

# Perioperative Strokes After 1001 Consecutive Carotid Endarterectomy Procedures Without an Electroencephalogram

## *Incidence, Mechanism, and Recovery*

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**Hypothesis:** That alternative methods of cerebral protection, especially routine shunting of all patients undergoing general anesthesia or shunting on the basis of neurologic assessment with the patient awake under cervical plexus block, result in outcomes of carotid endarterectomy comparable with those reported using electroencephalographic monitoring.

**Design:** Retrospective review of cases from a vascular registry established in 1990.

**Setting:** Tertiary care center.

**Patients:** Consecutive sample of 1001 patients who underwent carotid endarterectomy.

**Interventions:** Carotid endarterectomy procedures were performed without electroencephalographic monitoring, using general anesthesia with routine shunting or using regional anesthesia.

**Main Outcome Measures:** Overall stroke and mor-

tality rates and cause and consequence of the postoperative strokes.

**Results:** There were 14 nonfatal strokes (1.4%) and 2 deaths (0.2%), for a combined stroke and death rate of 1.6%. Nine (64%) of the 14 strokes appeared to result from a technical error during the endarterectomy. Mild deficits were noted after 7 strokes (50%), with the remainder resulting in deficits that required inpatient rehabilitation. Twelve patients with strokes (86%) eventually returned home without need for assistance.

**Conclusions:** Most postoperative strokes in this series were due to technical errors. Overall, even in patients with strokes initially requiring inpatient rehabilitation, there was good recovery of function. Low stroke and mortality rates can be achieved in carotid endarterectomy without the use of electroencephalographic monitoring.

*Arch Surg.* 1999;134:412-415

**W**ITH THE results of 2 major, randomized prospective trials reporting the expected benefits of carotid endarterectomy (CEA) vs medical management for symptomatic and asymptomatic carotid stenosis,<sup>1,2</sup> the number of patients undergoing this procedure has increased. For the benefits of surgery to be realized, however, the operation must be performed with a low complication rate in regard to stroke and mortality.<sup>3</sup> Since it is likely that in some instances placement of an indwelling shunt will prevent the development of postoperative stroke, the method of cerebral protection or cerebral monitoring is a topic of interest. Cerebral monitoring in general is conducted with an electroencephalogram (EEG) or use of regional anesthesia in an awake patient.<sup>4,5</sup> Carotid artery stump pressures also have been used to de-

termine the need for shunt placement based on predetermined thresholds.<sup>6</sup> The rationale for monitoring is to identify a subgroup of patients most likely to benefit from shunt placement. Some patients will demonstrate significant cerebral hypoperfusion, as measured by EEG changes, on carotid clamping. The presumption is that in the absence of a shunt, a small number of these patients will have a postoperative neurologic deficit. Electroencephalographic monitoring, however, requires additional equipment and expertise and generates a cost. Another method, which abrogates the need for cerebral monitoring, is the use of general anesthesia with routine shunting. At our institution, we have used regional anesthesia with shunting based on a neurologic change during the procedure, but we now perform CEA with general anesthesia and routine shunting almost exclusively. We reviewed 1001 consecutive CEAs performed during a 7-

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## PATIENTS, MATERIALS, AND METHODS

A computerized vascular registry was established in January 1990. Data from all patients who have undergone vascular procedures at the West Campus of the Beth Israel Deaconess Medical Center (formerly The New England Deaconess Hospital), Boston, Mass, were prospectively entered. We reviewed all consecutive patients who underwent CEA from January 1, 1990, through August 31, 1997. Patients who underwent combined procedures (coronary artery bypass grafting), aortic arch procedures, or operations for recurrent carotid stenosis were not included in this review. The 1001 CEAs were performed during these 7 years by 4 of the 5 of us (F.B.P., G.W.G., D.R.C., and F.W.L.) at our hospital. Patients who underwent bilateral CEAs during the study interval had their risk factors and results entered separately at the time of each operation. Most patients underwent general anesthesia with routine shunting. Proper function of the shunt was confirmed using a hand-held continuous-wave doppler. Some CEAs were performed under regional anesthesia with shunting on the basis of continuous neurologic assessment. A patch closure was used at the discretion of the individual surgeons based on the diameter of the internal carotid artery. Recently, all arteries are patched, most commonly with collagen-impregnated Dacron fabric. Typically, postoperative patients recovered overnight in the postanesthesia care unit or the vascular intensive care unit (a specialized vascular ward for stable, unintubated patients) and then were discharged to home or transferred to the floor.

Patient demographics and preoperative risk factors were also evaluated, including history of coronary artery disease or congestive heart failure and presence of diabetes mellitus. Data were obtained by registry review and additional review of hospital records in certain cases. Indications for CEA were classified as asymptomatic, symptomatic (which included transient ischemic attacks [TIAs] and amaurosis fugax), or completed stroke. We characterized patients who presented with unclear or nonlateralizing symptoms as asymptomatic.

Categorization of the extent of disability due to a postoperative stroke was as follows: mild indicates deficit limited to 1 extremity, requiring no inpatient rehabilitation or in-home assistance; moderate, deficits requiring inpatient rehabilitation for motor skills or speech; or severe, profound deficits requiring skilled nursing facilities, including ventilatory and nutrition support. Other complications tracked include congestive heart failure, myocardial infarction, arrhythmia, hyperperfusion syndrome, and severe cranial nerve injuries (requiring rehabilitation). The number of minor cranial nerve injuries was not present in the current database. The average length of hospital stay (LOS) includes all postoperative days, including those incurred during a second consecutive procedure after a CEA such as a peripheral bypass.

year period without the use of EEG. In addition, an attempt was made to characterize the cause of perioperative stroke as well as the resultant deficits.

## PATIENTS

Mean age of patients was 70.5 years (range, 39-94). Other overall characteristics of the 1001 patients with regard to preoperative risk factors are listed in the following tabulation:

Characteristics	% of Patients
Male	61
Female	39
Diabetes	38
Hypertension	70
Congestive heart failure	10
Previous coronary artery bypass graft	22
Overt coronary artery disease	46
Indications for CEA	
Asymptomatic	42.6
Symptomatic	49
Completed stroke	8.4

## LENGTH OF HOSPITAL STAY

For the whole group, the average LOS was 3.1 days (range, 0-62 days). Six hundred seventy-seven (67.7%) of the patients were discharged by postoperative day 2.

## COMPLICATIONS AND MORBIDITY

Complications are given in the following tabulation:

Complication	No. (%) of Patients
Nonfatal strokes	14 (1.4)
Death	2 (0.2)
TIA	4 (0.4)
Myocardial infarction	5 (0.5)
Congestive heart failure	8 (0.8)
Arrhythmia	8 (0.8)
Hyperperfusion syndrome	3 (0.3)
Severe cranial nerve injury	1 (0.1)

Overall, 14 strokes and 4 TIAs totaled 18 neurologic complications (1.8%).

## Transient Ischemic Attacks

Two of the 4 patients with TIAs presented with symptomatic stenosis, 2 were asymptomatic, and all underwent CEA with an indwelling shunt. On reexploration, an intimal dissection was noted in 2 patients, no abnormality in one patient, and only an occluded external carotid artery in the other.

## Strokes

Eleven (79%) of the 14 patients who suffered a postoperative stroke presented with a symptomatic stenosis, yielding stroke rates for asymptomatic and symptomatic patients of 0.7% and 1.9%, respectively. General endotracheal anesthesia with shunting was used in 11 patients (79%), with regional anesthesia used in the remainder. None of the strokes in the regional group was preceded by intraoperative clinical changes, and therefore the patients did not undergo shunting.

In those patients who underwent reexploration for ipsilateral postoperative neurologic deficits, several causes of the strokes were noted. In 5 patients, there was internal carotid artery thrombosis or the presence of fresh clot without an intimal flap. In 2 patients, a distal intimal flap with clot was apparent. In 1 patient, a distal kink with obstruction of flow was found, and, in another, the stroke resulted from an embolus or hypoperfusion, since no operative defect was identified, and since the patient did not undergo shunting.

The other 5 patients did not undergo reexploration, but some information was available. Heparin-induced thrombocytopenia and complete thrombosis of the internal carotid artery developed in 1 patient after a subsequent peripheral bypass graft 14 days after CEA. There was 1 intracerebral bleed noted on postoperative day 8. Emboli or hypoperfusion was presumed to be the cause of strokes in the other 3 patients, since all had patent internal carotid arteries radiologically. Thus, of the 14 postoperative strokes, 9 (64.3%) were likely due to technical errors during the endarterectomy and closure, since these patients had intimal flaps or presence of clot.

The initial manifestations of the strokes were as follows: 7 mild deficits (50%) that did not require any inpatient rehabilitation but prolonged the LOS to 6.3 days; 2 moderate deficits (14%) that required an LOS of 14 days and a subsequent period of inpatient rehabilitation; and 5 severe deficits (36%) that required intensive rehabilitation and, in 2 patients (14%), tracheostomy and gastrostomy tube placement. Their average LOS was 12.2 days before transfer to a skilled nursing facility. In the mild deficit category, all 7 patients showed continued recovery of motor or speech deficits, with 2 patients eventually having no recognizable deficit. In 1 patient, however, occlusion of his carotid repair developed, and he died of multiple-system organ failure as a complication of sepsis and renal failure 4 months after surgery. In the moderate deficit group, 1 patient showed some recovery of motor and speech loss and, although she eventually went home, she was still significantly debilitated. The other patient experienced a full recovery. In the severe deficit group, 1 patient suffered a subsequent ipsilateral TIA and, despite occlusion of the operative repair, the paresis improved and she did not require inpatient rehabilitation. Two patients were able to return home in less than 1 month and recovered most function except the ability to write in 1 patient and some speech disability in the other. Of the 2 patients who required tracheostomy and gastrostomy, 1 patient now lives at home with assistance from a health aide, whereas the other died at the rehabilitation center 2 months after surgery.

#### Death

There were 2 deaths within 30 days after surgery. One patient with severe renal insufficiency died in the recovery room from a suture line bleed, resulting in a respiratory arrest. The other patient died 8 days after surgery from complications of a myocardial infarction.

#### TYPE OF ANESTHESIA OR SHUNT

Eleven patients (79%) underwent general anesthesia; the remainder underwent regional anesthesia. Stroke rates

for both groups were 1.5% and 1.2%, respectively. Six (43%) of 14 patients underwent patching.

#### COMMENT

Our report presents data on 1001 CEAs performed without using EEG as a cerebral monitoring technique. Most of the operations were performed under general anesthesia with routine shunting, but some were performed under regional anesthesia. The stroke rate was 1.4%; the combined stroke and death rate, 1.6%. These results were very similar to those of the Asymptomatic Carotid Atherosclerosis Study,<sup>1</sup> in which all patients were asymptomatic, and to those of the Cleveland Clinic report on 1924 CEAs,<sup>7</sup> in which most were performed with routine shunting. The stroke rates reported in these series, including ours, represent clinically apparent strokes, since it is not standard practice to obtain preoperative and postoperative computed tomographic or magnetic resonance imaging scans in all patients. In 1 study, this practice increased the infarct rate from 2% to 12%.<sup>8</sup> The significance of asymptomatic strokes is not exactly clear, but when comparing results between series, one must realize that the so-called silent stroke rate may vary considerably.

Results of series in which selective shunting was used based on EEG changes reveal combined stroke and mortality rates ranging from 1.4% to 2.7%.<sup>4,9</sup> However, it is clear in these series and others that EEG is not 100% sensitive for predicting postoperative strokes.<sup>10</sup> Also, EEG changes do not always occur immediately on clamping, but can happen several minutes later, which can cause technical problems if it occurs during the actual endarterectomy. In addition, it is clear from series exclusively using regional anesthesia that some patients will not show signs of cerebral ischemia during CEA but still suffer a perioperative stroke.<sup>11</sup> Accordingly, these patients would not undergo shunting during the procedure. This occurred in 3 patients who suffered postoperative strokes after CEA performed under regional anesthesia in our study. The causes of the strokes in the regional group, however, were similar to those noted in the routine shunting group.

Overall, the data suggest that although only a small number of patients will benefit from shunting, there is no preoperative clinical factor or intraoperative technique, including close observation under regional anesthesia, that reliably identifies those patients. Based on this, our current practice is to use general endotracheal anesthesia with routine shunting in most cases. Since it is also evident that series using different techniques have similarly low morbidity rates, we do not believe that routine shunting is the only acceptable method. However, since all patients receiving general anesthesia undergo shunting, we concentrate on widely exposing the distal internal carotid artery to avoid the potentially dangerous situation of having to urgently insert a shunt in an environment with inadequate distal exposure. Some of the technical errors were possibly contributed to by the shunt itself, but the rate is extremely low.

Another observation that can be made from these data is that, as noted by Riles et al,<sup>12</sup> a number of the strokes were due to a technical error with the endarter-

ectomy or the distal end point. Thus, the already low stroke rates may be even lower.

In conclusion, performing CEA without EEG monitoring is a safe and reliable method. The results are likely due in part to the fact that CEAs were performed at a tertiary care center with a high volume of carotid procedures and reflect a multidisciplinary approach, including experienced nurses and anesthesiologists. However, technical errors still account for a large proportion of postoperative strokes after CEA, emphasizing the need for technical precision. Accordingly, more attention should be directed toward performing a precise endarterectomy and less to the method of cerebral monitoring. When strokes do occur, most patients can be expected to make a reasonable recovery and return to a level of function where they can live at home.

Presented at the 79th Annual Meeting of the New England Surgical Society, Toronto, Ontario, September 27, 1998.

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## DISCUSSION

**Jack Huse, MD, Meriden, Conn:** The North American Symptomatic Carotid Endarterectomy Trial (NAS CET) and the Asymptomatic Carotid Atherosclerosis Study (ACAS) have verified what surgeons have intuitively believed for decades, namely, that properly selected patients with high-grade carotid stenosis, regardless of symptoms, have a longer stroke-free survival with operative vs nonoperative therapy. This concept is valid only when surgical management results in a stroke and combined stroke and death rate of 1% to 3%. The maintenance of optimal cerebral perfusion is generally regarded as the critical factor for the successful carotid endarterectomy outcomes. How to best monitor this optimal cerebral perfusion has been the topic of countless articles in the surgical literature. Moore and Hall, in 1969, proposed the use of internal carotid artery stump pressure as

an index of collateral cerebral circulation during carotid clamping. Since that time, other authors have championed transcranial doppler ultrasonography (TCD) to monitor blood flow in the basal cerebral arteries. Pertinent to this morning's paper, the EEG has been shown to be an exquisitely sensitive measure of cerebral blood flow. Despite its sensitivity, the value of an EEG intraoperatively to reduce CEA complication rates is rightfully being called into question.

Dr Hamdan and his colleagues from the Beth Israel Deaconess Medical Center have provided a meticulous analysis of over 1000 cases of CEAs safely performed without the use of intraoperative EEG monitoring. Unfortunately, the sensitivity of an EEG to predict a postoperative stroke is not 100%. In fact, there are a number of papers documenting minimal or no evidence of intraoperative EEG changes in patients who have demonstrated significant neurologic deficits postoperatively. Conversely, there are papers documenting patients with substantial intraoperative EEG changes who did not develop any postoperative neurologic deficits. When faced with this mind-boggling dilemma (before having had the opportunity to read Dr Hamdan's paper), I did what all good scientists do, I asked my colleagues in Connecticut what they were doing referable to EEG monitoring. I'm pleased to report, at least on this issue, Massachusetts and Connecticut agree. The routine use of EEG monitoring in the operating room is not currently utilized in Hartford, New Haven, New Britain, or, I suspect, in other hospitals within the state that I failed to contact.

Cost-effectiveness is certainly important to all of this in this day and age, but patient safety and excellence of outcomes has always been our goal. It is therefore important we document the efficacy of CEA, without the added expense of intraoperative EEG monitoring. I believe this paper has successfully defended that position.

I have several questions for the authors. When you reviewed the technical errors that contributed to the incidence of postoperative neurologic deficits, did you discover any features which might be helpful in reducing future technical problems? And secondly, do you have any experience with the use of high-dose thiopental anesthesia as a method of cerebral protection during CEA?

**Padiath Aslam, MD, Augusta, Me:** I'd like to know if the same uniform technique was used with a classical longitudinal incision, or eversion endarterectomy had been done in later cases, as it is becoming popular? And also, whether any intraoperative arteriogram or intraoperative duplex scanning has been employed to see the adequacy of the endarterectomy?

**Dr Hamdan:** As for the technical errors that we identified, the most common one was a problem with the distal end point. One thing that we have discovered, especially when you are using a patch, is to extend the initial arteriotomy beyond the distal end point so that when you are sewing in the patch, or starting your primary closure, you are not closing directly over the area of concern. Other than that, I don't have other tips on avoiding technical errors except for being as precise with the endarterectomy and closure as possible.

As far as use of thiopental anesthesia, I apologize, but I'm not really familiar with that technique, and we don't have any experience with that at our institution.

To answer the second group of questions, this is a standard endarterectomy with a longitudinal arteriotomy. We don't perform eversion endarterectomies, although that has been shown to be a very successful technique.

We do not routinely evaluate the adequacy of our repair and closure with intraoperative duplex scan or arteriography. We do use a handheld continuous wave doppler at the end of the procedure. When there is a concern about the repair, we will perform an intraoperative arteriogram. However, this has been the case in only a small percentage of our patients.