Incidence and etiology of intracerebral hemorrhage following carotid endarterectomy

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In a consecutive series of 1930 carotid endarterectomies there were eight cases of postoperative intracerebral hemorrhage. One of these patients was operated on 2 weeks following cerebral infarction and had severe uncontrollable hypertension after surgery. A second patient had an intraoperative embolus and bled while fully heparinized on the 3rd postoperative day. Only one patient in the series bled into an area of documented cerebral infarction. The remainder of the cases represented hemorrhage into essentially normal brain.

Seven of the eight patients with intracerebral hemorrhage had high-grade internal carotid artery stenosis preoperatively. Although several factors have contributed to the brain hemorrhages in this series of patients, postoperative cerebral hyperperfusion which often follows endarterectomy may have played an important role. Defective cerebrovascular autoregulation in chronically ischemic brain regions may predispose patients to intracerebral hemorrhage after removal of a high-grade stenosis of the internal carotid artery.

Key Words □ cerebral autoregulation □ cerebral blood flow □ carotid endarterectomy □ intracerebral hemorrhage

Postoperative intracerebral hemorrhage is a rare complication of carotid endarterectomy. This complication has been reported almost exclusively in patients with evidence of cerebral infarction prior to surgery. Bruetman, et al.,4 reported hemorrhage in six of 900 endarterectomies (an incidence of 0.67%), all in patients with a preoperative neurological deficit. Caplan, et al.,5 reviewed the literature in 1978, and documented only 17 cases of postoperative intracerebral hemorrhage, all of which had preoperative evidence of permanent cerebral damage. A recent case reported by Bernstein, et al.,1 appears to be the first in which a neurologically intact patient suffered a catastrophic postoperative intracerebral hemorrhage.

Review of a consecutive series of 1930 carotid endarterectomies performed over an 18-year period by one surgeon (J.W.C.) revealed eight cases of postoperative intracerebral hemorrhage, an incidence of 0.41%. It is significant that six of these eight patients had no preoperative clinical or radiographic evidence of cerebral infarction in the region of the subsequent hemorrhage. These cases are presented because they illustrate aspects of disturbed cerebrovascular physiology as related to carotid atherosclerotic disease and cerebral ischemia.

Case Reports

Case 1

This 65-year old hypertensive woman presented 4 months after experiencing sudden blindness in the left eye. The diagnosis of central retinal artery occlusion was made, and there was no return of vision. Four weeks prior to admission she experienced a transient episode of diminished vision in the right eye which returned to normal within 10 minutes. However, 2 weeks later she experienced a sudden complete loss of vision in the right eye which resolved in 2 hours.

Initial neurological examination demonstrated a blind left eye, but was otherwise completely normal. An angiogram demonstrated a 90% stenosis of the right internal carotid artery (ICA) at its origin and a completely occluded left ICA (Fig. 1A). Two weeks after angiography, the patient underwent right carotid endarterectomy. On the 1st postoperative day her neurological condition was unchanged from the preoperative status, although the blood pressure was difficult to control, with systolic pressures as high as 200 mm Hg. By the 3rd day after surgery the hypertension was effectively controlled with levels of no higher than 140/70 mm Hg. On the 4th postoperative day, however, the
patient experienced a grand mal seizure and became unresponsive. Emergency angiography was performed which demonstrated a large avascular right suprasylvian mass and a patent ICA. She deteriorated rapidly and died several hours later. An autopsy confirmed a large right frontal hematoma with no evidence of ischemic changes (Fig. 2A).

Case 2
This 56-year-old man with diabetes mellitus controlled by diet was admitted after the acute onset of right hemiparesis and aphasia. These problems cleared completely within 3 hours of onset. However, the next day he experienced two more episodes of transient weakness and aphasia, each lasting less than 1 hour. Neurological examination after these episodes showed no deficits. Arteriography demonstrated greater than 90% stenosis at the origins of both ICA's (Fig. 1B). Twenty-four hours later the patient underwent a left carotid endarterectomy.

In the immediate postoperative period he was neurologically intact and normotensive, but he developed weakness of the right upper extremity on the 1st postoperative day. Emergency angiography was performed which demonstrated a patent ICA and normal intracranial circulation. Heparin was started and the patient's focal deficit resolved completely over the next 24 hours. On the 3rd postoperative day he complained of sudden severe headache and became unresponsive. Repeat angiography demonstrated complete occlusion of the left ICA and a stenotic plaque of the right ICA. Six days following angiography, a left carotid endarterectomy was performed and flow was restored in the left carotid artery. Postoperatively the patient did well, and 4 days later underwent a right carotid endarterectomy.

The immediate postoperative period was uneventful, with blood pressures in the range of 160/90 mm Hg. On the morning of the 3rd postoperative day the patient complained of sudden severe headache and had an elevation of blood pressure to 180/95 mm Hg. Neurological examination was normal at this time, but over the next 12 hours the patient became increasingly lethargic. A computed tomography (CT) scan demonstrated a large fresh left occipital hemorrhage. The patient was taken to the operating room where an emergency craniotomy was performed for evacuation of the hematoma. Except for a partial right visual field defect, he had an uneventful recovery.

Case 3
This 62-year-old man had a history of mild hypertension, a myocardial infarction 20 years prior to admission, and a femoral-popliteal artery bypass operation in the left leg 11 years prior to admission. Two months before admission he had noted an episode of numbness of the right arm which lasted 30 minutes, and 3 days before admission he experienced three episodes of transient left hemiparesis and slurred speech, each lasting about 10 minutes. At the time of admission there were no neurological abnormalities. An angiogram demonstrated complete occlusion of the left ICA and a stenotic plaque of the right ICA. Six days following angiography, a left carotid endarterectomy was performed and flow was restored in the left carotid artery. Postoperatively the patient did well, and 4 days later underwent a right carotid endarterectomy.

Case 4
This 62-year-old woman was admitted 14 months after acute onset of right hemiparesis and aphasia. At the time of admission she had severe weakness of the right arm and required a four-poster cane to assist her to walk because of continued weakness of the right leg. An angiogram demonstrated complete occlusion of the left ICA and a 90% stenosis of the origin of the right ICA. Two days later the patient underwent a right carotid endarterectomy and did well, with normal blood pressures, for several days postoperatively. On the 5th postoperative day she complained of visual difficulty, and a left homonymous hemianopsia was found on examination. A CT scan demonstrated a hemorrhage into the right occipital lobe. She was treated conservatively, and her neurological situation has remained stable.

Case 5
This 66-year-old hypertensive woman experienced four episodes of left arm weakness accompanied by left hemisensory loss over a 3-week period. Each time the deficit resolved within a few minutes. On initial evaluation she was noted to have bilateral carotid artery bruits, a mild drift of the left upper extremity, left-sided hyperreflexia, and a positive left Babinski sign. The neurological examination was otherwise normal. Cere-
Cerebral hemorrhage after carotid endarterectomy

FIG. 2. Gross autopsy specimens showing massive fresh intracerebral hematomas in Cases 1 (A) and 5 (B).

bral angiography carried out the day after admission demonstrated greater than 90% stenosis of the origin of both ICA's, with 50% stenosis of the left vertebral artery. Following arteriography the patient was considerably weaker on the left side than she had been initially. During the next several days the strength gradually improved, but the patient was left with 3/5 power in the left arm. Two weeks following angiography a right carotid endarterectomy was performed.

Immediately postoperatively the left arm was noted to be stronger than preoperatively, and the patient was alert and cooperative. However, her blood pressure was difficult to control and ranged as high as 200 mm Hg systolic. Two days postoperatively she suddenly became unresponsive and developed acute right transtentorial herniation. She died 24 hours later despite vigorous medical treatment. An autopsy demonstrated massive fresh hemorrhage into the right cerebral hemisphere (Fig. 2B) as well as multiple small foci of encephalomalacia compatible with a recent cerebral infarction.

Case 6

This 63-year-old diabetic woman reported a 1-year history of intermittent numbness and weakness of the right arm. The episodes lasted approximately 10 minutes each and then cleared completely. During the month before admission she suffered two episodes of inability to speak and decreased vision in the left eye. These episodes cleared completely within 15 minutes. Examination on admission revealed a slight pronator drift of the right arm, bilateral carotid artery bruits, and an absent left radial pulse. An angiogram demonstrated greater than 90% stenosis at the origin of the left ICA, a smaller atheromatous plaque at the origin of the right ICA, and left subclavian steal from the vertebral artery. A left carotid endarterectomy and ligation of the left vertebral artery were performed.

For the first 4 days after surgery the patient was unchanged from her preoperative condition, and she remained normotensive. However, on the morning of the 5th postoperative day she complained of the sudden onset of left temporal headache and increased weakness of the right arm. Examination revealed a right homonymous hemianopsia. Within 3 hours of her initial complaint she became unresponsive and developed severe hypertension. An emergency angiogram demonstrated a patent endarterectomy site but a large left parietal mass lesion with tentorial herniation. She deteriorated rapidly and died 12 hours later from a presumed intracerebral hemorrhage. An autopsy was not performed.

Case 7

This 73-year-old left-handed man had the sudden onset of left hemiparesis and loss of speech 16 months prior to admission. Over the next few weeks there was return of function in the left leg and partial return of function in the left arm with concurrent recovery of speech. Four months prior to admission the patient experienced transient monocular blindness of the right eye which resolved over 12 hours. Two months prior to admission he experienced transient weakness of the left leg which cleared in 20 minutes. Two days before admission he had a 24-hour period of increased left hemiparesis which resolved. On examination he had a mild aphasia and trace left arm drift. There was minimal spasticity of the left leg but no weakness. Cortical sensory changes were evident in the left hand. Cerebral angiography demonstrated atheroma with ulceration at the origin of the right ICA without a high degree of stenosis. Four days later a right carotid endarterectomy was performed. The postoperative course was benign, but 2 months later the patient experienced sudden aphasia and weakness of both legs. His condition fluctuated for 2 days before he was admitted to the hospital with progressive obtundation. A CT scan at that time showed a large hemorrhage into the left frontoparietal region. The patient continued to deteriorate and died 2 weeks later.
Case 8

This 65-year-old diabetic hypertensive woman presented 5 months following the acute onset of left arm weakness and gait difficulty. After her cerebral infarction she improved considerably. On the day before admission she had an episode of increased left-sided weakness which resolved within 15 minutes. At the time of initial evaluation she was noted to have a drift of the left arm, trace weakness of the left leg, and bilateral carotid artery bruits. The remainder of the neurological examination was normal. A CT scan of the head demonstrated mild hydrocephalus but no evidence of cerebral infarction. An angiogram demonstrated bilateral high-grade stenosis of the ICA’s. The patient underwent a right carotid endarterectomy and 7 days later a left carotid endarterectomy. There was no immediate change in her neurological condition, and she was discharged 5 days after the second operation. Three months later she experienced sudden right-sided weakness and aphasia. A CT scan was performed and demonstrated a large hemorrhage into the left thalamus and lateral ventricle. An angiogram showed that the ICA was patent and there were no intracerebral vascular anomalies other than diffuse atherosclerosis. The patient’s neurological condition improved slowly.

Summary of Cases

A summary of the important clinical characteristics of this group of patients is presented in Table 1. Several mechanisms may be active in the formation of hematomas in this group of patients. One patient (Case 2) probably had an intraoperative embolus and developed a reversible ischemic neurological deficit. This patient’s hemorrhage can be attributed to heparinization and bleeding into encephalomalacic brain. We are now cautious when instituting heparinization in patients suspected of having had an intraoperative embolus.

Case 6 had hemorrhage into an area of old infarction. Case 5 is the only patient in the series with a recent preoperative stroke. This patient’s cerebral infarction, which occurred during angiography, preceded surgery by 2 weeks, and it seems likely that her hemorrhage was related to poorly controlled postoperative hypertension. Postoperative blood pressure control is crucial in situations where a damaged blood-brain barrier can be anticipated. Interestingly, only one other patient (Case 1) had poorly controlled blood pressure postoperatively, but she became normotensive by the time of her presumed intracerebral hemorrhage.

In six of the eight patients there was no evidence of preoperative neurological deficit referable to the region where the hematoma developed, and only one of these six patients (Case 2) is likely to have experienced an intraoperative stroke. These data suggest that at least five patients in this series bled into presumably normal brain. The unifying feature of these cases is that seven of the eight patients had highly stenotic carotid arteries at the time of surgery. All of these patients had documented lesions causing greater than 90% stenosis of the artery, and three patients had contralateral complete carotid occlusion as well. Only Case 7 did not have preoperative carotid stenosis.

Discussion

The risk factors for intracerebral hemorrhage after carotid endarterectomy have been variously attributed to recent stroke, transient ischemic attacks, hypertension, anticoagulation, and cerebral hy-
perfusion.1,18 Our data suggest that long-standing high-grade stenosis of the ICA may represent a risk factor for postoperative intracerebral hemorrhage after carotid endarterectomy.

Reestablishment of flow in frankly infarcted cerebral tissues has been blamed for the abnormally high rate of fatal intracerebral hemorrhage in acute stroke patients undergoing carotid surgery.1,4,11,22 Animal studies of intracerebral hemorrhage following occlusion and reopening of the middle cerebral artery8 and the pathological studies of Fisher and Adams7 have been cited to support the theory that restoration of full arterial pressure to an area of recent ischemia can produce fatal hemorrhagic infarction. However, Sundt, et al.,19,20 speculated that hemorrhage after endarterectomy in acute stroke patients might be the result of particulate embolization at the time of surgery and not necessarily related to reflow.

Caplan, et al.,2 reported two postendarterectomy patients who experienced intracerebral hemorrhage into recently infarcted brain. These authors reviewed the literature on this topic and noted that many patients had an interval of days to weeks between surgery and hemorrhage; that occasionally the hemorrhages were located in areas outside the infarcted zone; and that some of these patients experienced transient postoperative improvement prior to the hemorrhage. Their conclusion was that the hemorrhages were the result of uncontrolled hypertension with bleeding into normal brain.

Certainly the prevalence and risk of uncontrolled hypertension after carotid endarterectomy cannot be denied. However, other factors may predispose these patients to intracerebral hemorrhage. Perioperative cerebral blood flow measurements reported by Sundt18 have demonstrated greatly elevated blood flow to the ipsilateral hemisphere following carotid endarterectomy even when blood pressure is not elevated. In some patients the flow increases to supranormal values, apparently related to paralysis of normal autoregulatory function. Sundt18 suggests that this syndrome of hyperperfusion may be associated with paroxysmal lateralizing epileptiform discharges, cerebral hemorrhage, and migraine variants. Reports of these types of complications have been presented previously,1,6,10,11 but to date only one case of hyperperfusion-induced intracerebral hemorrhage following carotid endarterectomy has been reported.1

Laboratory and clinical studies suggest that carotid stenosis in excess of 70% can cause decreased cerebral blood flow.1,32 Since seven of the eight patients in this series had high-grade carotid stenosis, we suggest that these patients had preoperative chronic cerebral hypoperfusion in the area of the subsequent hemorrhage. High-grade stenosis of the cervical carotid artery, as found in all patients discussed in this report, can profoundly affect the circulation to the brain. The relative deficiency of blood flow accompanying high-grade carotid artery stenosis creates a situation where the resistance vessels of the cerebral circulation dilate maximally in an attempt to increase local cerebral blood flow. After a long period of dilatation, the vessels become atonic and can lose the capacity for normal autoregulation. Operative correction of such lesions can be expected to create sudden alterations of blood flow patterns that were established by the relatively slow development of the atheromatous lesion. Excessive blood flow directed into a non-autoregulated vascular bed, as occurs following endarterectomy of a highly stenotic carotid artery, may result in disruption of small vessels and consequent hemorrhage into brain parenchyma.

In our series, at least three patients experienced severe unilateral headaches and one patient had a grand mal seizure as the first sign of intracerebral hemorrhage. Other studies have related the appearance of these symptoms following carotid endarterectomy to cerebral hyperperfusion.1,6,10,12,15,16,18 Together with the fact that five of our patients bled into noninfarcted brain, these factors suggest that cerebral hyperperfusion may have played a role in the genesis of these intracerebral hemorrhages. It is impossible to prove this theory retrospectively, and certainly other events contributed to the morbidity found in this group of patients. However, localized cerebral hyperperfusion and paralysis of autoregulatory function have been recognized as pathological substrata for hemorrhagic complications found in other types of cerebrovascular disorders.9,10,17

This mechanism is similar to the condition found in normal brain surrounding cerebral arteriovenous malformations (AVM's). Steal by the high flow in the AVM causes chronic ischemia in surrounding regions. The vascular beds of these regions are maintained in a state of maximal dilatation, and the normal resistance vessels lose the capacity for autoregulation. When the AVM is removed, normal perfusion pressures are returned to these surrounding regions which have impaired autoregulation. Consequently, cerebral edema and hemorrhage may result.16,17

Another analogous situation may be the transient neurological deficits sometimes seen following superficial temporal artery to middle cerebral artery anastomosis in the absence of recognizable pathology on the postoperative CT scans. We have observed this phenomenon in several of our own bypass patients, and Heros, et al.,9 have suggested that these problems might be related to increased blood flow in chronically ischemic brain. Elevated blood flow into a poorly autoregulated vascular bed may induce local cerebral edema and transient localized cortical dysfunction.

Since cerebral hemorrhage after carotid endarterectomy is such a rare occurrence, suggestions for the management and prevention of this complication are limited to strict control of postoperative hypertension. Study of this problem may help our understanding of the physiology of the cerebral circulation and contribute to a better appreciation of the pathophysiology of cerebral ischemia.
References


