Determining Criteria for Shunt Placement During Carotid Endarterectomy

EEG versus *Back Pressure*

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EEG monitoring and carotid back pressure were performed on 100 patients undergoing elective carotid endarterectomy. Shunts were inserted selectively in those patients who showed change in EEG after a trial period of carotid clamping (15%). No patient in the series awoke with a neurologic deficit. Back pressures were significantly lower in the shunted group and these pressures roughly correlated with EEG changes. Only one patient with a back pressure of >40 mmHg had EEG changes and this patient had a recent mild stroke. EEG changes were most frequent in patients with contralateral carotid occlusions and in asymptomatic significant stenoses. EEG is a more discriminating indicator for shunt insertion than back pressure, although a pressure >40 mmHg is safe in patients without recent stroke.

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USE OF INDWELLING SHUNTS during carotid endarterectomy remains an area of controversy. Opinions range from surgeons who never employ shunts to those who shunt routinely. Stroke rates do not differ significantly between these two groups.[1-5] This may be due to either differences in patient selection or the multifactorial nature of perioperative stroke. Nonetheless, most vascular surgeons feel that use of a shunt during endarterectomy in selected patients is justified. The rationale for intraoperative shunting is to augment cerebral perfusion during the vulnerable period of carotid clamping. It is important, then, to identify patients who are vulnerable to such ischemia. Criteria for "selective shunting" vary and may be divided into three categories: (1) alteration in consciousness during carotid clamping in patients under local anesthesia,[6] (2) reduced pressure in the distal internal carotid artery after clamping ("back pressure"),[7,8] and (3) EEG changes associated with carotid artery clamping.[9-12] In addition, certain clinical characteristics (*i.e.*, history of stroke, contralateral carotid occlusion, or symptoms of vertebrobasilar insufficiency) may indicate patients at high risk for perioperative cerebral infarction and some authors advocate routine shunting in these patients.[12,13] To study these questions, we have reviewed the records of 100 patients undergoing carotid endarterectomy during an 18-month period, in whom both stump pressure and EEG monitoring were performed.

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Materials and Methods

All patients included in this study were subjected to elective carotid endarterectomy under EEG monitoring. All endarterectomies were performed by two surgeons, the majority of operations under general anesthesia. Indwelling shunts were placed only if EEG changes were noted within 5 minutes of carotid clamping. An alteration in the EEG was considered significant if (1) there was a lateralized slowing temporally associated with carotid clamping or (2) there was bilateral or contralateral slowing related to carotid clamping in a patient with a contralateral carotid occlusion. Prior to beginning the endarterectomy, mean arterial back pressure in the carotid artery was measured, using a 19 gauge needle and a mercury manometer. The technique of back pressure measurement after clamping the common and external carotid arteries has been previously described.[6,7]

The records of each patient were reviewed with special attention to presenting symptom and the status of the contralateral carotid artery at the time of surgery. Operative indications in this group of patients included: completed stroke (24 patients), transient ischemic attacks (TIAs) (50 patients) and asymptomatic hemodynamically significant lesions (24 patients). Sixty-one patients had symptoms clearly referable to the carotid territory; in 15 patients symptoms were nonhemispheric. Most patients

with completed strokes were not operated on for 6 to 8 weeks although three were operated on within 2 to 4 weeks of their event. These patients had a mild residual deficit and a tight stenosis demonstrated on angiography.

Results

EEG Monitoring

All patients in this study were shunted on the basis of EEG changes during a 1-minute trial of clamping prior to endarterectomy. In every patient, these changes were reversed by placement of an indwelling carotid shunt. Using these criteria, shunts were employed in 15 patients (15%). No patient awoke with a neurologic deficit. While this does not prove that all 15 patients required a shunt, it does show with certainty that EEG correctly identified 85 patients as not needing intraoperative shunting. This latter number is used in evaluating the other criteria for shunt placement.

Stump Pressures

The distribution of stump pressures in shunted and nonshunted patients is shown in Table 1. In general, the shunted patients had a lower stump pressure than those who did not require a shunt and the mean stump pressure was significantly lower in the shunted group: 27.5 ± 3.8 mmHg *vs.* 44.0 ± 2.7 mmHg ($p < 0.05$). The distribution of shunt pressures was significant. Only one patient with a mean stump pressure >40 mmHg required intraoperative shunting. That patient had experienced a stroke 2 weeks prior to surgery but had recovered with minimal deficit. Early operation was performed because of the severity of stenosis. Despite an adequate back pressure (60 mmHg), right-sided slowing developed with carotid clamping and a shunt was inserted. Interestingly, this patient underwent contralateral endarterectomy 2 months later without EEG changes, although the stump pressure was 45 mmHg during the second operation.

Preoperative Clinical Characteristics

The preoperative characteristics of shunted and nonshunted patients are presented in Table 2. These are characteristics one would expect to be associated with poor perfusion during clamping and need for shunt placement. Patients with asymptomatic significant stenoses and those with a contralateral carotid occlusion had a significantly increased incidence of EEG changes with carotid occlusion. These clinical classifications were not sufficiently sensitive to predict the need for intraoperative shunt placement. In fact, the majority of patients in all clinical and angiographic categories did well without shunt placement. No increase in EEG changes was noted in patients with nonhemispheric symptoms.

TABLE 1. *Stump Pressure (mmHg)*

	>20	20–29	30–39	40–49	>50	Total
Shunted	2	6	6	0	1	15
Nonshunted	0	13	18	24	30	85

Discussion

The necessity of and indications for intraoperative carotid shunting continue to be debated. The strongest advocate of routine use of intraoperative shunting during carotid endarterectomy has been Thompson.[1,2] His position is strengthened by his low stroke rate following endarterectomy (1.4%). Nearly identical results are obtained, however, by Cooley's group who never employ intraoperative shunting.[4] The issue is complicated further by the fact that insertion of carotid shunt may be associated with morbidity such as air embolism, intimal damage, and intraoperative particulate embolization. Most surgeons feel that the presence of a shunt does, on occasion, interfere with the ability to perform an adequate endarterectomy, particularly in the case of lesions which end high in the internal carotid artery. Many vascular surgeons feel that selective shunting is the best compromise.

Varying indications for shunt placement have been proposed. Moore[7] monitored carotid back pressure in patients undergoing endarterectomy under local anesthesia and correlated back pressure with level of consciousness. He concluded that a mean stump pressure of 25 mmHg was the minimum to allow safe carotid reconstruction without use of an indwelling shunt. Similar studies have been performed by Hays in patients under general anesthesia who found that reconstruction without the use of a shunt was possible when stump pressure exceeded 50 mmHg.[8] Callow has used intraoperative EEG monitoring to select patients who might require shunting during endarterectomy.[13] His extensive experience with

TABLE 2. *Clinical Characteristics of Patients Undergoing Endarterectomy*

	Asymptomatic Stenosis	Nonhemispheric Symptoms	Hemispheric Symptoms	Contralateral Occlusion
Shunted	7 (41%)	2 (15%)	6 (11%)	3 (37.5%)
Nonshunted	17	13	55	8

289 patients suggests that shunts will be required in 15.6% of patients, with no correlation between EEG changes and stump pressures. He has suggested that patients undergoing carotid endarterectomy for nonfocal symptoms are more likely to have EEG changes and require shunt placement. Beebe has studied stump pressures and EEG tracings in 50 patients undergoing endarterectomy and could find no clear correlation between the two.[14] The Mayo Clinic has used regional cerebral blood flow to predict requirements for intraoperative shunting.[15] Most recently, comparisons of carotid stump pressure and jugular venous pressure to derive a cerebral perfusion pressure has been reported in 92 patients.[16]

Our study was undertaken to evaluate the criteria most commonly employed to select patients for placement of intraluminal shunts during carotid endarterectomy. Some bias is introduced, since EEG changes were the ultimate criterion for shunt placement. Nonetheless, no patient without EEG changes during clamping was found to have a postoperative neurologic complication, regardless of stump pressure. We cannot predict what incidence of stroke would have been in the 15 patients who had a shunt inserted because of EEG changes. It is important to recognize that EEG changes in themselves depend on factors such as arterial oxygen tension, anesthetic agents, and systemic blood pressure.[17] We have observed, as have others, that changes in the EEG can be reversed by altering these variables, and in some patients this may be an acceptable alternative to shunt insertion.

These data have allowed us to make several interesting conclusions about the relationship between stump pressure and EEG changes during carotid cross clamping. First, there is generally a good correlation between stump pressure and the frequency of EEG changes. While we did not find any absolute minimum stump pressure that was always associated with EEG changes, it was clear that such changes were more frequent at lower stump pressures. With one exception, no patient with a pressure >40 mmHg had EEG changes. This observation contrasts with observations by Callow and Brewster who both found a significant number of patients with EEG changes and stump pressures >50 mmHg.[13,18] The degree of change in EEG is not stated in these series, nor is the clinical status of patients with altered EEGs and high back pressures mentioned. Recent neurological deficits may have made this group more susceptible to injury. Alternatively, intraoperative embolization may have accounted for some of the EEG changes in his series. In any event, our results show a clear correlation between stump pressures of EEG and support the utility of stump pressure measurements when EEG is not available.

It has been stated that certain categories of patients, especially those with contralateral carotid occlusion or nonfocal symptoms, are at particular risk of cerebral ischemia at the time of carotid clamping.[19,20] Our data did not support this observation in patients with nonhemispheric symptoms of ischemia. We did not find these clinical criteria sensitive enough to be reliable predictors of intraoperative ischemia. We did find an increased incidence of EEG changes in patients with contralateral carotid occlusion and in those patients with asymptomatic significant stenoses. The latter finding is unexpected and may relate to lack of sufficient collateral circulation. It demonstrates that it is most important to monitor cerebral function when operating on the asymptomatic patient. The majority of patients in all clinical categories were safely operated on without a shunt. Severity of carotid disease seen on angiogram also did not predict the frequency of EEG changes. Eight of eleven patients with a contralateral carotid occlusion tolerated endarterectomy without shunt placement or EEG changes.

The mean stump pressure in our patients was somewhat lower than that reported in earlier series. Despite this, the incidence of shunting was not increased over previous reports and we found that EEG changes were rare over 40 mmHg. This places our series somewhere between the experience of Wylie and Moore. Reasons for the lower back pressures in our group are uncertain but probably reflect anesthestic technique and intraoperative blood pressure management.

Stroke associated with carotid endarterectomy is a multifactorial problem.[21] Patient selection, perioperative blood pressure control, cerebral ischemia during carotid clamping, and intraoperative embolization have all been implicated as causes of postoperative neurologic deficit. The similarity in stroke rates between shunted and nonshunted series argues that significant ischemia during carotid clamping is an infrequent cause of postoperative stroke. Use of an indwelling shunt during endarterectomy can only be expected to reverse deficits caused by ischemia during carotid clamping. Experimental work using Xenon determination of regional cerebral blood flow suggests that flows of approximately 15 ml/100 g/min can be tolerated for up to 1 hour without significant neurologic damage. Flows above this level can be tolerated for extended periods while flows below 10 cc/100 g/min result in neuronal damage after relatively brief periods.[22] It is this latter situation that will require use of an indwelling shunt. These are the individuals one would hope to identify.

Despite the likelihood that shunting is rarely required, it remains an important topic since severe cerebral ischemia, though infrequent, is preventable by appropriate use of an indwelling shunt. Many vascular surgeons favor some type of selective use of shunts during carotid endarterectomy. Our experience suggests that EEG is the most practical and discriminating criterion available. Endarterectomy under local anesthesia, while effectively

practiced by some surgeons, depends on adequate patient cooperation and may compromise performance of an adequate operation. These considerations have seriously limited its use in our institution. We have found stump pressures helpful but less discriminating than EEG. Stump pressure may give a false sense of security in patients with recent neurological events. Using stump pressure >40 mmHg alone as a criterion for shunt placement, our incidence of shunt use would have doubled (50% *vs.* 25% c EEG monitoring). Similarly, we have not found either clinical presentation or angiographic findings sensitive enough to be useful. While EEG change may not always be associated with a neurologic deficit, the opposite seems true in our series; *i.e.,* no patient with a normal EEG awoke with a deficit. We feel EEG is a safe and reliable way to monitor the adequacy of cerebral perfusion during endarterectomy and to minimize shunt use. When available, it is the method of choice to determine shunt placement. In the absence of EEG capability, carotid back pressure is an adequate alternative in the elective stable patient. In emergency situations or in patients with recent neurologic events, routine shunting is recommended if EEG monitoring is unavailable.

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