Surgical management of aneurysms of the distal extracranial internal carotid artery

THORALF M. SUNDT, JR., M.D., BRUCE W. PEARSON, M.D., DAVID G. PIEPGRAS, M.D., O. WAYNE Houser, M.D., AND BAHRAM MOKRI, M.D.

Departments of Neurosurgery, Otorhinolaryngology, Neurology, and Neuroradiology, Mayo Clinic, Rochester, Minnesota

Results, complications, and operative techniques of the surgical management of 20 aneurysms of the distal extracranial internal carotid artery (ICA) in 19 patients are reviewed. The proximity of these aneurysms to the styloid process is not considered as a chance occurrence, and the possibility is raised that these lesions are related to trauma from that structure. False aneurysms from spontaneous dissections are believed to occur only in those dissections that begin distally; they are not found in dissections that begin proximally. Treatment was individualized and dependent upon: 1) the size and location of the aneurysm; 2) symptomatology; and 3) hemodynamic considerations based upon intraoperative cerebral blood flow (CBF) measurements determined from the clearance of xenon-133 injected into the ipsilateral ICA. Methods of treatment included: resection of the aneurysm with placement of an interposition saphenous vein graft in seven patients; resection of the aneurysm with end-to-end anastomosis of the ICA in five; ICA ligation in three; clipping of the aneurysm in one; and extracranial-to-intracranial bypass in four. One patient sustained a postoperative cerebral ischemic complication from embolization which resulted in a mild permanent impairment in right hand dexterity. There were no other cerebral ischemic complications in the group, largely attributable, it is thought, to the use of intraoperative CBF measurements and continuous electroencephalograms. Four patients had transient dysphagia from traction damage to the pharyngeal and superior laryngeal nerves, and one patient with preoperative difficulty in swallowing required a gastrostomy. Long-term results have been excellent. Use of the operating microscope facilitated the suturing of the distal anastomosis in cases in which the ICA was reconstructed by an interposition vein graft or end-to-end anastomosis.

KEY WORDS • aneurysm • extracranial internal carotid artery • surgical procedure

Aneurysms of the extracranial internal carotid artery (ICA) are uncommon lesions. Much of the relatively restricted literature on the subject has referred to single cases,1,8,13,16,17,19,30,31,38,39 dealt with aneurysms primarily involving the carotid bifurcation,25 or discussed false aneurysms resulting from trauma or a previous carotid endarterectomy.11,25 Only a few reports include aneurysms of the distal ICA.5,7,14,15,25,28,37 The surgical approaches to false aneurysms10,11,20 and aneurysms of the carotid bifurcation23,25 are quite different from those used for distal ICA aneurysms, and will not be considered here. Aneurysms of the distal ICA, defined here as that section of the vessel composed of its middle and upper thirds, can be caused by trauma, spontaneous dissection, fibromuscular dysplasia,4,27 atherosclerosis,8,25,27 or infection.24,27 Mokri, et al.,27 recently reviewed the literature, the variable pathogenesis, the clinical symptomatology, and the arteriographic findings of these lesions.

It is our purpose here to consider the surgical management of these lesions. We believe that intraoperative electroencephalograms (EEG's) and cerebral blood flow (CBF) measurements are important adjuncts to the procedure. The importance of these studies and the results and complications of treatment will be placed in perspective by summarizing some typical cases. It is difficult to compare the results of management in this series to those of others in the literature because of differences in the types of aneurysms reviewed. The periods during which the various other series were collected (which is different from the date of the report) generally predated the introduction of the surgical microscope.5,7,15,23,25,29,35

Clinical Material and Methods

Between January, 1978, and January, 1985, 19 patients had surgical procedures for unilateral aneurysms
of the extracranial ICA and one patient underwent two procedures for bilateral aneurysms of that vessel on the Neurovascular Surgical Service at the Mayo Clinic. During the same time interval, approximately 1000 carotid endarterectomies and 250 extracranial-to-intracranial bypass procedures for anterior circulation disease were performed on this service. Thus, aneurysms of the extracranial ICA comprised considerably less than 1% of surgical procedures performed for carotid artery disease.

Type of Aneurysm

A dissection of the ICA was found to be the most common cause for an extracranial ICA aneurysm. Seven of these were traumatic dissections and six were secondary to spontaneous dissections. Fibromuscular disease was the cause of two aneurysms, three aneurysms were degenerative or of unknown origin, and one was mycotic.

Clinical Findings

Fourteen cases (the patient with bilateral lesions was considered two cases) presented with ischemic symptoms, one because of a painful mass, one because of headaches ipsilateral to the aneurysm, three because of increasing difficulty in swallowing associated with enlargement of a cervical mass, and one because of fever and a cervical mass. Five of the above patients complained of a pulsatile tinnitus. All but one of the 14 cases with ischemic symptomatology had sustained a small infarction in addition to repeated transient ischemic events.

Monitoring Procedure

All patients, except those undergoing a planned extracranial-to-intracranial bypass procedure, were continuously monitored during the operative procedure with EEG’s, and CBF measurements using the xenon-133 clearance technique were made at selected intervals. Details of these procedures have been reported previously.

Surgical Approaches

Patient Position and Operative Exposure. For patients undergoing a planned extracranial-to-intracranial bypass procedure (superficial temporal artery to middle cerebral artery branch anastomosis), the operation is performed using established techniques and exposures. In other cases, the patient is positioned and prepared as for an endarterectomy, except that hair is shaved to a level well above the zygoma anterior to the tragus of the ear. In patients in whom the ICA aneurysm is very high and those in whom it is thought that an ICA ligation alone might be an acceptable approach (dependent upon the results of the CBF measurements), the ICA is exposed as for an endarterectomy. In patients in whom a primary anastomosis is considered feasible or in whom it is planned to place an interposition saphenous vein graft, a high exposure of the ICA is undertaken prior to exposure of the carotid bifurcation and the external carotid artery.

Technique for Aneurysm Resection. The skin incision used in these patients is outlined in Fig. 1. The cervical segment of the skin incision lies in a skin line paralleling the anterior border of the sternocleidomastoid muscle and ascends to a point just behind the lobe of the ear. In the lower quarter of the postauricular sulcus, it drops to the bottom of the ear, skirts the earlobe, and ascends in a pretragal skin crease to the superior border of the zygoma.

The superficial cervical fascia is incised, and the posterior border of the parotid gland is exposed and elevated. The anterior inferior surface of the auricular cartilage is followed deep to its “pointer,” the triangular projection of cartilage at its medial limit. The temporal-parotid fascia is incised between the mastoid process and the posterior margin of the parotid, and the facial nerve is found subjacent to the fascia. A finger placed on the mastoid tip and directed forward, the cartilaginous “pointer,” and the palpable junction between the external auditory meatus bone (the tympanomastoid suture) all point to the main trunk of the seventh cranial nerve (Fig. 2). Once the main trunk is identified, the lower division and marginal mandibular nerve, which form the upper limit of the deeper dissection, can be traced forward by sharp dissection and safely elevated using the mobilized parotid tissues as a “bundle.”

The hypoglossal nerve is readily identified deep to the posterior belly of the digastric muscle and superficially to the external carotid artery. The latter can be followed to its origin from the common carotid artery. The carotid sheath is now incised and the plexus of veins crossing and surrounding the ICA is coagulated with a bipolar coagulator and divided. The descendens hypoglossi is severed from the hypoglossal nerve, and the muscular branch of the occipital artery to the sternocleidomastoid muscle is doubly ligated and divided as it sweeps over the superior margin of the hypoglossal nerve (Fig. 3). Division of the occipital artery and the descendens hypoglossi allows the surgeon to mobilize the hypoglossal nerve and elevate it out of danger. In most cases, it is necessary to doubly ligate and divide the occipital artery. The posterior belly of the digastric muscle is now followed to its point of insertion in the mastoid groove and divided here. As shown in Fig. 2, the stylohyoid muscle lies superior and parallel to the digastric muscle. It should be divided, too, exposing the deeper stylomandibular ligament, which must be resected for adequate distal exposure of the ICA.

At this point in the procedure, baseline CBF measurements are performed. These patients are usually young and healthy, so in most cases CBF measurements are within normal limits (45 to 55 ml/100 gm/min). Ample time is permitted for the clearance of xenon and then the patient is heparinized and a repeat measure-
Aneurysms of the distal extracranial ICA

**Fig. 1.** Skin incision follows the leading border of the sternocleidomastoid muscle to a point behind the ear. It swings anteriorly around the lower margin of the earlobe, then rises in front of the tragus to end above the level of the zygoma. Note the position of the parotid gland and the location of the facial nerve.

**Fig. 2.** The lower pole of the parotid gland has been mobilized and retracted anteriorly and superiorly after the superficial, deep, and temporoparotid fascia have been incised. The dissection is carried along the anterior border of the cartilage of the external ear canal and the anterior surface of the mastoid process. The posterior belly of the digastric muscle is exposed. The deep cervical veins will now be divided by bipolar coagulation and the internal carotid artery exposed distal to its origin from the common carotid artery. The carotid body and carotid sinus should be injected with xylocaine to avoid troublesome fluctuations in blood pressure.
The descendens hypoglossi nerve has been divided, and the occipital artery and muscular branch of that vessel to the sternocleidomastoid vessel are doubly ligated and divided. This frees the hypoglossal nerve from tethering effects by these structures and allows the surgeon to mobilize the structure superiorly out of danger. The internal carotid artery aneurysm is identified distal to the hypoglossal nerve and is noted to extend as far superiorly as the styloid process. The digastric muscle has been transected and reflected, revealing the aneurysm. The stylohyoid muscle is detached from the styloid muscle and reflected with the digastric muscle. The stylomandibular ligament has been incised and the mandible retracted anteriorly. The styloid process has been resected.

Segment achieved with temporary occlusion of the ICA below the level of the aneurysm, using a temporary aneurysm clip. In patients in whom CBF is well above 25 ml/100 gm/min, the surgeon can be assured that he will have enough time to perform a meticulous reconstruction of the ICA. In patients in whom CBF is 15 to 25 ml/100 gm/min but the EEG remains normal, adequate protection can be achieved by mild elevation of the peripheral perfusion pressure. Because shunting is seldom possible in these cases, a CBF below 15 ml/100 gm/min with Ethrane (enflurane) or halothane (but not forane) anesthesia is a source for concern and a bypass procedure should be considered. Occlusion flows below 10 ml/100 gm/min (regardless of the anesthetic agent) indicate probable ischemia at some point during an extensive reconstruction and is a reason to consider a bypass procedure as a preliminary step before further primary reconstructive procedures or as a treatment alone.

Interposition Vein Graft. In cases in which a primary reconstruction is undertaken, the distal ICA is temporarily occluded with a small aneurysm clip (or Fogarty catheter if there is insufficient room for a clip), the proximal ICA is also temporarily occluded well above the level of the carotid bifurcation (Fig. 4). Both the ICA and the vein graft are prepared with fish-mouth cuts. The distal anastomosis is accomplished with 7-0 or 8-0 interrupted nylon sutures using microvascular needle-holders. A small needle-holder and small sutures are required, as turning space for the needle is quite limited in this distal compartment. We believe that the operating microscope is essential for construction of the distal anastomosis. As the space is quite confined, proper illumination cannot be achieved without this instrument. The space is insufficient for standard instruments and techniques. Proximally, the anastomosis is accomplished with interrupted 6-0 Prolene sutures. Back-bleeding is permitted out of the ICA to clear the system of air before flow is restored.

In some cases, we have left the aneurysm in place and positioned the vein graft through the resected aneurysm (Fig. 5). The decision to resect the aneurysm or leave it in situ largely depends upon the ease of exposure of the distal ICA. When possible, it is probably a good idea to leave it in place, as excision of the aneurysm is often associated with damage to motor branches of the vagus leading to the pharynx. However, in some cases, it is not possible to identify the lumen of the distal ICA until the aneurysm has largely been resected. Also, in some cases, sufficient room is not achieved for the distal anastomosis until the aneurysm has been excised.

FIG. 3. The descendens hypoglossi nerve has been divided, and the occipital artery and muscular branch of that vessel to the sternocleidomastoid vessel are doubly ligated and divided. This frees the hypoglossal nerve from tethering effects by these structures and allows the surgeon to mobilize the structure superiorly out of danger. The internal carotid artery aneurysm is identified distal to the hypoglossal nerve and is noted to extend as far superiorly as the styloid process. The digastric muscle has been transected and reflected, revealing the aneurysm. The stylohyoid muscle is detached from the styloid muscle and reflected with the digastric muscle. The stylomandibular ligament has been incised and the mandible retracted anteriorly. The styloid process has been resected.
Aneurysms of the distal extracranial ICA

**FIG. 4.** The proximal and distal internal carotid arteries are temporarily occluded with soft low-pressure intracranial vascular clips. The proximal and distal ends of the internal carotid artery are prepared in fish-mouth fashion as is the saphenous vein which is sewn into place distally with the aid of the operating microscope using interrupted 7-0 or 8-0 monofilament nylon sutures and microvascular instruments. The proximal end of the anastomosis is constructed with 6-0 interrupted Prolene sutures. Although proximal and distal self-retaining retractors are illustrated in this diagram, less traumatic retraction is provided by the use of spring or elastic activated fishhook restraints.

**FIG. 5.** *Left:* When sufficient working space is available without resection of the aneurysm, it is advisable to leave the aneurysm *in situ* in order to protect motor branches from the vagus nerve leading to the pharynx. Unfortunately, in large aneurysms extending quite far distally, it is often not possible to perform the distal anastomosis until the aneurysm has been excised because of the space constraints. In this case, control of the distal internal carotid artery was possible distal to the superior margin of the aneurysm and accordingly the aneurysm was opened, a thrombectomy performed, and the wall of the aneurysm left in place. *Right:* Interposition vein graft has been placed between the distal and proximal internal carotid arteries in the bed of the collapsed aneurysm. Note the relative position of the hypoglossal nerve as it crosses the interposition vein graft.

*J. Neurosurg. Volume 64/Febuary, 1986*
Evaluation of Graft Flow. The saphenous vein used for the interposition graft is usually harvested from the leg in patients with a good venous system and from the thigh in patients who are asthenic or in whom the venous system appears smaller than average. Postocclusion CBF and electromagnetic graft flow measurements are performed routinely after flow is restored through the vein graft. All patients undergo angiography prior to discharge from the hospital.

End-to-End Anastomosis. In some patients there is sufficient length of the ICA available after the aneurysm has been resected to permit a primary end-to-end anastomosis. In these cases, the aneurysm is resected and the two ends of the carotid artery are approximated and prepared in fish-mouth fashion. The vessels are then anastomosed end-to-end using 12 to 14 interrupted 6-0 Prolene sutures.

Illustrative Cases

The application of the monitoring techniques employed and the role of the various surgical approaches used in this series are most conveniently reviewed by describing typical cases.

Case 5

This 23-year-old man received a blow to the neck in September, 1979, and 1 month later had a brief syncope spell that followed by a right-sided headache and a transient left hemiparesis. Angiography showed a small aneurysm of the right extracranial ICA opposite the C-2 vertebral body (Fig. 6 left). A computerized tomography (CT) scan at this time revealed the presence of a small right cerebral infarction.

Nine months later he had another major ischemic event from which he recovered. Angiograms documented an embolism in the trunk of the middle cerebral artery (Fig. 6 center) with enlargement of the cervical ICA aneurysm. Repeat studies 2 weeks later revealed lysis of the embolus in the middle cerebral artery (Fig. 6 right).

The patient underwent surgery on August 20, 1980. The aneurysm was exposed and isolated as described above. It occupied the middle third of the ICA and was somewhat shorter than it appeared on the angiogram. The CBF with ICA occlusion was well above the critical level, and the EEG remained normal. The aneurysm appeared to be grossly fusiform, and the saccular projection identified on the angiogram was not visible. The resected ends of the ICA were prepared in fish-mouth fashion, and a segment of saphenous vein, harvested from the right leg, was cut to the proper length, prepared in fish-mouth fashion, and anastomosed end-to-end to the proximal and distal ends of the ICA.

The patient had no hoarseness following surgery but

![Fig. 6. Case 5. Left: Angiogram after the initial ischemic insult revealing the presence of a small aneurysm of the extracranial right internal carotid artery opposite the C-2 vertebral body. The decision was made at this time to manage the patient conservatively. Center: Nine months later the patient sustained a transient hemiplegia. An angiogram at this time revealed enlargement of the cervical aneurysm (double arrow) along with a trunk occlusion (single arrow) of the middle cerebral artery just distal to the origin of the striatic vessels. Right: Angiogram performed approximately 2 weeks later shows normal flow at this time through the middle cerebral group but with persistence of the aneurysm in the extracranial internal carotid artery.](image)
Aneurysms of the distal extracranial ICA
did have transient dysphagia which had largely resolved by the time of his discharge from the hospital. Postoperative angiography showed a good flow through the interposition vein graft (Fig. 7), and 6 weeks after surgery he had a normal neurological examination.

Case 3

This 21-year-old man was referred to the Mayo Clinic in February, 1980, because of a left hemispheric infarction that produced a mild deficit in expression of speech (oral and verbal apraxia). His medical history was significant in that he had had bilateral mandibular fractures following a motorcycle injury 7 years previously. Angiograms revealed bilateral extracranial ICA aneurysms. The lesion on the right was small, and that on the left was large (Fig. 8).

The aneurysm was exposed and approached as described above. Occlusion CBF was well above the critical level required for adequate perfusion. The distal ICA was occluded with a No. 5 Fogarty catheter, which had been passed through a segment of the saphenous vein destined to be the interposition graft and then threaded through the aneurysm to the ICA at the base of the skull. The aneurysm was opened and the mural thrombus removed. The ICA was transected above and below the aneurysm and replaced with an interposition vein graft. After restoration of flow, CBF through the vein graft was recorded at 60 ml/100 gm/min.

Postoperatively, the patient had unilateral palatopha-
FIG. 9. Resected specimen from Case 3, illustrating the fusiform gross external appearance of these lesions. With serial sectioning, the apparent lumen and the false lumen can usually be identified. These lesions probably develop initially as a false aneurysm from rupture of all three layers of the vessel wall. Ischemic symptoms are usually related to embolization from soft clot adjacent to the persisting lumen of the vessel.

Case 7
This 48-year-old woman was referred because of an aneurysm in the left distal ICA located very near the base of the skull (Fig. 10 left). She had undergone angiography because of unrelenting unilateral headaches of 4 years' duration, resistant to various forms of medical treatment. The case was complicated by the pattern of the cerebral circulation. The right ICA (which was small) terminated in the middle cerebral artery, and both anterior cerebral arteries derived their entire supply from the left ICA. The distal basilar artery and both posterior cerebral arteries were supplied via a primitive trigeminal artery which arose from the distal left ICA. Thus, it was clear that flow through the left ICA had to be preserved.

The aneurysm was located just distal to a very elongated styloid process which indented the artery and the base of the aneurysm. After the styloid process was resected, the base of the aneurysm was dissected away from the adjacent nerves and soft tissue. It was then occluded with two high-tension aneurysm clips. Immediate postoperative angiograms (Fig. 10 right) verified the clipping and patency of the ICA.

The patient had considerable dysphagia following the operation, which was improved but still present at the time of discharge 2 weeks later. When she returned at 1 year, the angiogram was unchanged; she was free of headaches and the dysphagia had cleared.

Comment. The role of the styloid process in the creation of this aneurysm is only speculative. However, the adherence of the aneurysm to the structure and distortion around it suggested to us that this was not a chance occurrence. The styloid process, arising from the skull, can possibly traumatize the artery with head turning as the skull rotates. The artery, which is en-sheathed in dense fascia, does not rotate with the skull but rather moves with the neck. In our experience with spontaneous dissections, aneurysms occur only in those that begin distally (Fig. 11).

Case 11
This 43-year-old man was referred to us for further evaluation after the acute onset of blindness in the right eye. Funduscopic examination confirmed that visual loss was the result of multiple retinal emboli, and angiography showed it to be related to a giant aneurysm of the extracranial ICA. Computerized tomography delineated the limits of the lesion and clearly revealed that it extended to the base of the skull.

Excessive bleeding, attributed to aspirin administered to the patient preoperatively, complicated the operative procedure. There was only a minor change in CBF on ICA occlusion (baseline level: 42 ml/100 gm/min, occlusion level: 35 ml/100 gm/min). It was apparent that the patient would tolerate ICA occlusion, and accordingly the artery was doubly ligated and divided. The EEG remained normal throughout the procedure. He made a good recovery from the operation but discharge was delayed because of a neck hematoma. This responded well to open drainage.

Case 4
This 40-year-old woman had suffered marked impairment in her ability to communicate beginning in early 1972. She had become normotensive following renal artery surgery for renovascular hypertension-related fibromuscular disease of the renal artery, after which the episodes of transient speech impairment became more frequent. Arteriograms revealed a very tight stenosis from a dissecting aneurysm of the left ICA at the base of the skull (Fig. 12). A superficial temporal artery to middle cerebral artery bypass procedure was performed on August 27, 1975. There were no operative complications.

Postoperative angiography on August 25, 1977, showed that the bypass was widely patent and supplying the major share of blood flow to the middle cerebral artery complex (Fig. 13). The dissecting aneurysm appeared unchanged. The patient was essentially asymptomatic when evaluated in April, 1984, at which time a very strong temporal artery pulse was palpable.

Comment. The presence of fibromuscular disease in the renal arteries is strong evidence that a similar process involved the ICA's. It is probable that a dissection developed in the vessel that was previously involved with fibromuscular disease, and that this dissection obliterated the typical "stacked coin" appearance.
Aneurysms of the distal extracranial ICA

Case 12

This 53-year-old woman was referred because of an enlarging right cervical mass that was pulsatile. Angiograms revealed that this was an extracranial ICA aneurysm (Fig. 14 left). The associated elongation and tortuosity of the ICA permitted us to simply resect the aneurysm and anastomose the ends of the ICA end-to-end (Fig. 14 center). The patient recovered from the operation without incident, and postoperative angiograms demonstrated good flow through the repair site (Fig. 14 right).

Fig. 10. Case 7. Left: Preoperative angiogram showing an aneurysm (large arrow) of the internal carotid artery at the C-1 vertebral level projecting posteriorly and somewhat laterally. Note the presence of a trigeminal artery (small arrow). Right: Postoperative angiogram showing occlusion of the aneurysm with good flow through the internal carotid artery at the site of repair.

Case 12

This 53-year-old woman was referred because of an enlarging right cervical mass that was pulsatile. Angiograms revealed that this was an extracranial ICA aneurysm (Fig. 14 left). The associated elongation and tortuosity of the ICA permitted us to simply resect the aneurysm and anastomose the ends of the ICA end-to-end (Fig. 14 center). The patient recovered from the operation without incident, and postoperative angiograms demonstrated good flow through the repair site (Fig. 14 right).

Fig. 11. Left: Spontaneous dissections that begin in proximal internal carotid artery do not develop false aneurysms. Right: False aneurysm from a spontaneous dissection beginning in the distal internal carotid artery. Dil = dilatation.
FIG. 12. Angiograms in Case 4 showing fibromuscular disease with dissection and distal aneurysm. The distinctive "stacked coin" feature of fibromuscular disease is obscured following the development of a dissection.

Case 13

This 20-year-old woman was in good health prior to an automobile accident in which she sustained transient loss of consciousness and a blunt injury to her neck. She remained neurologically normal for the first few days following the accident and then developed transient difficulty in speech and use of the right upper extremity. Angiograms from her local institution revealed the presence of bilateral ICA dissections.

She underwent a superficial temporal artery to middle cerebral artery bypass and thereafter had no further transient ischemic events involving the left cerebral hemisphere. However, she returned approximately 12 months later with transient ischemic attacks involving the right cerebral hemisphere. Angiograms at this time revealed resolution of the dissection on the left but persistence of an aneurysm of the right ICA (Fig. 15 left). The bypass on the left was patent but not functional. Persistence of the aneurysm on the right and the occurrence of transient ischemic attacks referable to the right carotid system while the patient was receiving adequate antiplatelet medications led to the decision to reconstruct the right ICA using an interposition saphenous vein graft (Fig. 15 center and right).

When evaluated 1 year following the surgery, the patient was essentially asymptomatic except for some mild difficulty in mathematical computations which had been noted from the time of the accident.

Summary of Results

These patients presented with four primary symptom complexes which are summarized according to the type of aneurysm in Table 1. The complications of surgical management are summarized in Table 2 according to the type of operation. There were no deaths in the series. One patient, the individual with severe preoperative dysphagia, retained the dysphagia postoperatively and ultimately required a feeding gastrostomy. The long-term follow-up results in the other patients were excellent. Postoperative angiograms were performed on all patients, and patency was confirmed in all interposition grafts and bypass pedicles. End-to-end anastomosis in one patient with a dissection and preoperative physiological occlusion was occluded.

Discussion

Cerebral Blood Flow and Metabolism

The risk of ischemic stroke from unselected carotid ligation for the management of these difficult cases has been documented by a number of workers to approximate 30%. This is a good reason to study very carefully the angiographic patterns of the intracranial circulation and to monitor CBF before considering ICA ligation. It is beyond the scope of this report to consider in detail the rationale for monitoring in these cases or the con-
Aneurysms of the distal extracranial ICA

Fig. 14. Case 12. Left: Preoperative angiogram showing an extracranial internal carotid artery aneurysm associated with elongation and tortuosity of the internal carotid artery. These changes were the result of fibromuscular disease. Center: The aneurysm, along with a segment of internal carotid artery, is resected (A and B) and the vessel is repaired using an end-to-end anastomosis (C). Right: Postoperative angiogram showing good flow through the site of the primary end-to-end anastomosis. The typical appearance of fibromuscular dysplasia is now better appreciated than on the preoperative study.

Fig. 15. Case 13. Left: Superimposed right and left angiograms showing a patent temporal artery to middle cerebral artery anastomosis (small arrow) with resolution of the previous dissection present in the left internal carotid artery. The dissection of the right internal carotid artery has resolved but the aneurysm (large arrow) persists at the distal limit of the previous dissection. Center and Right: Postoperative anteroposterior (center) and lateral (right) angiograms, revealing good flow through the interposition vein graft with no areas of major narrowing or stenoses. The proximal and distal points of the anastomosis are identified by arrows.
Aneurysms are usually saccular, and in some cases even to have a neck, we have found that they are generally inseparable from the parent vessel over a wide length and that resection is required. The one exception in this series was the case in which it was possible to clip the aneurysm.

Although on angiography these aneurysms appear to be saccular, and in some cases even to have a neck, we have found that they are generally inseparable from the parent vessel over a wide length and that resection is required. The one exception in this series was the case in which it was possible to clip the aneurysm.

Atherosclerotic aneurysms are located more proximally in the ICA and are unrelated to possible trauma from the styloid process. This of course is also true for false aneurysms that occur after carotid endarterectomy.

Pathophysiology of Ischemia

All patients who have had ischemic symptomatology from these aneurysms have sustained a measurable infarction identifiable on CT. Ischemic cerebral infarctions can be either hemodynamic or embolic in origin; the former type is related to a drop in perfusion pressure distal to an occluded artery or a vessel with a high-grade stenosis, and the latter type is the result of emboli from a thrombogenic source and proximal artery. In the cases we have encountered with this lesion, emboli have seemingly been the etiology of the ischemic infarctions. Thus, in some cases with adequate collateral flow, it has been possible to isolate the aneurysm from the circulation merely by performing an ICA ligation. Once these aneurysms become symptomatic from emboli arising from a mural thrombus, the risk of a future stroke is quite high and surgery must be considered.

Analysis of Complications

We believe the use of CBF measurements and continuous EEG monitoring have reduced the incidence of both intra- and postoperative ischemic complications. The one cerebral ischemic complication that occurred in this series was not related to definite embolization from the distal sutural line. Immediate postoperative angiograms identified the source of the emboli, and intubation and anticoagulation therapy were instituted. The patient was maintained on anticoagulation therapy for 3 months, after which repeat angiograms revealed normal flow through the vessel with no areas of residual thrombi. We believe it is important not to reverse the heparin given during surgery, and that any ischemic complication occurring in these patients be immediately evaluated and the source determined.

In patients in whom collateral flow was adequate and whose treatment consisted of acute ICA ligation, prophylactic anticoagulation for 1 to 2 weeks is advisable in order to help prevent the propagation of thrombus from the site of ligation distal to the point of origin of the ophthalmic artery.

In general terms, one is able to avoid damage to the facial nerve, the parent trunk of the vagus nerve, the spinal accessory nerve, and the hypoglossal nerve. However, this has not been the case with muscular branches to the pharynx arising from the vagus nerve, the superior laryngeal nerve, and the glossopharyngeal nerve.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Chief presenting complaints in 20 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause of Aneurysm</td>
<td>No. of Cases</td>
</tr>
<tr>
<td>atherosclerotic or degenerative disease</td>
<td>4</td>
</tr>
<tr>
<td>fibromuscular disease</td>
<td>2</td>
</tr>
<tr>
<td>infection</td>
<td>1</td>
</tr>
<tr>
<td>traumatic dissection</td>
<td>7</td>
</tr>
<tr>
<td>spontaneous dissection</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Complications related to operative procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Procedure*</td>
<td>No. of Cases</td>
</tr>
<tr>
<td>resection of aneurysm, end-to-end ICA anastomosis</td>
<td>5</td>
</tr>
<tr>
<td>resection of aneurysm, interposition vein graft</td>
<td>7</td>
</tr>
<tr>
<td>ICA ligation</td>
<td>3</td>
</tr>
<tr>
<td>aneurysm clipping</td>
<td>1</td>
</tr>
<tr>
<td>bypass</td>
<td>4</td>
</tr>
</tbody>
</table>

* ICA = internal carotid artery.
Aneurysms of the distal extracranial ICA

Although damage to the glossopharyngeal nerve is frequently undetected because it remains asymptomatic except for sensory changes in the pharynx, damage to the pharyngeal and superior laryngeal branches of the vagus nerve results in considerable dysphagia. Even though the pharynx and larynx remain normally innervated on the contralateral side, the disturbance of deglutition is profound. Patients must be warned of this possible complication prior to surgery and informed that, if severe, it may require a gastrostomy for treatment. Thus far, this has occurred in only one patient, who had severe preoperative swallowing dysfunction; however, it is a complication of no minor significance.

Technical Considerations

We believe there are two keys to the successful exposure and reconstruction of the distal ICA. The first is the resection of the stylomandibular ligament, which allows the mandible to be displaced anteriorly, and the second is the use of the operating microscope, which allows the surgeon to work in a confined space with maximum illumination and small microsurgical instruments. We do not believe it is necessary to resect the mandible, dislocate the jaw, or resort to any other potentially disfiguring approaches to gain access to the distal ICA.

References

32. Sundt TM Jr, Michenfelder JD: Focal transient cerebral ischemia in the squirrel monkey. Effect on brain adenosine triphosphate and lactate levels with electrocortico-

Manuscript received April 20, 1985.
Accepted in final form July 10, 1985.
Address reprint requests to: Thoralf M. Sundt, Jr., M.D., Department of Neurologic Surgery, Mayo Clinic, Rochester, Minnesota 55905.