

Carotid Endarterectomy:

Neurologic Complications as Related to Surgical Techniques

WILLIAM H. PRIOLEAU, JR., M.D., ALBERT F. AIKEN, M.D., PETER HAIRSTON, M.D.

Three hundred seventeen carotid endarterectomies performed on 240 consecutive patients in four Charleston hospitals were reviewed. The overall incidence of stroke was 10.7% and the mortality 3.2%. From these 317 operations a standardized series of 253 operations performed on neurologically stable patients was analyzed for neurologic complications as related to the use of an intra-operative shunt. Additional factors studied were length of time of carotid occlusion and degree of contralateral carotid stenosis.

From the standardized series the incidence of stroke in 137 shunted cases was 9.5%, and in 116 non-shunted cases was 0.9%, a significant difference ($p > 0.01$). Carotid artery occlusion times from 30 seconds to 12 minutes in the shunted group, and three minutes to 24 minutes in the non-shunted group had no relationship to the incidence of stroke. Significant contralateral carotid artery stenosis, present in 28/137 shunted cases and 30/116 non-shunted cases, had no predictive value in the development of a stroke.

The use of an intra-operative shunt did not protect against stroke in these patients.

CAROTID ENDARTERECTOMY for stroke was first performed in 1953 by De Bakey.⁴ Since that time the operation has become the standard procedure for treatment of patients with atheromatous lesions at the carotid bifurcation. Despite extensive experience there remains the occasional operative complication of neurologic deficit. Surgeons differ in their idea of how the neurologic deficits develop, and consequently they differ with regard to measures to provide cerebral protection during the operation.

Much of the controversy surrounds the use of an intraoperative shunt. Proponents of using a shunt argue that reduction of the time of cerebral ischemia is important in avoiding strokes. Those who do not use shunts believe that the risk of arterial embolus from manipulation of a shunt outweighs the possible benefits of reducing the time of carotid occlusion. There are series of cases with low rates of neurologic

From the Medical University of South Carolina, Roper Hospital, Saint Francis Xavier Hospital, and North Trident Regional Hospital, Charleston, South Carolina

complications both with and without the use of shunts, suggesting that experienced surgeons may develop proficiency in doing the procedure by either technique when patients are properly selected.^{1,5,8-10}

Such series of cases leave unexplained however, the true nature of many strokes associated with carotid endarterectomy. Few patients come to autopsy, and the distinction between an embolus and prolonged transient ischemia is difficult to make.

There are methods available for comparing groups of shunted and non-shunted cases so as to suggest the mechanism of the development of a stroke. If the duration of carotid artery occlusion is an important factor in developing neurologic deficits, there should be an increased incidence of stroke with long occlusion times. If strokes occur with short occlusion times afforded by a shunt, the etiology would more likely be an embolus. If the contralateral carotid circulation is important in protecting the brain from ischemic infarct during operation, there should be an increased incidence of stroke when the contralateral circulation is impaired if ischemia is the important factor.

In a medical community divided with regard to use of shunts, carotid endarterectomies have been analyzed for use of a shunt, duration of carotid artery clamping, contralateral carotid artery occlusive disease, and incidence of stroke.

Materials and Methods

Three hundred seventeen carotid endarterectomies performed on 240 consecutive patients by 15 board certified surgeons form the basis of this report. The patients were from one university hospital and three

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TABLE 1. Operations Reviewed

| Hospital | Dates | Operations | Patients |
|-------------|-----------|------------|----------|
| MUH | 1962-1976 | 116 | 93 |
| St. Francis | 1973-1975 | 102 | 71 |
| Roper | 1973-1976 | 84 | 64 |
| Trident | 1975-1976 | 15 | 12 |
| | | 317* | 240 |

* 77 Patients—bilateral operations.

community hospitals within the dates indicated in Table 1.

The following details of the records were noted: (1.) Preoperative: Age, race, sex, method of radiologic examination, degree of occlusion of carotid and vertebral arteries, and preoperative neurologic status. (2.) Operative record: Dissection of the plaque from the artery wall prior to clamping, duration of carotid occlusion to the nearest minute, use of a shunt, use of heparin, reversal of heparin, and stump pressures when available. (3.) Postoperative: Survival, neurologic complications during hospital stay, time interval between operation and onset of neurologic symptoms, other complications such as hemorrhage or myocardial infarct.

A motor deficit present for at least several days and agreed upon by more than one observer was required to be considered a stroke. Sensory changes and transient dysarthria were not considered strokes. The type of stroke was not expressed as transient or permanent as the information available for the immediate postoperative course was inadequate to determine which category was appropriate in many instances.

Overall results were determined for operative (hospital) mortality (Table 2) and the incidence of stroke with and without the use of a shunt (Table 3).

To focus on the problem of embolus vs. prolonged carotid occlusion an effort was made to standardize the series by eliminating as many strokes as possible that appeared to be related to aspects of the case other than possible embolus or prolonged occlusion. Therefore operations were eliminated for any of the following reasons: (1.) Preoperative neurologic instability. (2.) Total occlusion of the carotid artery on which the operation was being performed. (3.) Obvious compli-

TABLE 3. Total Series Stroke Following Shunted and Non-Shunted Operations

| | Operations | Stroke | % |
|----------|------------|--------|-------|
| Shunt | 176 | 22 | 12.8% |
| No Shunt | 141 | 12 | 8.5% |
| Total | 317 | | |

TABLE 2. Overall Results 317 Operations/240 Patients

| | Number | Percent |
|-----------|--------|---------|
| Stroke* | 34 | 10.7% |
| Mortality | 10 | 3.2% |

* Stroke—Motor Deficit.

cations with management of a shunt. (4.) Use of embolectomy catheter. (5.) Multiple operations under the same anesthetic. (6.) Postoperative thrombosis of the carotid artery on which the operation was performed.

By eliminating the above categories of patients, a total of 64 cases, the cause of a stroke in the remaining cases could more likely be narrowed down to the time of carotid occlusion or the occurrence of embolus.

The standardized series consisting of 253 operations was analyzed for the occurrence of stroke as a function of the carotid occlusion time for the shunted (Fig. 1) and the non-shunted operations (Fig. 2).

To evaluate the importance of contralateral carotid artery circulation as a protective mechanism the incidence of stroke was determined in cases with high grade and low grade contralateral carotid artery stenosis. Of the 253 operations in the standardized series there were 243 with x-ray reports describing the degree of contralateral carotid artery stenosis. Cases where the stenosis was described as mild, moderate, 50% or

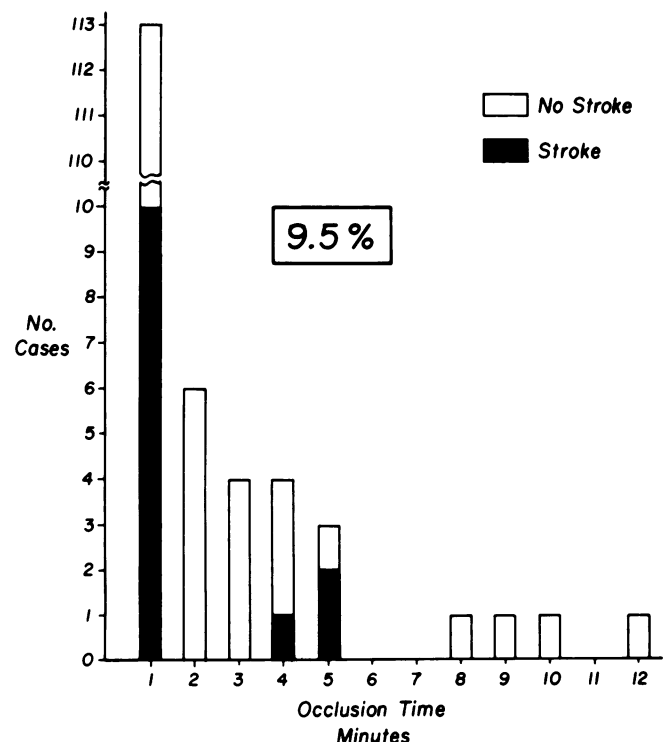


FIG. 1. In 133 operations using a shunt there were 13 strokes (9.5%), most of which occurred with an occlusion time of one minute.

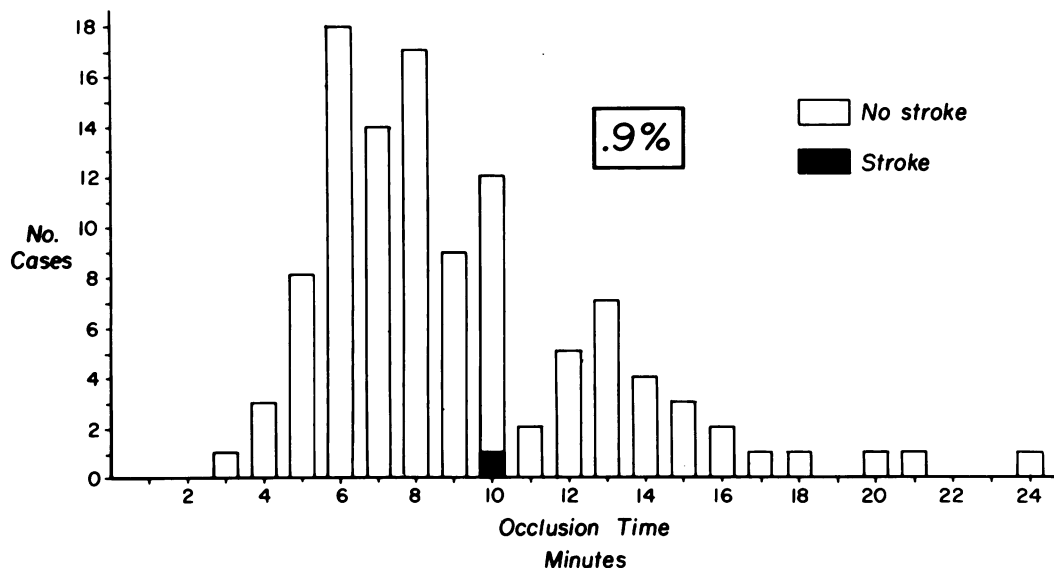


FIG. 2. In 110 operations not using a shunt there was one stroke (0.9%) occurring with a 10 minute occlusion time.

less, and previously endarterectomized arteries were placed in a group of low grade stenosis. Cases described as greater than 50% stenosis, severe, or total occlusion were placed in a group of high grade stenosis.

To see if the degree of vascular disease was equivalent in the shunted and the non-shunted groups, the incidence of high grade contralateral carotid artery stenosis was compared for the two groups.

Results

There were 34 strokes (10.7%) and 10 deaths (3.2%) in 317 operations on 240 patients (Table 2).

In the total series of 317 operations (Table 3) there were 22 strokes in 176 shunted cases (12.8%). There were 12 strokes in 141 non-shunted cases (8.5%), not a significant difference.

In the standardized series of 253 operations (Table 4) where strokes would more likely be related to embolus or time of occlusion there were 13 strokes in 137 shunted cases (9.5%), and one stroke in 116 non-shunted operations (0.9%), $p < 0.01$.

Occlusion time appeared to have no relation to the incidence of stroke as noted in Figures 1 and 2. The range of occlusion times in shunted patients was 30 seconds to 12 minutes and in the non-shunted cases three minutes to 24 minutes.

In the non-shunted cases with 17, 21, and 24 minute occlusion times there was severe contralateral carotid occlusion suggesting that the degree of contralateral

carotid occlusion is not an adequate measure of the need for haste in conducting a carotid endarterectomy. The case with a 24 minute occlusion time had a contralateral carotid artery occlusion and in addition a contralateral subclavian artery stenosis.

In cases both of low grade and high grade contralateral carotid artery stenosis there was a higher incidence of stroke among shunted cases (Table 5). In the cases of high grade contralateral carotid artery stenosis where the shunt might have been of value in reducing the chances of ischemic damage there were three strokes in 31 shunted cases (9.7%) and one stroke in 31 non-shunted cases (3.2%).

The patients on whom a shunt was used were not at greater risk than the non-shunted cases from the standpoint of vascular disease of a vessel that might be important in cerebral protection (Table 6). There were 31 cases of the 140 shunted operations with a high grade lesion of the contralateral carotid artery (22%) and 31 cases of the 103 non-shunted operations with a high grade lesion of the contralateral carotid artery (30%).

Discussion

The brain does not appear to undergo ischemic damage during the conduct of carotid endarterectomy without a shunt with occlusion times up to 15 minutes.

TABLE 5. Comparison of Populations at Risk

| | Stroke | No Stroke | % |
|------------|--------|-----------|------|
| Low Grade | | | |
| Shunt | 8 | 101 | 7.3% |
| No Shunt | 0 | 72 | 0% |
| High Grade | | | |
| Shunt | 3 | 28 | 9.7% |
| No Shunt | 1 | 30 | 3.2% |

TABLE 4. Standardized Series Total Operations—253

| | Strokes | Operations | Percent |
|----------|---------|------------|---------|
| Shunt | 13 | 137 | 9.5% |
| No Shunt | 1 | 116 | 0.9% |

p less than 0.01

TABLE 6. Comparison of Populations at Risk

| | High Grade* | |
|-----------------|-------------|-------|
| Shunt 140 | 31 | (22%) |
| No Shunt 103 | 31 | (30%) |

* Degree of Contralateral Stenosis.

The incidence of stroke remains low, even in the presence of severe stenosis of the contralateral carotid artery.

Too few cases in this series had occlusion times beyond 15 or 20 minutes to evaluate the safety of carotid occlusion for prolonged periods. In the report by Akl et al.,¹ however, there were 55 out of 77 endarterectomies with occlusion times over 20 minutes and a low incidence of neurologic complications suggesting that the duration of carotid occlusion can be quite prolonged without the occurrence of stroke.

Unless a shunt is intervening in a process leading to ischemic injury, it is hard to justify its place in the operation. This is especially true as placing a shunt in an artery necessitates manipulation and the possible dislodgment of atheroma to form an embolus. In Fig. 1 it is suggested that the strokes occurring with short occlusion times in shunted cases were the results of such manipulation, as the time of carotid occlusion could hardly be sufficiently long to cause ischemic changes to the brain.

In a detailed study of cerebral blood flow and carotid endarterectomy Boysen found no consistent pattern to the patients who developed strokes and concluded that embolus was the greatest threat to successful outcome of the operation.³ Our data support this conclusion.

The usual cerebral protection by moderate elevation of blood pressure and use of heparin appears adequate during the conduct of carotid endarterectomy. Routine determinations of stump pressure^{1,3,7,8} or monitoring

by electroencephalography^{2,6} might help pick out candidates who could theoretically benefit from a shunt, but in the absence of clear indications the use of a shunt does not seem warranted as the risks outweigh the benefits.

Carotid endarterectomy can be performed with a low incidence of neurologic complications without the use of a shunt when there is a meticulous attention to the avoidance of dislodging atheromatous material which may form an embolus.

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DISCUSSION

DR. JESSE E. THOMPSON (Dallas, Texas): I was intrigued by Dr. Hairston's paper, since the shunt was introduced into carotid surgery in an attempt to reduce mortality and strokes, rather than cause them.

Movius and Gaspar lowered operative mortality from 16% to 1%, and operative strokes from 16% to 5%, using a shunt, and in our experience mortality went from 4.8 to 1.5%, and stroke incidence was reduced by two thirds with a shunt. Likewise Boysen and Engell in Denmark, in a beautiful series of clinical investigations, have shown that a shunt is a very reliable technique for restoring carotid flow, for restoring cerebral blood flow, and for reversing EEG changes to normal.

Recent discussion has been not whether the shunt is effective, but whether it should be used routinely or only selectively in those severe cases where cerebral blood flow is inadequate, and some

form of cerebral support is mandatory. Selective use of the shunt in the worse cases, or under operative duress, is thus a very important point.

I think the implications of this study may be misleading; namely, that the shunt contributes to an increased mortality and stroke morbidity. I suggest that we inquire further into other factors which are more likely responsible for deaths and deficits, but have nothing to do with the shunt. These include clinical classification, selection of patients, timing of operation, intraoperative anesthetic and technical management, postoperative management, and, especially, proper technique of shunt insertion.

(Slide) Production or aggravation of strokes by operation can occur from multiple causes, all related to cerebral infarction from thrombosis, embolism, or metabolic factors. For comparison of results, one must classify patients into groups on the basis of neurologic status. Thus mortality will range from 0% in asymptomatics to 60% in acute, frank strokes.