Results of Carotid Endarterectomies for Transient Ischemic Attacks-Five Years Later

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EASTCOTT, PICKERING, AND ROB reported successful reconstruction of a stenotic internal carotid artery for neurologic symptoms in 1954.[8] Since then several large series of operations on the carotid artery have been reported.[2,3,6,10,11,12] Carotid endarterectomies have been most frequently performed on patients with transient cerebral ischemic attacks (TIA). The reports of a collaborative study randomized into nonoperated and operated groups of patients with TIA suggest that carotid endarterectomies decrease late mortality rates.[1] In addition, patients who are operated upon have fewer TIA in the follow-up period.[9]

During the past 10 years 503 carotid endarterectomies have been performed at the University of Rochester, of which 285 were performed for TIA. It was possible to evaluate some of these patients for longer than 10 years. For the purposes of this presentation, however, we selected 103 consecutive patients operated upon for symptoms of TIA more than 5 years ago. The status of the patients at exactly 5 years following operation was analyzed. This retrospective study provides prognostic information useful in the evaluation of patients with TIA being considered for carotid endarterectomy.

Materials and Methods

The 103 patients in this study exhibited characteristics common to patients with symptomatic atherosclerotic lesions. There were 65 men and 38 women. The ages of the patients ranged from 46 to 80 years and 46% were in the 60–70 age range. Diabetes mellitus was present in 18% of the patients. Blood pressure recordings greater than 150/90 mm. Hg or a history of hypertension was observed in 45% of the patients. There was electrocardiographic evidence of arteriosclerotic heart disease in 24% of the patients. Aneurysms or symptomatic peripheral arterial disease had been present in 17% of the group. Serum cholesterol determinations were performed on 57 patients, of whom 44 demonstrated levels greater than 275 mg./100 ml.

Symptoms (Table 1)

All of the 103 patients had histories of transient ischemic attacks (TIA). These attacks were transient episodes of local neurologic deficit which were rapid in onset and of less than 24 hours duration and from which recovery was complete. Ipsilateral eye symptoms, contralateral motor and sensory symptoms, or speech difficulties were observed in 85% of the patients. The ipsilateral eye symptoms consisted of scotomata, blurred vision, or transient blindness and occurred 39% of the time. Contralateral sensory or motor symptoms consisting of weakness, paralysis, numbness, or paresthesias occurred in 59% of the patients. Speech difficulties consisting of motor or expressive aphasia occurred in 17% of the patients. Speech symptoms were observed only if the involved arteries supplied the dominant cerebral hemisphere. Other symptoms such as dizziness, syncope, headache, seizures, and confusion occurred in some of the total group and only

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these nonclassic symptoms were observed in 15% of the patients.

The severity of the problem and the desire for immediate treatment by the majority of the patients are reflected in an analysis of the time of onset, time of the last, and frequency of TIA occurring prior to operation (Table 2). Thirty-nine per cent of the patients became symptomatic within 3 months of operation; 53% had multiple attacks at intervals of less than 3 weeks; 66% suffered the last attack within 1 month of operation. Only 13% of the patients had histories of single episodes and these single attacks occurred more than 6 months prior to operation in only 1% of the patients.

Bruits and Ophthalmodynamometry

The results of both a careful examination for bruits and ophthalmodynamometry were available in 54 patients (Table 3). Definite bruits were heard 84% of the time and ophthalmodynamometry was positive in 59% of the patients. However, ophthalmodynamometry was positive in the absence of a bruit 7% of the time. Therefore, one or both of the tests were positive in 91% of the examinations. This, of course, means that in 9% of the patients the diagnosis of arterial occlusive disease required angiography.

Electroencephalography

Electroencephalograms were obtained on 39 patients prior to operation and 41% of these patients demonstrated at least some minor abnormality on the tracing. These abnormalities usually consisted of intermittent mild to moderate focal slowing in the mid-temporal and central areas.

Angiography

Angiograms were performed which visualized all four extracranial cerebral vessels in 63 patients prior to operation. Angiograms which visualized the involved vessels were obtained in another 18 patients. No angiograms were obtained in 19 patients who were operated on early in the study. In all that were operated upon there was a greater than 30% narrowing of the diameter of the internal carotid artery as seen on the AP and lateral angiogram, or by examination of the removed atherosclerotic core.

TABLE 1. *Neurologic Symptoms in 103 Patients with TIA*

Symptoms	TIA Only	% Patients	
Classic	88	85%	
Ipsilateral Eye	39		39%
Contralateral Motor or Sensory	61		59%
Speech	17		17%
No Classic Symptoms	15	15%	
Other			
Dizziness	20		19%
Syncope	12		12%
Headache	2		2%
Seizures	5		5%
Confusion	1		1%

TABLE 2. *TIA Prior to Operations in 103 Patients*

TIA	Number of Patients	Percentages
First		
0–3 mo.	40	39%
3–12 mo.	24	23%
>1 yr.	39	38%
Frequency		
q. 0–7 days	24	23%
q. 1–3 wks.	31	30%
q. 1–12 mo.	35	34%
Isolated		
<6 mo.	12	12%
>6 mo.	1	1%
Last		
0–7 days	36	35%
1–4 wks.	32	31%
1–12 mo.	34	33%
>1 yr.	1	1%

Operation

The operations were performed between January 1, 1961 and December 31, 1966.

A general anesthetic was used in 94 operations of which 7, early in the study, were accompanied by total body cooling to esophageal temperatures of 31–32 C. A local anesthetic was used in 11 operations. In most of the operations general anesthesia was used and an attempt was made to maintain the blood pressure at normotensive or even slightly hypertensive levels.

The operations were performed through a transverse incision along a skin crease at the level of the thyroid cartilage. The anterior facial vein was divided and the carotid bifurcation was mobilized—taking care to avoid injury to the hypoglossal nerve. A longitudinal arteriotomy was made over the atherosclerotic plaque beginning at the distal end of the common carotid artery and extending along the postero-lateral side of the internal carotid artery to the end of the palpable plaque. In some instances, the incision was initially made through only the adventitia and outer media to enable placement of staysutures and partial performance of the thromboendarterectomy before the vessels were occluded. Care was taken to remove all of the shreds of media and to carefully cut the atherosclerotic intima at the point where it fused with normal intima. Five thousand units of heparin were injected into the distal carotid artery after occlusion of the vessels and 50 mg. of protamine sulfate were given intravenously following closure of the arteriotomy. The total time of occlusion was less than 10 minutes in 11% of the opera-

TABLE 3. *Bruits and Ophthalmodynamometry*

Bruit	Ophthalmodynamometry	Number of Patients	Per cent
Present	Positive	28	52%
Present	Negative	17	32%
Absent	Positive	4	7%
Absent	Negative	5	9%
		54	100%

tions and greater than 20 minutes in only 5% so the usual time was between 10 and 20 minutes. Internal shunts were used on only two occasions when technical problems arose which prolonged the period of occlusion beyond 25 minutes. In four instances redundant artery was excised and an end-to-end anastomosis performed between the common carotid artery and the internal carotid artery. Small rubber tissue drains were left through stab wounds in the subcutaneous tissue for a period of 24 hours. No anticoagulants were used in the postoperative period.

Patients without complications were discharged from the hospital within 5 days of operation and were then seen periodically. It was possible to maintain direct contact with or confirm the death of 100% of the patients 5 years following operation.

Surgical Results

Early Clinical Results

Eighty-two (79%) of the patients were asymptomatic during the first 30 days following operation. Transient mild weakness of the opposite extremities beginning immediately after operation and lasting for 1 to 2 days was observed in 15% of the patients. At the end of this early follow-up period of 30 days, 94% of the patients were without neurologic symptoms or deficits. One death occurred and was related to a major cerebral infarction and myocardial infarction. There were six patients who demonstrated evidence of a definite cerebral infarction with worsening of neurologic status following operation, including the one death. Two of the patients were hemiplegic and aphasic and still showed dysarthria and hemiparesis on discharge from the hospital. One patient demonstrated slight but definite facial weakness. Another showed some arm weakness.

Minor complications were observed following three operations. One patient developed a wound hematoma which required evacuation. One patient developed a wound infection requiring drainage. Eighteen patients developed transient weakness of the tongue with deviation toward the operated side presumably secondary to traction on the hypoglossal nerve during operation.

Late Results

The late results recorded included mortality, neurologic status of the patients, and occurrence of other complications of generalized atherosclerosis.

Mortality

Thirty-five (34%) of the patients died within 5 years of operation (Fig. 1). The mortality rate during the first year was 10%. The mortality rate was 5 to 8% for each ensuing year. At the end of 5 years 68 (66%) of the patients were alive.

Myocardial infarctions were considered the cause of death of 24% of the patients of which one died in the hospital following operation (Table 4). In 17 of these 25 patients the diagnosis was supported either by a convincing clinical course, positive electrocardiogram, or an autopsy. The diagnosis of myocardial infarction must be considered only probable in the other eight patients who died at home, frequently suddenly, and on whom no autopsies were performed. Five patients died of strokes. One patient died from nephrosclerosis. Three patients died of cancer and one from other causes.

The overall mortality rate of 34% during 5 years was analyzed in relation to the preoperative status of the patient (Table 5). The mortality rate for patients 70 to 79 years of age was 52% as compared to 19% and 38%, respectively, for the 50 to 59, and 60 to 69 year age group. Thirty-nine per cent of hypertensive patients died and 30% of those without hypertension also died. There was a mortality rate of 56% in patients with atherosclerotic heart disease as compared to 27% when arteriosclerotic heart disease was not pres-

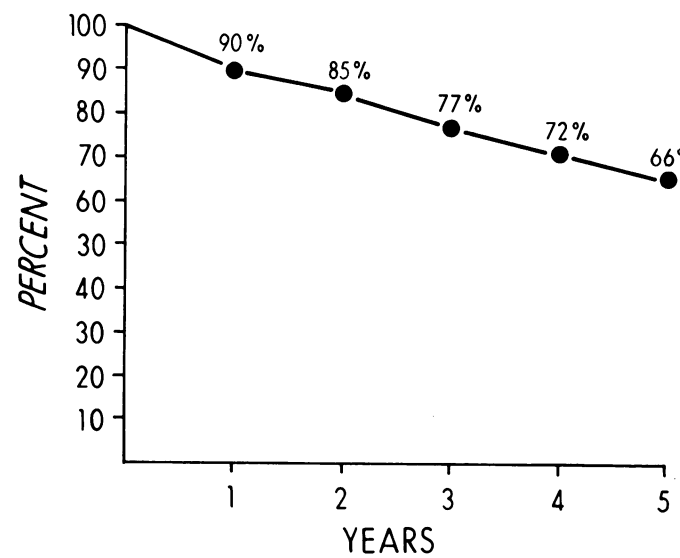

FIG. 1. Survival rate of 103 patients following carotid endarterectomy for TIA's.

TABLE 4. *Causes of Deaths*

	Number	%
Myocardial Infarction	25	24%
Cerebrovascular Accident	5	5%
Nephrosclerosis	1	1%
Cancer	3	3%
Pneumonia	1	1%
Total	35	34%

ent. Thirteen of 14 (93%) of the deaths in patients with arteriosclerotic heart disease were secondary to myocardial infarctions as compared to 12 of 21 (57%) of patients without arteriosclerotic heart disease. The mortality rate in patients with diabetes was 42% as compared to 32% in nondiabetics. Of the eight patients who preoperatively had both diabetes and arteriosclerotic heart disease, six died within 5 years.

Neurologic Status

The late neurologic status was first analyzed in regard to those symptoms and signs thought to be related to lesions of the carotid artery on which the operation was performed (Table 6). Seventy-eight of the 103 patients remained completely free of preoperative symptoms throughout their follow-up. Sixteen patients continued to complain of the same symptoms but they occurred less frequently and on only one occasion in four patients. These symptoms consisted of motor and sensory losses, dysphasia, or visual symptoms in only five patients. The other 11 patients were originally operated on with nonclassic symptoms such as dizziness, poor memory, seizures, or syncope.

Three of the 103 patients continued to complain of the same symptoms with the same frequency following operation. One patient continued to have seizures and another continued to complain of headaches and tremor—repeat angiograms demonstrated patent carotid reconstructions. The third patient continued to have intermittent episodes of amourosis, and hemiparesis. An angiogram demonstrated thrombosis of the reconstructed carotid artery. A second reconstruction was performed which also thrombosed.

Six patients were discharged from the hospital with significant persistent neurologic deficits which appeared soon after operation (Table 7). Three died and three lived at least 5 years. Three of the six demonstrated minimal deficits when last seen. One continued to have expressive aphasia which interfered with his profession as a priest but did not affect activities of daily living. Two patients demonstrated significant deficits which interfered with activities of daily living.

Eighty-eight of the 103 patients were operated on for "classic" symptoms of motor and sensory loss, dysphasia, or visual disturbances. Seventy-six of the 88, or 84%, had no neurologic complications and were relieved of their symptoms. Fifteen of the 103 patients complained only of nonclassic symptoms of dizziness, syncope, headache, seizures, or confusion. Only two of the 15, or 13%, were relieved of symptoms.

Twenty-four of the 103 patients developed new neurologic symptoms not considered to be related to lesions of the carotid artery operated on. Twenty-one patients complained of motor, sensory, speech, or visual symptoms. Three complained only of vertigo, ataxia, syncope, or dizziness. Thirteen patients complained only of transient symptoms. Eleven patients suffered completed strokes with residual deficits which were mild in five, moderate in four, and severe in two patients (Table 7). Angiograms were available on 15 of the 25 patients and significant lesions of the unoperated carotid artery were demonstrated in 12 patients (11 with TIA and 1 with a completed stroke). Carotid endarterectomies were performed on these 12 patients.

A total of 17 of the 103 patients demonstrated significant lesions of their opposite carotid arteries and endarterectomies were performed within 5 years of first operation. This includes the above mentioned 12 symptomatic patients as well as five patients with asymptomatic carotid lesions. Seventy-one per cent of the second operations were performed within 1 year of first operation.

Five patients died of strokes. One patient developed an infected false aneurysm which required ligation of the carotid artery which caused hemiplegia and death 7 months following original operation. One patient had fewer symptoms following operation but died suddenly of a stroke 4 months later. Two patients who

TABLE 5. *Mortality Rate as Related to Preoperative Status*

	No.	Deaths	Mortality Rate %
Age–Years			
26–49	3	0	0%
50–59	29	5	18%
60–69	47	18	38%
70–79	23	12	52%
80–89	1	0	0%
Hypertension			
Present	46	18	39%
Absent	57	17	30%
Arteriosclerotic Heart Disease			
Present	25	14	56%
Absent	78	21	27%
Diabetes			
Present	19	8	42%
Absent	84	27	32%
Arteriosclerotic Heart Disease and Diabetes			
Present	8	6	75%

TABLE 6. *Late Neurologic Status Related to Operated Carotid Artery*

Category	Number of Patients	Late Neurologic Symptoms							
			Fewer		Same		Early Worsening—Late Neurologic Deficits		
		None	Classic	Nonclassic	Classic	Nonclassic	None or Mild	Moderate	Severe
Died	35	23	3	4	0	2	1	1	1
Lived	68	55	2	7	1	0	2	0	1
Total	103	78	5	11	1	2	3	1	2

had early worsening following operation with moderate and severe residual deficits, died following further progression of neurologic deficits, 26 and 59 months after operation. One patient had no neurologic symptoms referable to the carotid artery operated upon, but died of a stroke with symptoms referable to the opposite carotid artery 32 months later.

Neurologic deficits were present in 18 patients at the end of the study. Of the 35 patients who died, three had deficits as a result of original operation, seven had deficits related to lesions of the opposite carotid artery, and one patient suddenly died of a stroke without prior neurologic deficits. There were 68 living patients of whom four had mild deficits, two had moderate deficits, and one was severely incapacitated.

Discussion

The risk of death within 30 days following carotid endarterectomy for symptoms of TIA is very low. There was only one death in this series and in all of the larger series of cases reported, the operative mortality rate has been less than 5%.[2,3,5,10,11,12]

The risk of death within 5 years of operation is significant. Thirty-four per cent of the patients in this series died. It is difficult to compare this mortality rate with other series because of differences in methods of reporting. However, in a controlled and randomized study the mortality rate in a follow-up averaging 42 months was lower in the operated group than the control group.[1] The 34% mortality rate is not unlike that observed in other series of patients with symptomatic atherosclerotic lesions followed for just 5 years. Boyd followed 1,476 patients with intermittent claudication of the lower extremities due to arteriosclerotic occlusive disease.[4] The estimated 5-year mortality rate of patients in the 45–74 year age group was 28%.[4] Serial evaluations were made on 103 patients with autogenous venous bypass grafts performed for atherosclerotic occlusive disease of the femoral and popliteal arteries.[7] The 5-year mortality rate was 26% for patients operated on with symptoms of claudication, 42% if pain at rest was present, and 76% when the indication for operation was gangrene.

TABLE 7. *Cerebrovascular Accident-Opposite Side with Neurological Deficit*

	Mild	Moderate	Severe
Died <5 yrs.	3	2	2
Lived 5 yrs.	2	2	0
Total	5	4	2

The causes of death were remarkably similar in the two groups of patients. Myocardial infarctions were responsible for the death of 24% of patients who had carotid endarterectomies and 26% of the patients who had venous bypass grafts. Other complications of atherosclerosis were responsible for the deaths of an additional 6% of the patients in each group. Five per cent of this group died of strokes.

The mortality rate was influenced by the preoperative status of the patient. Fifty-two per cent of the 70–79 year old group, as compared to the 19% of the 50–59 year old group, died within 5 years. Of the 25 patients with preoperative evidence of arteriosclerotic heart disease 14 (56%) died whereas only 27% of those without angina or electrocardiographic changes died. Six of the eight patients with both arteriosclerotic heart disease and diabetes did not survive 5 years.

Carotid endarterectomy provided permanent relief of preoperative symptoms in 76% of the patients. However, when the preoperative symptoms were of the type classically associated with carotid lesions 84% of the patients were relieved. If the symptoms were nonclassic only 13% were relieved. This failure to significantly effect nonclassic symptoms was previously observed by Fields.[9] This suggests that either the patient's symptoms were not related to the carotid lesion or that carotid endarterectomy cannot improve symptoms related to associated vertebrobasilar insufficiency as effectively as we had hoped.

There is a slight risk of developing permanent neurologic deficit during, or soon after, operation and this incidence has been reported as being between 1 and 7.7%. We observed a 6% incidence in this series but three of the deficits were minor. Transient deficits were observed in another 15 patients. The incidence of all of these early neurologic complications has decreased

with experience.[6] Symptoms of stroke which were consistent with the carotid artery operated upon were observed in eight patients of which six occurred at the time of operation and only two occurred during the follow-up period.

The fact that the carotid stenosis operated upon was only part of a generalized process was emphasized by the fact that 11 patients suffered strokes compatible with other lesions of the extracranial cerebral vessels. The additional 17 patients who underwent endarterectomy of the opposite carotid artery within 5 years of original operation reflects the usually widespread nature of atherosclerotic lesions.

Conclusion

The status of 103 patients 5 years following carotid endarterectomies performed for transient cerebral ischemic attacks (TIA) was analyzed.

Thirty-four per cent of the patients died within 5 years. Twenty-four per cent of the patients died of probable myocardial infarctions and an additional 5% died of strokes. Mortality rates were increased when there was preoperative evidence of arteriosclerotic heart disease or diabetes or if the patient was over 70 years of age.

Carotid endarterectomy provided permanent relief of classical carotid occlusion symptoms of contralateral motor or sensory loss, ipsilateral visual disturbances, or dysphasia in 84% of the patients. Symptoms such as dizziness, syncope, headache, seizures, and confusion disappeared in only 13% of patients who were operated upon for only those nonclassic symptoms.

Twelve per cent of the patients had endarterectomy of the opposite carotid artery for appropriate neurologic symptoms and 5% of the patients had prophylactic endarterectomies for asymptomatic lesions.

Sixty-six per cent of the patients were alive at 5 years of whom only three had significant neurologic deficits and four had mild deficits.

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Discussion

Dr. Jesse E. Thompson (Dallas): As Dr. Rob has shown so nicely, patients with TIAs are ideal candidates for stroke prevention by means of carotid endarterectomy.

Among untreated patients reported in the literature, an average of 35% developed actual strokes if followed up to 5 years and in one study from England, the incidence was 62 per cent.

Our figures are very similar to Dr. Rob's in all respects. In our total series of 537 TIA operations, over a 16-year period, the average mortality was 0.7%. In the last 10 years, since general anesthesia and a temporary inlying shunt have been used routinely, operative mortality in 420 TIA cases has been .5%, which is quite acceptable.

With the routine use of a shunt for cerebral protection, the total incidence of permanent neurologic deficits related to operation has been 1.5% and most deficits are now related to embolization or severe postoperative hypertension.

The long-term functional results have also been satisfactory. 81% of the survivors have had no further TIA while an additional 15% have had fewer attacks of less severity. The total incidence of strokes, including operation induced, long-term, fatal and nonfatal, has been 5%, or a seven-fold reduction in the expected incidence among untreated patients.

Despite these results however, the fourth parameter, long-term survival, so far has shown no statistically significant improvement. The majority of long-term deaths, as Dr. Rob showed, are now cardiac rather than cerebral in origin.

Thus, hypertension and coronary artery disease, especially when associated with previous myocardial infarction, appear to be limit-