REPAIR OF CAROTID ARTERY BIFURCATION Atherosclerosis was first described in 1954 and two major reviews, in 1968 and 1970, provided the impetus for broad acceptance and application of this procedure.1,2 Recent reports in the medical literature have presented conflicting information regarding the results of carotid endarterectomy in community hospitals. Carmichael reported a series of 467 carotid endarterectomies performed in a community hospital and found a combined permanent stroke/mortality rate of 2.2%.3 The combined experience of 11 surgeons in two community hospitals reported by Easton noted a permanent stroke/mortality rate of 21.1%.4 Coincident to the latter report, a prospective evaluation of all carotid endarterectomies performed at the Lehigh Valley Hospital Center was instituted. The purpose of this study was to test the hypothesis: Carotid endarterectomy can be performed safely in a community hospital. The study began on September 1, 1977, and terminated on May 1, 1982 (56 months).

Methods and Methods

Carotid endarterectomy was performed on 743 occasions in the 56-month interval. Twenty-four surgeons performed these procedures. The operations were conducted under general anesthesia and inlying shunts were used. Carotid stump pressures were measured sporadically and electroencephalogram monitoring was not done. All patients were evaluated preoperatively by the surgeon as well as a neurologist or general internist. The patients were also evaluated using noninvasive vascular laboratory techniques.

Each patient underwent ocular pneumoplethysmography (OPG-Gee) on three occasions. At the time of the preoperative test, vascular laboratory personnel reviewed the patient record and pertinent neurologic history and physical findings were noted on the vascular laboratory report. An immediate postoperative OPG was performed in the recovery room. The neurologic status of the patient at that time was recorded on the recovery room OPG report. A physician was available for immediate interpretation of all recovery room OPG tests. The results of any test which suggested thrombosis or serious lumen compromise of the endarterectomy site were communicated immediately by the physician interpreting the test directly to the surgeon. The OPG was again repeated prior to the hospital discharge of the patient, usually the fourth postoperative day. All arteriograms were reviewed jointly by the physician-director of the vascular laboratory and the radiologist.

Results

The patients undergoing carotid endarterectomy ranged in age from 40–81 years. The mean age was 65 years. There were 468 males (63%) and 275 females (37%). In 684 cases the endarterectomy was performed as the primary procedure and in 59 cases the carotid surgery was done concomitantly with coronary artery bypass grafting.

The operative procedures were performed by 24 surgeons. The frequency with which they performed carotid endarterectomy in the 56 months studied varied from one to 219 operations. The mean was 31. All of the 24 surgeons were board certified. There were 12 thoracic surgeons, four neurosurgeons, and eight general vascular surgeons. All the general vascular surgeons had completed formal training programs in vascular surgery. All the surgeons were members of the division of vascular surgery and privileges to perform carotid endarterectomy were granted by the department of general surgery after reviewing the applicant’s credentials.

Of the 743 procedures, 553 (74%) were performed for symptoms referable to the operated artery. There were 190 procedures performed on asymptomatic lesions. Of the latter group, 146 (77%) lesions were of hemodynamic consequence, as demonstrated by OPG. Thus, 94% of the carotid endarterectomies were performed for symptomatic disease or lesions of hemodynamic consequence. There was no morbidity or mortality associated with the 44 procedures on hemodynamically inconsequential asymptomatic lesions. These were usually lesions noted in patients who had undergone contralateral endarterectomy or were detected in patients prior to other major surgery.

A new neurologic deficit was noted postoperatively in 39 patients (5.3%). Deficits were temporary in 26 (3.5%) and permanent in 13 (1.8%). A deficit was...
considered temporary if the symptoms resolved within 30 days following surgery. There were 20 deaths in the series of 743 carotid endarterectomies (2.7%). Fifteen of these were attributed to neurologic causes and five were cardiac related. Thus, the permanent stroke/mortality rate was 33/743 (4.4%). Two of the cardiac related deaths occurred in the group of 59 patients who underwent combined coronary bypass grafting and carotid endarterectomy. None of the patients in this subgroup suffered either a temporary or permanent neurologic deficit. Of the 190 asymptomatic patients operated upon, five or 2.6% incurred stroke or death.

The sensitivity and specificity of the OPG-Gee in detecting hemodynamically significant lesions is well documented.8 There were 42 patients in whom the OPG was considered equivocal. These 42 patients had preoperative OPG tests which suggested, but were not diagnostic of, unilateral carotid stenoses of pressure-significance (75% or greater, cross-sectional area), since the reduction of the ophthalmic systolic pressure on the side of the suspected stenosis was not at least 5 torr as required by the standard criteria for a positive OPG. All of the 42 patients were noted to have a reduction of calibrated oculur pulse amplitude on the side of the suspected stenosis to less than 80% of that noted on the opposite side. In all of these 42 patients arteriography and operative findings confirmed severe stenoses. This additional criterion has been formalized in a recent report.9 By incorporating this new criterion with the standard criteria, the 42 tests were considered true-positive studies.

Ocular pneumoplethysmography was positive in 40/743 (5.4%) of the recovery room tests. On the fourth postoperative day 60/743 (8%) were positive and indicated thrombosis or persistence of a lesion of hemodynamic consequence. There were 15 strokes among these 60 patients, and ten of them were fatal.

The incidence of temporary neurologic deficit, permanent stroke, and death was examined with respect to the frequency with which the operation was performed by the surgeon. Figure 1 illustrates the relationship of postoperative permanent strokes plus mortality to the frequency with which the surgeon performed carotid endarterectomy. This relationship fits a straight line with a correlation coefficient of 0.93.

Table 1 tabulates the results when subdivided by the number of procedures the surgeon performed. Four of the 24 surgeons performed 456 of the procedures. There were 20 strokes (4.4%) and 11 of the 20 were fatal. There was one cardiac death, without associated brain injury. The nonfatal stroke was 9/456 (2.0%) and the mortality was 12/456 (2.6%). The combined stroke/mortality rate was 4.6%. Temporary postoperative neurologic deficit included those associated with operative manipulation of cranial nerves, transient exacerbation of preoperative neurologic deficits, and all new transient neurologic deficits. Transient symptoms or deficits were noted following 19 of the procedures (4.2%).

The remaining 20 surgeons performed 287 procedures. Temporary neurologic deficits were noted fol-

lowing seven procedures (2.4%). There were eight strokes (2.8%), and four of the eight were fatal. There were four cardiac deaths without associated brain injury. The nonfatal stroke rate was 4/287 (1.4%) and the mortality rate was 8/287 (2.8%). The combined stroke/mortality rate was 4.2%. There was no significant difference between the two groups in any of the measured parameters. Even if one compares the group of 13 surgeons who did 10 or fewer cases in the 56 months of the study to those 11 who did more than 10 carotid endarterectomies, no statistically significant differences could be demonstrated in morbidity or mortality.

Discussion

The age range and sex distribution of the 743 patients in this series is similar to that reported by others. Thompson noted a mean age in his series of 63.1 years and DeWeese reported an age range in 46-80 years.2,3 A preponderance of males is noted by most authors being 65-67% of each of the above reports, respectively. The current series does differ somewhat in that it includes 59 patients who underwent coronary bypass grafting and carotid endarterectomy as a combination procedure. In this subgroup there were two deaths (3.4%) and no permanent neurologic deficits.

For the entire series the mortality rate (2.7%), the permanent stroke rate (1.8%), and the temporary neurologic deficit (3.5%) were similar to numerous other reports.2,3 The overall permanent stroke/mortality rate in our series was 4.4%. This finding from a community hospital is markedly different from the 21.1% permanent stroke/death rate reported by Easton.5 Part of this difference may be explained by the fact that of the 228 carotid operations reported by Easton only 25% were done for ipsilateral TIA's and only 56% were done for ipsilateral TIA's or mild strokes. In an abstract reviewing the more recent experience at that same community hospital, the combined stroke/mortality rate in 474 operations was 4.4%.6 These dramatically improved results were attributed to better patient management. In a similar turnabout, West et al reported a decrease in the permanent stroke/mortality rate from 10% (1967-70) to 0.9% (1971-75). They felt their improved results were due to not only better patient management, but also to improved surgical technique, and recommended careful consideration of the surgeon as well as the institution before recommending surgery.7

Selection of patients for surgery followed an evaluation similar to that recommended by Sandok et al.10 Symptoms (transient ischemic attack or stroke) were referable to the operated carotid artery in 74.4% of the patients. In the 190 asymptomatic patients, noninvasive studies (OPG-Gee) indicated a hemodynamically significant lesion in 76.8% and this was confirmed angiographically. Postoperatively, permanent stroke or death occurred in 2.6% of this subgroup. Other series report 10-46% of patients operated upon for asymptomatic lesions or symptoms not directly attributable to the operated carotid artery.2,4 Long-term fol-
low-up of the 743 operations was varied because of the large number of surgeons involved in the study. Most of the patients have been seen at six month intervals and non-invasive testing performed.

The OPG was positive in 5.4% of the recovery room tests and 8.1% of the tests performed in the fourth postoperative day. These results are similar to the data reported by Ortega et al. In contrast to Ortega’s data obtained from the experience of three surgeons in one group who accepted immediate reexploration when the OPG was abnormal in the recovery room, the data from the study included an additional 21 surgeons, a number of whom had not adopted this policy. This may be the reason for the increase in the fourth postoperative day positive OPG tests since asymptomatic occlusions were not diagnosed or treated immediately postoperatively. It is clearly a difficult decision to return the asymptomatic patient to the operating room following carotid endarterectomy.

If the OPG was found to be positive in the recovery room the result was communicated immediately to the surgeon. At the discretion of the surgeon the patient was returned immediately to the operating room and the endarterectomy site explored. Evaluation included digital palpation of a thrill or pulse gradient across the repair, Doppler ultrasound for the presence and quality of flow, operative angiography, and repeat arteriotomy to correct any defect (distal flap, thrombosis, narrowing) found. The results of this method of management are presented in detail elsewhere and are beyond the purpose of this presentation.

The current series was analyzed to determine the results of surgery based upon the frequency with which the individual surgeon performed the operation. The combined permanent stroke and mortality rate did not appear to change with the frequency with which the surgeon performed the operation (fig. 1). The linear relationship had an excellent correlation coefficient of 0.93 with a significant of $p < .001$. When the results of individual surgeons were segregated according to the number of operations performed per year, the above relationship was confirmed in that there was no statistically significant difference in the incidence of either neurologic deficit (temporary or permanent) or death (table 1). Although we expected to demonstrate a learning curve with regard to the results of operation, this was not the case. This may be explained by the fact that all 24 surgeons performing the procedures had reached the plateau phase of the curve and thus even in those who did the operation infrequently the results were as good as for those who performed endarterectomy more commonly. Since all the surgeons were certified by their appropriate board and they had been granted privileges for performing carotid endarterectomy only after being approved by the division of vascular surgery in the department of general surgery, this explanation seems possible. An alternate explanation may be that calculation of an individual complication rate is suspect because of the large number of surgeons (13) who did so few carotid endarterectomies (<10) during the 56 months of the study (type two error). It should be noted that the four highest complications rates, calculated as a percentage from the raw data plotted in figure 1, were incurred by surgeons who did less than 20 procedures during the study period. Similar results have been reported by Robertson et al from Baptist Memorial Hospital in Memphis, Tennessee. In a retrospective study of a year interval, two experienced neurosurgeons performed 182 carotid endarterectomies while a group of eight “vascular surgeons” did 168 such operations. The morbidity and mortality were similar for both groups. However, the experience of the entire neurosurgical service for the same time interval was 385 carotid operations and the mortality and morbidity data for the 16 neurosurgeons performing the remaining 203 operations (average 12.6 each) was “considerably higher”, than for the more experienced neurosurgeons.

It appears that carotid endarterectomy in a community hospital is a safe procedure, with a combined stroke/mortality rate of less than 5%. This safety is not predicated on frequency of performance of the operation, but it appears to be directly related to the adequacy of initial training, under a wide variety of circumstances. Careful assessment of this training will insure good surgical judgment and technical expertise.

### Acknowledgment

The authors wish to express their gratitude to the surgeons of the Lehigh Valley Hospital Center for their participation in this study.

### Table 1: Mortality and Morbidity Following Carotid Endarterectomy

<table>
<thead>
<tr>
<th>Frequency of procedure (per year)</th>
<th>&gt;24</th>
<th>24 or Less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of surgeons</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Temporary deficit</td>
<td>19 (4.2%)</td>
<td>7 (2.4%)</td>
</tr>
<tr>
<td>Permanent deficit</td>
<td>9 (2.0%)</td>
<td>4 (1.4%)</td>
</tr>
<tr>
<td>Mortality</td>
<td>12 (2.6%)</td>
<td>8 (2.8%)</td>
</tr>
<tr>
<td>Total procedures</td>
<td>456</td>
<td>287</td>
</tr>
</tbody>
</table>

There is no statistically significant difference in the parameters measured for the two groups.
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 connection with carotid endarterectomy.

The value of carotid endarterectomy in the prevention of ischemic stroke is still questioned: there is no definitive study as dizziness and patients with asymptomatic bruits. From one institution to another. The perioperative technique, morbidity and mortality rate vary considerably.

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.

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 studied, (fig. 1). There was no control group.

All the patients were evaluated within a month of the onset of symptoms. The clinical diagnosis of TIA or IBI was based upon the case history and general phys-
Review of a community hospital experience with carotid endarterectomy.
L G Slavish, G G Nicholas and W Gee

Stroke. 1984;15:956-959
doi: 10.1161/01.STR.15.6.956

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