

Carotid Endarterectomy: An Analysis of 234 Operative Cases

DANIEL B. NUNN, M.D.*

This paper offers a computer-assisted analysis of the author's experience with 234 carotid endarterectomy procedures in 188 patients. The patients' ages, sex, smoking habits, symptoms, carotid bruits, arteriographic findings and associated diseases are summarized.

There were 28 operations in asymptomatic patients, 170 operations in patients with transient ischemic attacks (TIA), 35 operations in patients with a completed stroke and one operation in a patient with a stroke in evolution. After surgery, transient neurologic deficits were noted in both the asymptomatic group (two instances) and the group with TIA (5 instances); permanent neurologic deficits followed 4 operations in the TIA group (2.4% incidence). Two operative deaths occurred in the TIA group (1.2% mortality), and 10 deaths occurred after operation for a completed stroke (28.6% mortality). Nine of the deaths in the completed stroke group followed operations performed less than 2 weeks after a stroke.

A 100% followup was obtained, and the average period of followup was 48 months. Of the patients surviving operation, all in the asymptomatic group were judged functionally normal, 94% of the TIA group were either functionally normal or improved, 76% with a completed stroke were improved, and the patient with a stroke in evolution was unchanged. There were 69 late deaths with heart disease accounting for 58% of the deaths and stroke another 17%.

THE FIRST SUCCESSFUL carotid endarterectomy for stroke was performed by Dr. Michael E. DeBakey in 1953.¹² Since then, carotid endarterectomy has become the standard operative procedure for selected patients with cerebrovascular insufficiency caused by arteriosclerotic involvement of the proximal internal carotid artery. Numerous reports of clinical experience with carotid endarterectomy have demonstrated the efficacy of the procedure and have helped establish more precise indications for operation.^{1-9,13} Nevertheless, there are still differences of

From the Departments of Surgery, St. Vincent's Medical Center and Methodist Hospital, Jacksonville, Florida

opinion concerning various aspects of treatment. It is, therefore, important to evaluate periodically additional series of cases in an effort to resolve problems and further improve the results of surgical management. Accordingly, this paper reports a computer-assisted analysis of the author's experience with carotid endarterectomy during the 10-year period from 1963 to 1973; the results of this study are collated with those reported by other investigators.

Material and Methods

Between July, 1963, and July, 1973, a total of 234 carotid endarterectomies were performed for arteriosclerotic narrowing and ulcerated plaques in 188 patients. Forty-six patients underwent bilateral operations; in each patient, the procedures were done at least one week apart.

Operative cases were classified into four clinical categories designated as asymptomatic, transient ischemic attacks (TIA), completed stroke, and stroke in evolution. The classification of cases was based upon each patient's clinical findings and the relationship of these findings to the carotid artery subjected to endarterectomy. For example, a right carotid endarterectomy in a patient with a recent persistent neurologic deficit on the left side was classified in the completed stroke group; however, a left carotid endarterectomy performed later in the same patient without symptoms or signs referable to the left carotid was classified in the asymptomatic group.

Carotid arteriograms were made in all patients prior to operation, but were not obtained routinely following endar-

Submitted for publication June 10, 1975.

*Clinical Assistant Professor of Surgery, University of Florida School of Medicine/Jacksonville Hospitals Educational Program, Inc.

TABLE I.

Arteriographic Findings	Appropriate Artery	Inappropriate Artery
Stenosis less than 50%	14	54
Stenosis less than 50% with ulcerated plaque	8	10
Stenosis 50% or greater	160	41
Stenosis 50% or greater with ulcerated plaque	40	11
Ulcerated plaque alone	4	6
Complete occlusion	8	23
Normal	0	50
No arteriogram	0	39

terectomy. The arteriographic examinations were performed under local anesthesia and sedation. In most patients, a percutaneous puncture technique was used for carotid arteriograms, and vertebral arteriograms were not made unless clinically warranted. The other patients underwent selective carotid arteriography as part of a 3 or 4 vessel catheter study performed by the transfemoral Seldinger technique. Hypaque 50% or Renografin-60 was manually injected and serial films were taken with an Elema-Schonander x-ray unit.

All operative procedures were performed under general endotracheal anesthesia. Hypercarbia was avoided, and an effort was made to maintain blood pressure near preoperative levels. Each patient was given 5,000 units of Heparin intravenously at least 5 minutes before occluding the carotid artery with vascular instruments. An internal shunt was used during all endarterectomies except those in which the internal carotid was completely occluded preoperatively. The arteriotomies were closed with continuous 6-0 Dacron sutures without the use of a patch. Heparin was counteracted with protamine sulfate only during the latter part of this series in those cases in which there had been significant hypertension or considerable bleeding from the wound surfaces. Postoperative anticoagulants were not used.

In evaluating the early results of surgery, deaths which occurred in the course of the operation, during the postoperative hospitalization period, or within 30 days after surgery were considered operative mortalities.

Followup examinations were made at regular intervals and at the conclusion of the study. If death occurred prior to the end of the study, the date and cause of death were ascertained along with the clinical condition of the patient prior to his demise. Late results of surgery were evaluated on the basis of a patient's functional status with respect to the artery subjected to operation. Each operative case was categorized as functionally normal, improved, the same, worse, or normal or improved then worse.

This series of operative cases was analyzed using the following method. Initially, a data extraction worksheet was designed to contain a numerical list of items which could be used to describe the salient features of each case.

After reviewing a patient's records, items pertaining to that particular case were identified by circling the appropriate numbers on a separate worksheet; the worksheet was completed by assigning the case a series number and listing the patient's age and the followup period in months. Information recorded on the worksheets was keypunched on data cards, and a computer programed to read the cards and store the information on disc packs. Another program enabled the computer to analyze the stored information and provide specific answers in response to questions of interest.

Clinical Data

The 188 patients in this series included 118 males and 70 females; 178 patients were Caucasians and 10 were Negroes. The patients ranged in age from 32 to 89 with a median age by decade of 61 to 70 years. The average age for all patients was 64 years with males averaging 63 years and females 66 years.

Information regarding smoking was available in the records of 153 patients, and there were 91 smokers and 62 non-smokers. A non-smoker was defined as one who either had never smoked or had not smoked for at least two years.

There were 28 operations in asymptomatic patients, 170 operations in patients with TIA, 35 operations in patients with a completed stroke, and one operation in a patient with a stroke in evolution.

The 28 operative cases in the asymptomatic group were reviewed to determine the clinical condition which had prompted the decision for prophylactic surgery. The majority of operations (24) were performed in patients who had previously undergone endarterectomy on the opposite carotid because of either TIA or a completed stroke. Two operations preceded major surgical procedures for correction of concomitant arterial occlusive disease involving the lower extremities. The other two operations were done in patients hospitalized primarily for evaluation of asymptomatic carotid bruits.

A variety of symptoms attributed to cerebrovascular insufficiency were noted in the cases classified in the TIA and completed stroke groups. A complete list of symptoms comprised unilateral motor weakness, unilateral sensory deficit, amaurosis fugax, aphasia, dysarthria, dizziness, vertigo, syncope, diplopia, tinnitus, and photopsia. In a combined analysis of both groups of cases, the symptoms which occurred more frequently were dizziness (58%), unilateral motor weakness (41%), amaurosis fugax (26%), and aphasia and dysarthria (26%).

Preoperatively, a systolic bruit was audible over the appropriate carotid artery (i.e. the one subjected to operation) in 98 (42%) of the 234 operative cases. In 22 (9%) of the cases, a bruit was detected over the inappropriate artery only; 35 (15%) cases had a bruit over both carotid arteries.

Significant medical abnormalities other than cerebrovascular insufficiency were found in 210 (90%) of the

TABLE 2.

Clinical Group	Number of Deaths	Cause of Death	Procedure Mortality
Asymptomatic	0		0
TIA	2	Cardiac (1) Cerebral (1)	1.1%
Completed stroke	10	Cerebral (7) Cardiac (2) Pneumonia (1)	28.6%
Stroke in evolution	0		0

operative cases. The associated diseases and their incidence of occurrence were hypertension (51%), vascular disease affecting the lower extremities (44%), heart disease (44%), hyperlipidemia (25%), cerebral occlusive disease (22%), diabetes mellitus (18%), chronic bronchitis and pulmonary emphysema (15%), vertebral artery insufficiency (6%), and cerebral aneurysm (4%).

Arteriographic Findings

The preoperative arteriographic findings for both the appropriate and inappropriate arteries in all cases are summarized in Table 1.

Bilateral carotid arteriograms were made in 195 of the 234 operative cases. An analysis of the cases with unilateral arteriograms revealed that in 34 cases the secondary stage of a bilateral endarterectomy was performed without the benefit of repeat carotid arteriography. Also, unilateral arteriograms were obtained in three cases with a completed stroke who had undergone early operation (less than two weeks after onset of a stroke) and two cases in the TIA group. One of the TIA cases had a limited examination because a serious complication (acute thrombosis of the carotid with resultant amaurosis fugax) had developed during unilateral percutaneous carotid arteriography; fortunately, following emergency thromboendarterectomy with successful restoration of flow, there were no neurologic sequelae.

With regard to the findings in the appropriate carotid arteries, there were 14 cases with stenosis less than 50%, 8 cases with stenosis less than 50% and an ulcerated plaque, 160 cases with stenosis 50% or greater, 40 cases with stenosis 50% or greater and an ulcerated plaque, 8 cases with complete occlusion and 4 cases with an ulcerated plaque alone. Cases with stenosis less than 50% with or without an ulcerated plaque and cases with an ulcerated plaque alone were reviewed to determine their clinical category. Of the 14 cases with stenosis less than 50%, there was one in the asymptomatic group, 12 in the TIA group, and one in the completed stroke group. In the 8 cases with stenosis less than 50% and an ulcerated plaque, there were 2 in the asymptomatic group, 5 in the TIA group, and one in the completed stroke group. Three of the 4 cases with an ulcerated plaque alone were in the TIA group, and the other

TABLE 3.

Time of Operation After Stroke	Number of Operative Cases	Postoperative Deaths
< 24 hours	8	3 (cerebral)
One to thirteen days	21	4 (cerebral) 2 (cardiac)
> 2 weeks	6	1 (carcinoma of lung and pneumonitis)

case was in the asymptomatic group. It should be noted that all of the cases in the asymptomatic group suffered a previous stroke caused by occlusive disease in the opposite carotid or cerebral arteries.

Vertebral arteriograms were made in 45 of the operative cases. The incidence of serious complications resulting from all arteriographic studies, whether involving one or more vessels, was 0.4% (1 in 234).

Early Results of Surgery

Seven operative cases required emergency reoperation because of postoperative hemorrhage. All of these cases had hypertension, and none received protamine sulfate following the use of Heparin. With the exception of one case, the hemorrhage occurred within one to 3 hours after endarterectomy. In 4 cases, there was excessive capillary bleeding from the skin and subcutaneous tissues alone. Two cases had bleeding from the arterial suture line, and in one case postoperative thrombosis of the internal carotid developed. The remaining case sustained a major hemorrhage from the carotid suture line 20 days after surgery; bleeding was thought to have been caused by defective suture material which had broken. Except for the postoperative death in the case with carotid thrombosis, the other cases recovered without ill effects.

After carotid endarterectomy, transient neurologic deficits were noted in both the asymptomatic group (2 instances) and the group with TIA (5 instances); permanent deficits followed 4 operations in the TIA group (2.4% incidence). When the asymptomatic and TIA groups were combined, the total incidence of transient and permanent neurologic deficits was 3.5% and 2% respectively. Although most (8 instances) of the neurologic deficits were noted within 24 hours after surgery, 3 instances of transient deficits developed later in the postoperative period (two on the third day and one on the tenth day). Some of the factors contributing to the development of postoperative neurologic deficits were operative hypotension, postoperative hypertension, the presence of cerebral and contralateral carotid occlusive disease, and the inadvertent compression of the operated carotid while elevating the mandible to prevent respiratory obstruction.

A total of 12 deaths occurred either during the postoperative hospitalization period or within 30 days after surgery;

TABLE 4. Late Followup Analysis

	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	112	118	120	Total Number Cases	Average Months Followup
Number of Months	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	112	118	120		
Asymptomatic	4	3	1	1	3	5	5	1	3				1		1							28	34
Transient Cerebral Ischemia	27	8	16	13	17	13	17	14	16	6	1	4	2	3	2	4	1	1	1	1	1	168	39
Completed Stroke	5		1		3	2	4	2	3	1	1	1		1		1						25	41
Stroke in Evolution													1									1	78

no deaths occurred in the course of the operative procedures. Table 2 outlines the procedure mortality for the various groups of cases. There were two deaths (one cardiac and one cerebral) in the TIA group, and the mortality rate was 1.2%. Ten deaths followed surgery for completed strokes (28.6% procedure mortality). In the completed stroke group, the causes of death were cerebral (7), cardiac (2) and pneumonia (1). There were no post-operative deaths in the asymptomatic and stroke in evolution groups.

The 35 cases in the completed stroke group were reviewed to determine the effect of timing of operation on procedure mortality. Results of this review are summarized in Table 3. Twenty-nine cases underwent endarterectomy less than 2 weeks after onset of a stroke; 9 of the 10 deaths in the completed stroke group followed surgery in these cases.

Eight operations in the completed stroke group were performed for complete occlusion of a carotid artery. Restoration of flow was possible in 6 cases; however, one case developed a carotid-cavernous sinus fistula following the use of a Fogarty embolectomy catheter to remove distal clot. Four deaths (3 cerebral and 1 cardiac) occurred postoperatively.

Twenty-three endarterectomies were done for carotid stenosis in the presence of a completely occluded carotid on the contralateral side. There were 4 operations in the asymptomatic group, 17 operations in the TIA group, and 2 operations in the completed stroke group. After surgery, a transient neurologic deficit was noted in one case (TIA). None of the cases developed a permanent neurologic deficit, and only one death (cardiac) occurred.

Late Followup

A 100% followup was obtained and the average period of followup was 48 months. Details of followup in terms of months and number of cases in each clinical group are depicted in Table 4.

The functional status of the surviving operative cases either at the completion of the study or prior to late death is shown in Table 5. All cases in the asymptomatic group were judged functionally normal, 94% of the cases in the TIA group were functionally normal or improved, 76% of the cases with a completed stroke were improved, and the case with the stroke in evolution was unchanged.

A total of 69 late deaths occurred during the followup period (Table 6). The majority of deaths (58%) were caused by heart disease; 17% of the deaths were attributed to stroke.

Discussion

It is generally agreed that arteriographic findings of either 50% stenosis or an ulcerated plaque constitute a significant surgical lesion in patients otherwise considered suitable candidates for carotid endarterectomy. Indeed, 212 of the

234 operative cases in this series had carotid arteriograms with such findings. It is noteworthy, however, that 14 of the remaining cases had arteriographic findings of stenosis less than 50% without obvious ulceration; in the absence of other etiologic factors, the area of stenosis was regarded as a probable source of platelet and atheromatous cerebral emboli.

Patients with carotid arteriosclerosis who are asymptomatic can be categorized as follows: 1) those with known stenosis or ulceration in one carotid after bilateral arteriograms and endarterectomy on the opposite side; 2) those with an asymptomatic carotid bruit who must undergo major surgery for other problems; and 3) those with an asymptomatic carotid bruit alone. The management of asymptomatic patients in all categories is a controversial issue.^{2,10,11,12,14} In an important study concerned with this matter, Javid et al.,⁹ studied the natural history of carotid atheromas in 93 patients by means of serial arteriograms over a period of one to 9 years. They found a significant increase in size of the atheromas in 62% of the lesions studied. Also, Thompson¹² followed a group of 92 patients with asymptomatic carotid bruits who were not subjected to endarterectomy. During a 10-year followup period, 41 (45%) of these patients developed either TIA (26%) or completed strokes (19%). Additional studies are needed which allow for a comparison of the results of non-surgical and surgical treatment. At present, the author favors endarterectomy for asymptomatic patients with significant stenosis or ulceration who have undergone operation on the contralateral carotid. Asymptomatic patients with a carotid bruit who require other major surgery are first evaluated by arteriograms after which endarterectomy is performed if significant lesions are present. Although routine arteriography is not advised for patients with an asymptomatic carotid bruit alone, such patients who have arteriograms with significant findings are considered possible candidates for endarterectomy. The results of surgery for asymptomatic patients in this series (no postoperative deaths or permanent neurologic deficits) would seem to justify this approach.

In this series, a total of 198 carotid endarterectomies were performed in patients without a neurologic deficit prior to operation (asymptomatic and TIA groups). The operative mortality was 1%, and there was a 2% incidence of permanent neurologic deficits postoperatively. These results compare favorably with those reported by other investigators. Following 399 endarterectomies in which general anesthesia and a shunt were used, Thompson¹² noted a 0.25% operative mortality and a 1.5% incidence of permanent deficits. DeWeese et al.⁴ performed 237 operations using general anesthesia and maintenance of normal or slightly hypertensive blood pressure without a shunt; they reported a mortality rate of 2%, and an incidence of permanent deficits of 9%. Fields et al.⁸ reporting for the

TABLE 5.

	Asymptomatic	TIA	Completed Stroke	Stroke in Evolution
Functionally normal	28 (100%)	84 (51%)	1 (4%)	
Functionally improved		74 (45%)	19 (76%)	
Functionally same		3 (2%)	4 (16%)	1 (100%)
Functionally worse			1 (4%)	
Functionally normal or improved then worse		4 (2%)		

Joint Study of Extracranial Arterial Occlusion, reviewed 169 operations in which various methods were used to prevent operative cerebral ischemia; the operative mortality was 3.5%, and the incidence of permanent deficits was 7.7%.

This study and others previously reported have shown that carotid endarterectomy performed less than two weeks after onset of a completed stroke is associated with a high operative mortality (up to 42%).^{1,4,13} The risk of early surgery is primarily related to a change in the blood-brain barrier which permits increased vascular permeability after an acute persistent neurologic deficit; this change gradually resolves over a 6 to 12 week period. If blood flow is restored surgically during the first two weeks of the change in the blood-brain barrier, there is considerable danger of converting an ischemic infarct into a hemorrhagic one. Consequently, most surgeons now agree that patients should not be subjected to endarterectomy within two weeks of the development of a completed stroke. For similar reasons, operation is also no longer recommended for patients with a stroke in evolution.

It has become evident that the majority of patients with complete occlusion of the internal carotid fail to benefit from endarterectomy.² The mortality rate following operation for an acute occlusion is prohibitive, and the chance of restoring flow two or more weeks after occlusion is extremely low. As a result, many surgeons, including the author, believe that patients with this lesion should not be

TABLE 6.

Cause of Death	Asymptomatic	TIA	Completed Stroke	Stroke in Evolution
Cardiac	4	30	6	
Cerebral	2	9	1	
Malignancy	2	5	1	
Renal		1		
Pneumonia		1		
Pulmonary Embolism		2		
Following other surgery		2		
GI Hemorrhage		1		
Suicide		1	1	
Total Deaths	8	52	9	0

considered suitable candidates for endarterectomy. On the other hand, those patients with significant stenosis or ulceration in the opposite carotid should have surgical correction of the stenotic or ulcerated lesion. Twenty-three such procedures were performed in this series using general anesthesia, systemic heparinization, and a shunt for cerebral support; the operative mortality was 4.3% (one cardiac death), and there were no permanent neurologic deficits postoperatively.

Finally, the results of late followup in this series have substantiated the effectiveness of carotid endarterectomy in the prevention of recurrent stroke. The basic disease process of arteriosclerosis, however, remains unaltered, and there is no convincing evidence that endarterectomy prolongs survival. The majority of late deaths following endarterectomy have been caused by associated coronary arteriosclerosis.

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