Chapter 186: Interventional Neuroradiology of the Skull Base, Face, and Neck

Richard E. Latchaw

There have been significant technical advances in angiographic equipment, catheter size and design, embolization materials, and techniques for physiologic testing before embolization; these advances have allowed the subspecialty of interventional neuroradiology to blossom. State-of-the-art techniques and equipment will be described in this chapter, followed by a description of how they can be used for a variety of abnormalities including tumors and vascular lesions. Rather than being an exhaustive discussion of the treatment of individual diseases, this presentation serves to acquaint the referring clinician to the use of the tools and the basic principles of endovascular treatment for lesions of the skull base, face, and neck. This knowledge should not only give clinicians a sense of the sophistication of the interventional techniques, but also encourage them to seek the assistance of interventionalists when dealing with difficult tumors and vascular lesions.

Materials and Techniques

Interventional techniques

Angiographic x-ray equipment

The key to all interventional radiographic procedures is the ability to see a lesion and its afferent and efferent blood supply with the highest possible resolution in all projections. For lesions of the skull base, face, and neck, major emphasis is placed on branches of the external carotid artery, with lesser emphasis on branches of the thyrocervical and costocervical trunks and of the internal carotid and vertebral arteries. Arteries or their collateral channels act as conduits for embolic material to the lesion. However, there are many dangerous collaterals leading to intracranial vessels or to the blood supply of the cranial nerves. Catheterization techniques are so sophisticated today that the majority of arteries (and occasionally veins) a few millimeters or greater in size can be catheterized, but it is essential that embolization into dangerous collateral channels be avoided. Hence, superb visualization is of paramount importance.

Sophisticated C-arm positioners allowing variable projection of the object of interest have been available for a number of years, but are single plane. I believe strongly that biplane visualization is extremely helpful. The tiny arteries near the skull base frequently overlap, and biplane visualization is helpful for the superselective catheterization of these small tortuous channels. The procedure is long and may be uncomfortable for the patient, so rapid catheterization is essential. Biplane C-arm positioners have recently become available and will soon be state-of-the-art for large centers. However, one can accomplish the same goal by combining a ceiling-mounted single-plane C-arm with a portable high-resolution C-arm for the opposite plane.

Film/screen combinations for angiography have given way to digital acquisition technology (arterial digital subtraction angiography (DSA) should nogt be confused with the older and rarely performed venous DSA of the early 1980s). No longer must the angiographer wait for films to be slowly developed in a processor. Rather, the digital angiogram is ready for review seconds after the run, enabling rapid decision-making. There have been rapid advancements in the quality of digital subtraction angiography. Pixel matrices of 512 and, most recently, of 1024 squared in the subtracted mode are available at frame rates of 7.5 frames per second or greater. Angiography with this type of resolution and speed allows for the rapid mapping of the circulation to and from the lesion. The DSA road-mapping technique is extremely helpful for rapid catheterization of a specific artery in the midst of unwanted overlapping arteries. This technique uses a contrast-filled frame as a mask during real-time fluoroscopy so that the guidewire and catheter are superimposed on the image of the blood vessels, allowing catheterization of the desired vessel.

Injection of embolic material in contrast material with real-time high-resolution subtracted fluoroscopy allows visualization of the progressive occlusion of the vessels feeding the lesion. As embolic occlusion of the feeding arteries nears completion, reflux of contrast and emboli or flow to collateral circulatin must be avoided; monitoring the procedure with high-resolution fluoroscopy helps to avoid these complications.

All these technical advances have resulted in marked improvement in the speed, efficacy, and safety of these endovascular procedures.

Angiographic catheters

The catheters that I most commonly use for diagnostic angiography are 4 and 5 French polyethylene catheters with the shape of the distal tip altered according to the age of the patient and the vessels to be catheterized. Highly supple catheters are commonly available and have made selective catheterization much easier than in former years.

The invention of the Tracker catheter (Target Therapeutics, Inc, San Jose, Calif) in the mid-1980s produced a revolution in neuroradiologic interventional procedures performed both inside and outside the head. The Tracker-18 catheter has an extremely flexible distal portion that is variable in length and measures 0.018 inch in diameter; it is so small that it may catheterize vessels of a few millimeters. Guidewires as small as 0.010 inch are used for this superselective catheterization. The Tracker-25 and Tracker-38 catheters are used for selective catheterization of larger vessels. Flow-directed catheters made of Pursil (Cook-Europe, Inc, Paris) are also used for tortuous vessels.

The use of these catheters has allowed not only more selective catheterization for better embolization, but catheterization deeper into the vasculature, frequently beyond sites of anastomosis to dangerous collaterals.

Embolic agents

There are a number of embolic agents available for the variety of lesions found at the skull base and in the face and neck. These agents include particulate materials, metallic coils, liquid agents, and releasable balloons. Each has its own place in the armamentarium.

The goal of particulate embolization is to have the particles pass deeply into a lesion such as a tumor, not just to occlude the feeding artery and thereby allow collateral circulation to continue perfusing the tumor. The two most commonly used particulate materials are

Gelfoam (Upjohn Pharmaceuticals, Kalamazoo, Mich) and polyvinyl alcohol (PVA Contour Emboli, Interventional Therapeutics Corp, San Francisco, Calif)(Berenstein and Kricheff, 1979; Latchaw and Gold, 1979). Gelfoam is generally obtained as a solid rectangular piece from which individual pieces are cut during the procedure according to the size necessary for vascular occlusion. This tableside preparation of the Gelfoam pieces is a tedious procedure. Gelfoam braks down as early as 72 hours after embolization; this lack of permanence detracts from its efficacy if surgery is not performed within a few days following the procedure. However, this lack of permanence may be considered a safety feature because arteries to normal tissue inadvertently embolized during the procedure will recanalize within a few days. Gelfoam has been used as a preoperative embolization material for neoplasms that are to be operated upon within 48 hours, and for cases such as epistaxis in which the goal is to slow down the bleeding sufficiently so that the body's hemostatic mechanisms will stop the hemorrhage. A plug of gelfoam can also be used within an artery to protect the distal distribution to normal tissue or to dangerous collaterals, knowing that the plug will break down within a few days. Gelfoam powder is available, but is generally mixed with PVA. Gelfoam powder must always be used with great care because its particles (approximately 50 microm) in solution act as a liquid, easily passing through tiny collateral channels to produce end-artery occlusion of tiny feeders to cranial nerves or pass into the cerebral circulation.

PVA is a more permanent embolic material, although it too may break down over months to years. In addition, much of the efficacy of the vascular occlusion is due to a combination of PVA plus blood clot, with partial or complete recanalization of the vessel occurring as the blood clot dissolves. PVA is an excellent material if surgery is to be delayed for a number of days. It also produces a more permanent result than Gelfoam when used to stop epistaxis or in other nonsurgical procedures. It is easy to use, being supplied as relatively uniform particles between 150 and 1000 microm in size. Mixing the PVA with Gelfoam powder tends to make the PVA more slippery, which facilitates its passage through the catheter (Horton et al, 1983). However, great care must be exercised when using this combination because the gelfoam powder acts like a liquid.

Metallic coils are used for occluding vessels that measure a few millimeters to a centimeter or more. Their size prohibits their moving more distally into the embolized lesion. They are best used for occluding the feeding artery after particulate embolization; the particles are embolized deeply into the lesion with the coil facilitating the final occlusion of the feeding artery. Strands of silk may be used in the same way. Coils have been used to occlude bleeding vessels such as in epistaxis or following trauma. They are easy to use and many coils may be deposited rapidly in an emergency situation. I discourage the use of coils in embolization for epistaxis in order to spare the proximal vasculature if repeat embolization is necessary.

Microfibrillary collagen (Avitene, Avicon, Inc, Fort Worth, Tex) is a hemostatic agent that may be mixed with contrast material for embolization (Kumar et al, 1982) or mixed with other embolic agents such as PVA and ethanol (Dion et al, 1988). It is closed to a liquid than a particulate material. Any extracranial embolization procedure with a liquid agent should be approached with trepidation because occlusion of the end-arteries to the face, tongue, and cranial nerves may lead to necrosis, and intracranial embolization may occur as the liquid slurry passes through tiny collaterals. Such intraarterial liquid embolization should be performed only when superselective catheterization is directly into the lesion and there is no chance of unwanted vascular occlusion.

Liquid tissue adhesives such as iso-butyl-cyanoacrylate (IBCA) or n-butyl-cyanoacrylate (NBCA) produce polymerization of rapidly flowing blood within seconds (Berenstein and Kricheff, 1979; Brothers et al, 1989). They are excellent embolic agents for a lesion with rapidly flowing blood such as an arteriovenous malformation (AVM) or fistula (AVF). IBCA or NBCA are commonly used for an AVM or AVF of the brain. AVM or AVF of the face or neck is rare and one could consider using such embolic agents in these instances; however, extreme care must be exercised to prevent skin necrosis.

Experience with the use of absolute ethanol embolization for venous malformations and hemangiomatous lesions of the head and neck is relatively limited. There are reports of success using absolute ethanol intravenously for venous and capillary malformations that are not supplied or minimally supplied by arterial feeders and heretofore have been extremely difficult to remove surgically (Berenstein and Choi, 1983; Dion et al, 1984; Yakes et al, 1989, 1990). The theory is that alcohol is extremely toxic to the endothelium, which is the key to permanently destroying such a lesion rather than simply starving it by occluding feeding arteries. Sotradecol (3%) is also an excellent sclerosing agent, is less painful on injection than alcohol, and may be opacified.

Finally, releasable balloons are primarily used for fistulas where there is a single artery-to-vein connection or sufficiently few connections that direct blockage of the fistula(s) corrects the problem. The most experience has been with intracranial carotid-cavernous sinus fistulas, but this technique can be used for vertebral artery - vertebral venous fistulas (usually post-traumatic), or for any other type of fistula in the face or neck (Berenstein et al, 1986; Debrun et al, 1981; Halbach et al, 1987). Whereas the original releasable balloons had a latex tie to occlude the balloon once it is released, researchers over the last 6 years has centered on a valve mechanism that will keep the balloon inflated (Interventional Therapeutics, Inc, San Francisco, Calif).

Provocative testing to ensure the safety of embolization

There are two important techniques that were primarily developed at the University of Pittsburgh, (to which I was previously affiliated) that help to ensure the safety of vascular occlusion at the skull base. The first involves the injection of 1% xylocaine into an arterial feeder that is considered a candidate for embolization in order to protect against permanent cranial nerve palsy (Horton and Kerber, 1986). This provocative test will anesthetize the cranial nerve if there is blood supply leading to it from the vessel catheterized. For example, before embolizing a vessel feeding a glomus jugulare tumor, with that vessel potentially feeding the seventh cranial nerve (CN VII), 25 mg of 1% xylocaine is injected. If a seventh cranial nerve palsy develops, the catheter must be repositioned more distally or a different vessel must be selected for embolization. The nerve palsy fades over approximately 30 minutes. Critics of this test suggest that a false-positive test may occur because a liquid anesthetic can be injected into the capillary bed whereas particles stop short of terminal arterioles so that devascularization is rare. Therefore it is likely that a negative test is trully negative and reassuring.

The second provocative test is the temporary balloon test occlusion (BTO) of the internal carotid artery, with blood flow measurement for precise quantification of the effects on cerebral blood flow (CBF) during temporary or permanent occlusion of the carotid artery. Carotid occlusion might be necessary during surgery for a skull base tumor, for the thrombosis of an unclippable aneurysm, or if carotid occlusion has to be performed to close a carotid-cavernous fistula. The traditional method of testing is occlusion of the internal carotid artery with the patient heparinized and observed for 15 minutes. If the patient has no neurologic deficit from the carotid occlusion, he "passes" and it is assumed that blood flow is adequate for permanent occlusion to occur. Unfortunately, such a qualitative test does not provide precise quantification of the blood flow to the hemisphere at risk. Blood flow values above 20 cc/100 g/min allow neuronal function to occur, with values less than that precipitating neuronal dysfunction. It is conceivable that blood flow values slightly above 20 cc/100 g/min would leave the patient without symptoms while on the angiogram table, but intraoperative or postoperative hypotension, decreased cardiac output, or decreased oxygenation might precipitate cerebral infarction.

The xenon/CT cerebral blood flow analysis program was instituted at the University of Pittsburg in the early 1980s with this technique extended to the BTO procedure. Briefly, the patient inhales 31% xenon and 69% oxygen over a 4-minute period of time while undergoing sequential CT scans. A blood flow map is produced, with precise quantification of flow values in all portions of both cerebral hemispheres (Yonas et al, 1987). The BTO test is performed by passing a No. 5 French Swan-Ganz balloon catheter or a 5-French guidable balloon catheter system (eg, Meditech occluding balloon, MediTech Inc, Waterton, Mass) into the internal carotid artery. Balloon inflation is performed to totally block flow in the internal carotid artery, as determined fluoroscopically. If there are no neurologic symptoms over 15 minutes of observation, the patient "passes" the first stage of the test. The volume of balloon inflation is recorded. The patient is taken to the CT scanning suite, the balloon is inflated to the same volume, and a xenon/CT CBF test performed. The balloon is deflated and the study repeated in 10 minutes, after the xenon has been expelled, so that differences in CBF between the occluded carotid and nonoccluded studies can be compared (FIg. 186-1)(Erba et al, 1988).

The BTO with xenon/CT quantification has allowed us to stratify patients into four categories of risk. Patients who have neurologic symptoms simply with balloon inflation have an isolated hemisphere and do not undergo xenon/CT CBF analysis. Patients who are asymptomatic with balloon inflation are categorized in terms of the drop of CBF to the ipsilateral hemisphere. Those with a drop greater than 20 cc/100 g/min to the middle cerebral distribution on the side of carotid occlusion relative to the contralateral side undergo temporary bypass or other intraoperative procedure to ensure adequate blood flow during surgery. If permanent carotid occlusion is performed, either an extracranial-to-intracranial bypass is performed as part of the surgical procedure or the patient's blood pressure and cardiac output are elevated to ensure adequate cerebral perfusion (Erba et al, 1988).

Lesions for Endovascular Treatment

Neoplasms

Chemodectomas

Chemodectomas (nonchromaffin paragangliomas) are tumors related to chemoreceptor tissue. There are a number of locations for these tumors in the head and neck: those found along the promontory of the middle ear are *glomus tympanicum tumors,* those related to chemoreceptor tissue in the jugular bulb are *glomus jugulare tumors,* those related to the vagus body in the high cervical region are *glomus vagale tumors,* and those related to the carotid body at the common carotid artery bifurcation in the neck are *carotid body tumors.* In the rare case there is a chemodectoma related to the aortic body in the superior mediastinum. Multiple tumors are found in approximately 10% of cases (Fig. 186-2), and a familial form exists (Spector et al, 1975).

Glomus tympanicum tumor. This tiny tumor usually presents with pulsatile tinnitus and otoscopically is seen as a reddish-blue mass behind the tympanic membrane. CT scanning allows the differentiation of this small tumor from an extension into the middle ear cavity of a larger glomus jugulare tumor. It is also necessary to exclude an aberrant internal carotid artery. In the former case the bony plate between the jugular foramen and the middle ear is destroyed, whereas in the latter case the posterior bony margination of the carotid canal is missing (Larson et al, 1987). These tumors are usually small enough for surgery to be performed without embolization.

Glomus jugulare tumor. The patient usually presents with dysfunction of CN IX, X or XI, and XII if the tumor is large. Pulsatile tinnitus is also common. CT or MRI scanning is usually the first diagnostic test performed, with the diagnosis generally made and the extension of the tumor evaluated. The tumor begins in the region of the jugular foramen and may extend inferiorly into the upper neck, superolaterally into the middle ear by destroying bone, posteromedially and posterolaterally into the posterior fossa, and anteriorly to envelop the petrous internal carotid artery. Bone destruction can be extensive, simulating a malignant tumor, as the chemodectoma spreads through the skull base. Destruction around the foramen magnum may occur, with compression of the brainstem (Latchaw et al, 1990).

The tumor is fed by multiple external carotid artery branches, with each of these arteries feeding a specific compartment of tumor. The ascending pharyngeal (bilaterally at times) and middle meningeal (posterior division) arteries are the most commonly involved, with the stylomastoid branch of the occipital and the posterior auricular arteries providing supply less frequently (Fig. 186-3). If the tumor extends posteriorly around the foramen magnum, supply may be from the anterior and posterior meningeal branches of the vertebral artery. Intradural tumor within the posterior fossa may be fed from anterior and posterior inferior cerebellar arteries. Tumor surrounding the high cervical or petrous portion of the internal carotid artery may parasitize tiny branches of these segments (Fig. 186-3) (Moret et al, 1980, 1982; Valavanis, 1986).

The glomus jugulare tumor is highly vascular, which makes surgery in this confined bony area difficult. Therefore, embolization may be of great help (Simpson et al, 1979). Because the diagnosis has generally been made on the basis of CT or MR before angiography, the patient is prepared with consent forms for both angiography and embolization in the same sitting. The arterial feeders are mapped with high-resolution subtraction angiography in two planes, as previously described (Fig. 186-4). Selective catheterization of the multiple feeders is then performed, followed by embolization of particulate material, most commonly PVA, either alone or mixed with 25% to 33% of absolute alcohol, and/or Avitene (Fig. 186-4). As previously discussed, before injecting external carotid branches that may supply the seventh cranial nerve (CN VII), particularly the stylomastoid artery, 1% hylocaine is injected as a provocative test to ensure that the cranial nerve is not devascularized during the embolization procedure (Horton and Kerber, 1986).

Glomus vagale tumor. This tumor originates from the vagus body high in the neck at the C1-C2 level. This tumor may extend superiorly so that differentiation from a glomus jugulare tumor is difficult and may be moot. The typical appearance is that of anterior displacement of the high cervical internal carotid artery. Blood supply is from multiple branches of the external carotid artery, particularly the ascending pharyngeal artery. The arterial supply is mapped as for the glomus jugulare tumor although there are generally fewer sources of supply than for the glomus jugulare tumor (Fig. 186-5). Evaluation of potential supply from ascending and deep cervical branches of the thyrocervical and costocervical trunks, respectively, and of neuromuscular branches from the ipsilateral vertebral artery should also be made. The feeding vessels are catheterized and embolized appropriately, particularly with PVA (Fig. 186-5). Again, the xylocaine provocative test is used if there is any question regarding potential cranial nerve insult.

Carotid body tumor. The carotid body tumor is a highly vascular mass occurring in the crotch between the origins of the internal and external carotid arteries, splaying them apart. There are commonly many tiny feeders from the distal common carotid and proximal internal carotid arteries that are too small to be catheterized selectively to the degree necessary to avoid reflux of particles into the internal carotid artery. However, there are usually major feeders from the external carotid artery, particularly the ascending pharyngea, superior thyroidal, lingual/facial, and carotid body branches (Fig. 186-6). These can be selectively catheterized and much of the tumor may be appropriately embolized with PVA to make surgery easier with less blood loss (Fig. 186-6).

Juvenile angiofibroma

The typical history of angiofibroma is that of recurrent epistaxis and nasal obstruction in an adolescent male. The tumor has a typical location adjacent to the nasal choana and within the nasopharynx and pterygopalatine fossa. The tumor may extend anteriorly through the nasal cavity or superiorly into the sphenoid sinus. Rarely, it extends into the subtemporal fossa. Bone destruction of the lateral wall of the sphenoid sinus or of the anterior temporal fossa allows it to enter the intracranial cavity.

Typically, blood supply is from the internal maxillary artery and its branches, the ascending pharyngeal (which may be bilateral), and the ascending palatine arteries (Fig. 186-7). Tumor may remain extracranial and receive supply from collaterals of the petrous and cavernous segments of the internal carotid artery (ICA) (Davis, 1987; Lasjaunis, 1980; Lasjaunis et al, 1990). Intracranial extensions may receive supply from the accessory middle meningeal artery and from branches of the petrous and cavernous ICA. Because the middle meningeal, accessory meningeal, and foramen rotundum arteries supply cranial nerves within the cavernous sinus (Lasjaunis, 1980), I prefer to catheterize the internal maxillary artery beyond the origin of the accessory middle meningeal artery for particulate material embolization of tumors that are purely extracranial (Fig. 186-7). Supply from the middle meningeal and accessory meningeal arteries can be embolized with care, usually preceded by a lidocaine test. Other arteries are catheterized and embolized as necessary. Such embolization will dramatically decrease the blood loss at the time of surgery (Davis, 1987; Lasjaunis, 1980; Lasjaunis et al, 1990; Pletcher et al, 1975).

Other neoplasms

Hypervascular solid masses involving the face and neck, other than those previously discussed, are uncommon. Occasionally a hypervascular thyroid tumor receiving its blood supply from both the superior and inferior thyroidal arteries will be amenable to embolization. The inferior thyroidal artery is a branch of the thyrocervical trunk and the superior thyroidal artery is the first branch of the external carotid; both are generally easy to catheterize. Lingual/facial angiography and injections into the thyrocervical and costocervical trunks should be made to evaluate tumor extension or other sources of blood supply.

Meningioma may occasionally extend through the skull base into the parapharyngeal and/or facial structures. Besides intracranial tumor embolization, embolization of this extracranial component may be of value before surgery.

Lesions of vascular etiology

Epistaxis

Epistaxis may be secondary to trauma or from a congenital vascular malformation such as in hereditary hemorrhagic telangiectasia. The most common cause, however, is spontaneous bleeding, with or without hypertension, from small vessels along the nasal septum and superior margins of the nasal cavity. Bleeding from the anterior aspect of the nasal cavity is usually self-limited and does not require endovascular therapy, but posterior nasal hemorrhage is more inaccessible and more difficult to manage. Cautery, ligations of the internal maxillary and/or ethmoidal arteries, and nasal packing may be ineffective. The latter may be associated with pulmonary or cardiac problems in elderly patients, therefore embolization may be necessary.

Bilateral selective internal carotid, internal maxillary, facial and ascending pharyngeal artery angiography should be performed in order to visualize the feeders to the bleeding site (Fig. 186-8). It is preferable to start with the presumed noninvolved side first, ending with the vessels most likely to be involved, so as to decrease the recatheterization time to perform embolization. Digital subtraction angiography has dramatically decreased the time for angiography. The site of bleeding is often not seen, so that embolization is performed in vessels that are more likely to be responsible (Fig. 186-6) (Davis, 1987; Jasjaunis et al, 1979; Riche et al, 1979). Small feeders from inferior ethmoid branches of the ophthalmic artery cannot be safely embolized, but small feeders from the internal maxillary, facial, and ascending pharyngeal arteries may be safely embolized. Either Gelfoam or PVA is used; PVA is preferred because of its more permanent nature. Metalic coil occlusion of the proximal portions of the vessels is discouraged because this would hamper access if future embolizations are necessary.

Arteriovenous fistula

Arteriovenous fistula (AVF) may occur following direct facial trauma, or from iatrogenic trauma such as facial surgery. For example, temporomandibular joint or maxillary sinus surgery may result in an AVF (Fig. 186-9). Whatever the cause, selective angiography defines the site of fistula, which is generally easy to occlude with an appropriately sized releasable balloon(s) (Fig. 186-9) (Berenstein et al, 1986).

Dural arteriovenous malformation (AVM) of the transverse and sigmoid sinuses

Transverse and sigmoid sinus dural AVM presents with tinnitus and a bruit that may be objective or only subjective. The tinnitus may be progressive, leading to severe subjective symptoms and because of venous congestion may lead to cranial nerve palsies and occasionally to intracranial hemorrhage. This is probably an acquired lesion secondary to thrombosis of the sigmoid sinus or jugular bulb, leading to an opening of arteriovenous (AV) shunts in the dura. Increased flow through these AV shunts is progressive, with venous outflow either through a recanalized ipsilateral sinus or through the contralateral sinus. Occasionally at angiography the persisting venous stenosis or occlusion is apparent (Houser et al, 1979).

Arteriography reveals many supplies to the dura including multiple uinilateral or bilateral external carotid artery branches and dural branches of the internal carotid arteries. Arterial embolization alone is usually only palliative, with multiple other dural sources increasing in size as the primary feeders are occluded. Particulate matter embolization is particularly discouraging, and usually if only the arterial side is embolized, a tissue adhesive such as NBCA must be used. A much better solution appears to be a combined arterial and venous approach. Following arterial embolization, coils or NBCA may be deposited in the transverse and sigmoid sinuses so that the AV connections along the sinus are occluded on both sides of the dura (Halbach et al, 1989).

Extracranial vascular malformation and hemangioma (symptomatic vascular malformation)

The terminology of this group of disorders is very confusing. Mulliken has subdivided these lesions into vascular malformations and hemangiomas. Vascular malformations are further subdivided into arterial (high-flow), capillary, and venous malformations (slow flow). Vascular malformations differ from hemangiomas in that they are present at birth whereas only approximately 30% of hemangiomas are present at birth. Hemangiomas have a 5:1 female to male ratio and there is a proliferative phase followed by involution so that 90% of hemangiomas that are present at birth regress by early childhood. Capillary hemangiomas are generally found in childhood whereas the adult form is a cavernous hemangioma. On the other hand, vascular malformations that are present at birth do not regress spontaneously like hemangiomas, and may be dormant until some type of factor, such as local trauma, causes them to enlarge (Mulliken and Glowacki, 1982; Mulliken and Young, 1988). Some hemangiomatous lesions appear to contain arteriovenous fistulae and seem to be mixed lesions. The most appropriate term is probably *symptomatic vascular malformation,* and characterization should be made according to the angiographic findings.

Therapy for infantile or early childhood hemangioma is necessary only if there is airway obstruction such as from hemangioma of the tongue or subglottic tissues. Even if the hemangioma is in the periorbital region and interferes with normal eye function, time should be allowed for regression, followed by eye muscle and cosmetic surgery. In the adolescent or adult, however, problems may be simply cosmetic. The vascular malformation may infiltrate surrounding tissues such as the alveolar ridge, resulting in hemorrhage when eating.

Embolization therapy is determined according to the angioarchitecture of the lesion. A lesion that on angiography has rapid flow with enlarged arterial feeders is analogous to a cerebral AVM, and a polymerizing agent such as IBCA or NBCA is necessary for embolization because of the rapid flow, with or without subsequent surgery (Brothers et al, 1989). If there is a slower arterial component, embolization with particulate materials such as PVA can be performed (Fig. 186-10). If there is primarily a capillary or venous component, direct puncture of the lesion with the instillation of a sclerosing agent such as 100% ethanol or sotradecol may be extremely effective. The procedure must be performed so that venous channels leading to important structures such as the cavernous sinus are not injured. Using a small butterfly needle, the malformation/hemangioma is punctured, and veins leading to the eye and cavernous sinus are manually compressed while tourniquets are placed to produce stasis of bloow withing the vascular malformation. This ensures prolonged direct contact between the toxic agent and the endothelium of the lesion (Berenstein and Choi, 1983; Dion et al, 1984; Yakes et al, 1989, 1990).

Aneurysms

The treatment of a congenital intracranial aneurysm is beyond the scope of this chapter. The use of the BTO procedure before endovascular occlusion for an intracranial aneurysm has been described. Congenital aneurysm of the cervical internal carotid artery is rare. Aneurysm formation of the high cervical internal carotid artery is generally posttraumatic, with the internal carotid artery pinned against the second cervical lateral mass when the head is hyperextended and rotated at the time of trauma. Surgery usually requires disarticulation of the mandible followed by aneurysmorrhaphy and patch graft. Therefore, balloon occlusion may be an acceptable alternative. Because the mouth of such an aneurysm is usually wide, it is generally not possible to place a balloon into the aneurysm and spare the parent vessel. Although occlusion of the carotid artery proximal to the high cervical aneurysm may suffice, it is generally easy to pass a catheter and releasable balloon beyond the aneurysm, and with the placement of another balloon below the aneurysm, complete occlusion of the aneurysm without collateral filling is ensured (Mehringer et al, 1983). The BTO procedure should precede aneurysm ablation.

Pseudoaneurysm of the cervical internal carotid artery may occur iatrogenically following a surgical procedure. Inadvertent biopsy of an aberrant carotid artery in the middle ear cavity may also occur, leading to rapid blood loss into the middle ear cavity and beyond

(Fig. 186-11). Again, these are generally best handled by trapping with balloons proximal and distal to the aneurysm (Reilly et al, 1983). It is preferable that the patient be tested for adequate cerebral blood flow before each occlusion.

Tinnitus-producing fibromuscular dysplasia of the carotid artery

The causes of pulsatile tinnitus are many (see Chapter 173). One cause is fibromuscular dysplasia (FMD) of the internal carotid artery, which usually occurs at the level of the second cervical segment. The webs of the dysplasia produce eddy currents of blood flow, leading to tinnitus. The webs may be stretched by using an angioplasty catheter, which decreases the tinnitus (Hasso et al, 1981).