stroke occurs from one to five times as often as death following endarterectomy,8-14 an additional 1,000 to 9,000 persons in this group may have had a stroke. This would result in a combined mortality and morbidity of 2,000 to 10,800. These data are quite sobering and certainly should not be dismissed lightly.

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The Practice of Carotid Endarterectomy In A Large Metropolitan Area

THOMAS BROTT, M.D., AND KAREN THALINGER, M.D.

SUMMARY All carotid endarterectomies performed in the greater Cincinnati metropolitan area during 1980 were reviewed. For the 431 procedures performed in 16 hospitals, the operative stroke rate was 8.6% (37 of 431), and the operative mortality rate was 2.8% (12 of 431). The combined morbidity and mortality was 9.5% (41 of 431). Fifty percent of the procedures were done for asymptomatic carotid disease (216 of 431). The stroke rate was 5.6% for the asymptomatic patients and 11.6% for the symptomatic patients (difference significant, p < 0.05). Neurosurgeons and vascular surgeons had similar surgical morbidity. All of the operative strokes involved the hemisphere ipsilateral to the endarterectomy. Fifty-seven percent of the operative strokes (21 of 37) occurred after a neurologically intact interval lasting hours to days. Four occurred following combined endarterectomy-coronary bypass surgery, and one was an intracerebral hemorrhage. The other late strokes (17) occurred without evidence for cardiac embolus or hemorrhage, consistent with a thrombogenic-embolic or emboligenic operative site, and raising the question of need for adjunctive perioperative medical therapy.

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CAROTID ENDARTERECTOMY has become a common mode of therapy in the setting of internal carotid artery stenosis and ipsilateral TIA. The procedure is also performed by some for carotid stenosis and prior ipsilateral cerebral infarction, for asymptomatic carotid stenosis, and occasionally for vertebralbasilar insufficiency. Justifications for the procedure hinge on the comparisons of the surgical morbidity and mortality to the reported natural history in those treated medically, and in those untreated. Recent surgical literature would indicate a perioperative stroke rate of less than 3% in major centers. However, Easton and Sherman reported a considerably higher combined stroke and death rate in the community hospital setting (21.1% of 228 endarterectomies). Their report was recently updated by Modi et al, and a combined neurologic deficit-death rate was 8.9%, still higher than that reported from major teaching centers. The present study
was performed to determine the indications, morbidity, and mortality with carotid endarterectomy in a large metropolitan area, including teaching hospitals and community hospitals, and including procedures performed by house officers, vascular surgeons, and neurosurgeons.

Methods

The records of all patients undergoing carotid endarterectomy during 1980 at the 16 general hospitals in Greater Cincinnati were reviewed. These hospitals served a 1980 population of approximately 1.4 million. Physician notes, nursing notes, anesthesia records, operative notes, angiogram and other x-ray reports were studied for every patient. Each note or report without exception was reviewed by a board certified neurologist. Six indications for surgery were identified. The category TIA included those patients so identified by their physicians, as well as those with transient focal neurologic symptoms where the history recorded was sufficient for the neurologists to make that diagnosis; in patients with the TIA involving the hemisphere contralateral to the operation, the indication was classified as asymptomatic carotid stenosis. Stroke included those patients with prior cerebral infarction documented by history and exam and/or CT scan. Asymptomatic bruit included those patients whose evaluation and surgery depended primarily on the identification of the bruit. Asymptomatic stenosis included those patients identified by angiography during evaluation for symptoms referable to the contralateral carotid. An indication was classified as dizziness when that symptom was specified without inclusion of simultaneous cranial nerve symptoms. Other was the indication for those patients whose histories were insufficient to allow categorization to one of the above categories.

A perioperative TIA was identified when focal neurologic signs were noted by a physician or nurse, and the deficit was not referred to subsequently after 24 hours. Perioperative stroke was identified when any hemispheric deficit not noted preoperatively was recorded on two successive days by either a physician or nurse. The stroke was classified as immediate if it was identified either immediately at operation or in the recovery room, or if it was noted at the time of the first recorded neurological examination (usually in the recovery room). Stroke after interval was identified when the patient was recorded to have been neurologically normal postoperatively prior to the hemispheric deficit. When a stroke was so identified, vital signs, physician notes, and any laboratory or x-ray data obtained were carefully reviewed (e.g. post deficit CT scan).

Each patient was further classified as to sex, age, hospital, surgeon, preoperative angiogram, use of a shunt, local or general anesthesia, and any other complication. Regardless of outcome, all intra-operative technical complications were recorded. Any complication noted by nursing notes was signified.

Face Sheet Diagnostic coding was not used when inspecting the records as it was an unreliable guide to complications. Statistical analysis was performed by Vicki Hertzberg, Ph.D., (Department of Environmental Health, University of Cincinnati College of Medicine) using the Fisher exact test and confidence limits for proportions. Power calculations were performed according to the method of Rosner.

The specialty board status of the 47 staff surgeons was not investigated.

Results

As noted in table 1, a total of 431 procedures were performed on 371 patients. The leading single indication was TIA, (141 or 32.7%). The second leading indication was that of ipsilateral cerebral infarction, (74 or 17.2%). The procedure was performed for asymptomatic carotid bruit in 67 (15.5%), and for asymptomatic carotid stenosis in 63 (14.6%). Sixty procedures were performed for dizziness without cranial nerve symptoms (13.9%). The indications for the remaining 26 procedures could not be so specified. The TIA and stroke groups indicated that 215 procedures were done for ipsilateral symptomatic disease (49.9%) while 216 procedures were performed for asymptomatic carotid disease (50.1%). Vascular surgeons more frequently operated for asymptomatic carotid disease than did neurosurgeons, 56.7% vs. 32.4%, p < 0.0001 (fig. 1).

Patients aged 60–69 accounted for 45.2% of the endarterectomies while only 7.4% of the procedures were performed on those under age 40 or over 80 (fig. 2). Males accounted for 60.2% of the operations. Sixty procedures were performed for asymptomatic carotid disease (50.1%). Vascular surgeons more frequently operated for asymptomatic carotid disease than did neurosurgeons, 56.7% vs. 32.4%, p < 0.0001 (fig. 1).

Thirty-seven of the endarterectomies resulted in stroke (8.6%) (table 2). Stroke was more likely to occur in the setting of prior ipsilateral symptomatic disease (25 of 215, or 11.6%) than in the setting of asymptomatic disease (12 of 216, or 5.6%). This difference in perioperative stroke was statistically significant, 0.01 < p < 0.05 (fig. 3). When the indications were subdivided further, no statistically significant differences were noted in stroke (table 2). Each of the strokes involved the hemisphere ipsilateral to the operated carotid artery. No brainstem strokes were identified.

Twenty-one of the 37 perioperative strokes occurred after a neurologically intact interval lasting hours to days (57% of the stroke group). Technical problems or hypotension were noted at operation in only 3 of the 37. Of the 18 TIA’s identified perioperatively, 10 also

<table>
<thead>
<tr>
<th>Indications for Carotid Endarterectomy</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral TIA</td>
<td>141</td>
<td>32.7%</td>
</tr>
<tr>
<td>Asymptomatic bruit or stenosis</td>
<td>130</td>
<td>30.2%</td>
</tr>
<tr>
<td>Ipsilateral infarction</td>
<td>74</td>
<td>17.2%</td>
</tr>
<tr>
<td>Dizziness without cranial nerve sympotms</td>
<td>60</td>
<td>13.9%</td>
</tr>
<tr>
<td>Other</td>
<td>26</td>
<td>6.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>431</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
occurred following a neurologically intact interval postoperatively. In none of the post-"lucid interval" neurologic events was atrial fibrillation, acute myocardial infarction, or hypotension identified.

Of all strokes detected, 18.9% resulted in death, 73.0% involved a focal deficit still present at hospital discharge, and in 8.1% the deficit was apparently resolved at discharge (table 3). None of the persistent focal deficits were detected by the nurses without also being detected by the physicians, but 22 of the 37 strokes (59.4%) were not identified or coded on the medical record face sheet. CT scans were performed following 6 of the 37 strokes and 1 intracerebral hemorrhage was identified.

Twelve patients died (2.8%). Eight deaths involved patients with perioperative stroke; 4 of the 8 died during the initial 5 postoperative days from transtentorial herniation diagnosed clinically and/or by CT scan (3 infarcts and 1 intracerebral hemorrhage); one patient died on the eighteenth day of unknown cause complicating persistent coma and fixed dilated pupils, and the other 3 perioperative stroke patients died from cardiac arrest on postoperative day 13, 19 and 63. The last patient was included as his prolonged postoperative course was actively complicated by his perioperative stroke, requiring continuous hospitalization until death; just prior to cardiac arrest he developed renal failure. Four of the 12 deaths involved patients without perioperative strokes; 3 were cardiac deaths complicating combined cardiac bypass graft surgery, and the fourth patient developed a myocardial infarction on the second postoperative day with ventricular fibrillation and death on day 5.

Other complications were identified: three patients had intractable headaches, 2 patients had respiratory arrest, 2 patients had respiratory failure, 2 patients developed transient vocal cord paralysis, 2 patients required reexploration for wound hematoma, and 2 patients sustained documented myocardial infarctions. Morbidity and mortality did not vary with age, including the 19 operations performed on patients age >80 (fig. 4). Use of shunt, type of anesthesia, and specialty of surgeon could not be related to morbidity (fig. 5).

Two-thirds of the procedures were carried out by vascular surgeons, and one-quarter by neurosurgeons. Forty-seven total staff surgeons were identified, and 24 performed 5 or fewer procedures during 1980, but

### Table 2. Perioperative Stroke and Death Rate by Indication

<table>
<thead>
<tr>
<th>Stroke or Indication</th>
<th>Stroke</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ipsilateral TIA</td>
<td>17/141</td>
<td>12.1%</td>
</tr>
<tr>
<td>Asymptomatic bruit or stenosis</td>
<td>10/130</td>
<td>7.7%</td>
</tr>
<tr>
<td>Ipsilateral infarction</td>
<td>8/74</td>
<td>10.8%</td>
</tr>
<tr>
<td>Dizziness without other cranial nerve symptoms</td>
<td>2/60</td>
<td>3.3%</td>
</tr>
<tr>
<td>Other</td>
<td>0/26</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>8.6%</td>
</tr>
</tbody>
</table>

Figure 2. Number of carotid endarterectomies broken down by age and sex.

Figure 3. Perioperative stroke and death rates broken down by indication. The difference in the perioperative rates for "symptomatic" and "asymptomatic" carotid endarterectomies was statistically significant, 0.01 < p < 0.05.
TABLE 3  Severity of Perioperative Stroke

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>% of all strokes</th>
<th>% of all operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massive (directly caused death)</td>
<td>7</td>
<td>18.9%</td>
<td>1.6</td>
</tr>
<tr>
<td>Significant (deficit present at discharge)</td>
<td>27</td>
<td>73.0%</td>
<td>6.3</td>
</tr>
<tr>
<td>Minor (no documented deficit at discharge)</td>
<td>3</td>
<td>8.1%</td>
<td>0.6</td>
</tr>
<tr>
<td>TIA (deficit &lt; 24 hours)</td>
<td>18</td>
<td>0%</td>
<td>4.2</td>
</tr>
</tbody>
</table>

15 of the 37 strokes were recorded and/or coded on the patients' medical record face sheet.

These "least active" surgeons matched the most active with respect to perioperative stroke or death rate (table 4). Two surgeons had morbidity or mortality significantly higher than their staff colleagues ($p < 0.05$, table 4). Excluding their results from the study yields a lower community peri-operative stroke rate (7% vs. 8.6%) and death rate (2.3% vs. 2.8%).

Seventeen endarterectomies were performed immediately prior to coronary artery bypass graft surgery. Four of these procedures resulted in stroke and all four of these infarctions occurred following an initial post-operative normal neurologic interval. This morbidity was not significantly different statistically from the total group. The Type II error was >40%.

Angiogram reports were reviewed on every patient. Stenosis was graded as severe if the report specified 75% or greater stenosis, or if the report described the stenosis as severe, marked, significant, hemodynamically significant or moderately severe. Irregularity and ulceration were not included in this grading. Two hundred and twenty-two of the endarterectomies were done in the setting of severe ipsilateral carotid stenosis. Twenty-two of these patients sustained perioperative stroke (9.9%) and 8 patients died (3.6%), a morbidity not statistically significantly different from that of those with lesser stenosis. Nine operations were done for internal carotid artery occlusion and 2 of these 9 cases involved endarterectomy of only the external carotid artery. None of the 9 resulted in morbidity or mortality. While patients were subdivided according to age, symptoms, and degree of stenosis, other important variables for assessing operative risk (e.g. pre-operative blood pressure, cardiac, and pulmonary status) could not be consistently determined.

Discussion

The above series is the first metropolitan area wide study of carotid endarterectomy and covers a population of 1.4 million for one year. The 431 operations made it one of the larger reviews and the study year of 1980 makes it the most current of the large reviews. Therefore, the results should be more representative of the actual practice of carotid endarterectomy than those of prior studies. The Cincinnati community-wide perioperative stroke rate of 8.6% and death rate of 2.8% exceeded morbidity and mortality reported from single centers by a disturbing margin. The large number of operations reviewed resulted in 95% confidence limits for the stroke rate of 6.7% and 12.3%, and 95% confidence limits for the death rate of 1.3% and 4.3%. The combined morbidity and mortality for carotid endarterectomy of 9.5% was also high, with 95% confidence limits of 6.7% and 12.3%. The data call into question the quantitative value of carotid endarterectomy as it is currently performed in large metropolitan areas.

TIA was the most common single indication for surgery (32.7%) but half of the operations were done for asymptomatic carotid disease (50.1%). This fraction may increase. Non-invasive vascular laboratories were operational in only 7 of the 16 hospitals in 1980 and now are operational in 13. Three additional vascular laboratories are now located in physician offices. The equipment used today is better able to detect carotid bifurcation disease. Digital subtraction angiography was not available during our study year of 1980 but now is operational in 3 of the 16 hospitals and planned for 7. As more anatomic disease is detected, more carotid endarterectomies may be performed in patients with and without symptoms. Such a trend may or may not begin in the future.

FIGURE 4. Perioperative stroke and death rates by age. The difference in stroke and death were not statistically significant.

FIGURE 5. Perioperative stroke and death rates broken down by surgical training, shunt use, or simultaneous coronary artery bypass graft (CABG). The differences in stroke and death were not statistically significant.
**TABLE 4. Perioperative Stroke and Death Rate by Surgeon (most active and least active)**

<table>
<thead>
<tr>
<th>Surgeon Type</th>
<th>Operations</th>
<th>Stroke</th>
<th>Death</th>
<th>Stroke or Death†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular surgeon A</td>
<td>52</td>
<td>1</td>
<td>1</td>
<td>(1.9%)</td>
</tr>
<tr>
<td>Vascular surgeon B</td>
<td>33</td>
<td>3</td>
<td>2</td>
<td>(9.0)</td>
</tr>
<tr>
<td>Vascular surgeon C</td>
<td>27</td>
<td>1</td>
<td>0</td>
<td>(3.7)</td>
</tr>
<tr>
<td>Vascular surgeon D</td>
<td>23</td>
<td>2</td>
<td>0</td>
<td>(8.7)</td>
</tr>
<tr>
<td>Neurosurgeon A</td>
<td>19†</td>
<td>6</td>
<td>1</td>
<td>(31.6)</td>
</tr>
<tr>
<td>Vascular surgeon E</td>
<td>17</td>
<td>3</td>
<td>3</td>
<td>(17.6)</td>
</tr>
<tr>
<td>Neurosurgeon B</td>
<td>16</td>
<td>1</td>
<td>0</td>
<td>(6.2)</td>
</tr>
<tr>
<td>Staff surgeons</td>
<td></td>
<td>72</td>
<td>4</td>
<td>(5.6)</td>
</tr>
<tr>
<td>(n = 24)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All staff surgeons</td>
<td></td>
<td>402</td>
<td>37</td>
<td>(10.2)</td>
</tr>
<tr>
<td>(n = 47)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House officers</td>
<td></td>
<td>29</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(n = 15, all performed &lt; 5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant difference relative to staff colleagues.
†Does not double count stroke patients who died.

It is not fortunate. Prophylactic carotid surgery is still of unestablished benefit in asymptomatic patients, even in centers with reported low morbidity. Endarterectomy was safer for our asymptomatic patients (5.6% stroke rate) than for symptomatic patients (11.6%), but the combined stroke and death rate of 6.9% for the asymptomatic patients was alarming (stroke patients who died were not double counted). The data suggest prophylactic carotid surgery may be detrimental if performed outside centers with proven low morbidity.6

The training background of the surgeon related strongly to clinical indication for surgery. Those considering themselves vascular surgeons more frequently operated in the setting of asymptomatic carotid stenosis (p < 0.00001). No doubt this relates in part to the differences in referral patterns. Vascular surgeons are more likely to evaluate patients with anatomically diffuse vascular disease, while neurosurgeons are more likely to see the patients with focal neurologic symptoms. The vascular surgeons also interpret the anatomic study in 16 of the 16 vascular laboratories in Cincinnati.

The stroke and death rates did not vary with type of surgical training. Nor did the rates vary with experience or with a given surgeon’s frequency of operating. Twenty four of the surgeons performed 5 or fewer endarterectomies in the year and obtained success equal to their busier colleagues. This latter finding is unexplained and contrary to inferences drawn from single surgeon studies.1,3 The inter-surgeon variability found involved a higher morbidity or mortality for two active staff surgeons, and a lower morbidity and mortality for the house officers (table 3). Excluding only the “bad results” still yields a high peri-operative stroke rate (7.0% vs. 8.6%) and a high death rate (2.3% vs. 2.8%). The “good results” of the house officers (zero morbidity and mortality in 29 cases) could not be explained by patient age, symptoms, or degree of stenosis.

Sundt et al12 and others have rightly demonstrated the importance of patient medical risks and subsequent results of carotid endarterectomy. Unfortunately, the Cincinnati medical records were not consistently detailed enough to assess preoperative blood pressure history, cardiac status, pulmonary status and other possibly important medical variables. The high morbidity and mortality could be artificial in part if the operative population was overly weighted with poor risk patients. However, the patient variables we did identify and the high frequency of surgery for asymptomatic disease (50.1%) do not suggest the Cincinnati operative group to be of higher risk than the groups in other surgical studies.

Perioperative stroke may be undercounted in prior endarterectomy studies. In Cincinnati medical records, stroke was often not listed as a discharge diagnosis (22 of 37) even though the persisting deficits were recognized and recorded in progress notes by the physicians who later completed the records. The perioperative stroke diagnosis required a time consuming page-by-page record review by 2 board certified neurologists for each of the 371 operated patients. In earlier studies of carotid endarterectomy, methods and criteria for diagnosing perioperative stroke are not specified in detail.7–13 In our study, diagnosis of perioperative stroke from the record face sheet and/or ICD-CM diagnoses codes would have resulted in a 5.1% stroke rate instead of the 8.6% rate. For our study population, a given surgeon’s personal retrospective review could have undercounted morbidity, depending upon his methods of review and upon his criteria for stroke.

We did not find evidence to suggest our criteria for diagnosing perioperative stroke volume were too inclusive. Physician progress note or nursing note documentation of a new central nervous system focal deficit for at least 2 days was required. Empirically, the deficits of the 37 patients designated as strokes were diagnosed and recorded by the physicians, and never exclusively by the nurses. The outcome of these patients was also consistent with that reported in other acute stroke populations: 7 died as a direct result of the stroke, 1 died later from neurologic and medical complications, and 26 of the 29 survivors had deficit(s) at discharge (see table 4).13,14

Criteria for stroke diagnosis in future surgical studies should be carefully defined, and the criteria should be no less sensitive than criteria used in studies of medical treatment.15,16
The timing of perioperative stroke is consistent with the emerging literature supporting the arterial wound site as a source of significant postoperative thrombus and/or embolus formation. A majority (57%) of the perioperative strokes occurred after a normal waking post-op interval of hours to days. We cannot exclude carotid spasm or intracerebral hemorrhage in these patients. However, we did exclude hypotension, atrial fibrillation, and myocardial infarction as etiologic variables. The thrombogenic nature of the post-operative vessel wall has been experimentally demonstrated in dogs. Hertzler et al used digital subtraction angiography following 262 endarterectomies and demonstrated a very low frequency of internal carotid occlusion (1.9%) but a higher frequency of irregularity, stenosis, or external carotid artery occlusion (8.7%). Steed et al analyzed perioperative neurologic complications in conscious patients. Only one complication occurred during carotid clamping while two occurred upon release of the clamp and fifteen occurred in the first five postoperative days.

Deen and Sundt were able to significantly retard wound site thrombus formation in dogs using aspirin and dipyridamole perioperatively (heparin was less effective). For coronary artery bypass graft patency, Chesebro et al demonstrated the protective effects of aspirin and dipyridamole. Clearly, the post-endarterectomy patient is at higher risk for at least the interval needed for complete re-endothelialization and remodeling of the arterial lumen. Our own patients are placed on aspirin as soon as they begin oral intake postoperatively, and the aspirin is continued for at least one year. Further study of peri-operative medical therapy seems indicated, including study of pre-operative therapies.

Each of the four strokes following combined carotid endarterectomy-coronary artery bypass graft surgery (n = 17) was ipsilateral to the endarterectomy. Each stroke also followed a post operative neurologically normal interval. Perhaps a fresh carotid luminal wound site is least desirable when immediately followed by the lower flow of cardiac bypass and the later systemic effects of major surgery. Recent studies of patients with asymptomatic carotid bruit or stenosis have not supported the need for prophylactic endarterectomy prior to major surgery or prior to coronary artery bypass graft.

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