The reason for this can be extremely careful selection of patients for surgery, great surgical skill in the operation and variables not sensitive enough when investigating such a highly selected group of patients. The good results during follow-up may be due to the fact that patients selected for surgery tend to have better prognosis than those patients selected for medical therapy.

The great differences in the results of carotid endarterectomy obviously depend on patient selection and surgical skill. The combination of careful patient selection and a well-trained operative team will probably result in a low postoperative complication rate and in a low long-term stroke morbidity. As of today there are no controlled studies to prove this. New modes of therapy, such as anti-aggregates have been introduced and better resources for taking care of patients with risk factors for stroke are available. If the complication rate following surgery remains high, then less radical measures may be of more importance.

Acknowledgment

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References

Although asymptomatic carotid bruits are an established risk factor for ischemic stroke, the management of asymptomatic patients with carotid bruits and carotid stenosis remains controversial. Carotid endarterectomy is performed in increasing numbers of patients although its efficacy has not been demonstrated convincingly for either asymptomatic or symptomatic disease. Since a requirement of any treatment is that benefits should outweigh risks, increasing numbers of patients although its efficacy has not been demonstrated convincingly for either asymptomatic or symptomatic disease. Since a requirement of any treatment is that benefits should outweigh risks, the stroke risk reduction after carotid endarterectomy must outweigh the combined hazards of angiography and surgery.

The relatively benign outcome of patients followed with bruits varies widely but the best perspective is obtained from community studies in Evans County and Framingham, where the overall stroke rates were 2.3% and 1.7% per annum. In addition to increased stroke risk, these patients have an increased cardiac risk, and an overall mortality, from causes other than stroke, of approximately 4% per annum.

The best estimates of the protection afforded by carotid endarterectomy are from studies in patients with transient ischemic attacks (TIAs), figures which may not apply to asymptomatic patients. Both the Extracranial Arterial Occlusion Joint Study and the Mayo Clinic reported a two-thirds reduction in stroke rates following uncomplicated carotid endarterectomy. The reduced long-term risk is offset by the more immediate complications of surgery. For carotid endarterectomy, surgeons with a high level of expertise achieve peri-operative stroke and/or death rates less than 5% (table I), and operative stroke and death occurring with about equal frequency. Angiographic complications should also be considered, but are omitted from further discussion because recent technological refinements have reduced permanent neurological sequelae to well below 1%.

These data are the basis for evaluating the merits of carotid endarterectomy in patients with asymptomatic carotid stenosis.

Selection of Endpoints

If stroke risk alone is considered, the net stroke reduction at three years in the surgical group is 42%, and the 'break-even point' is 13 months (fig. 1). The 'break-even point' is the moment when the number of strokes in each group is equal. A randomized surgical trial would require 1214 patients in each group to achieve a statistically significant result (table 2, trial 1).

If both stroke and death risks are considered (fig. 2), the net (stroke and/or death) risk reduction at three...
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A Muuronen

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