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Clifford R. Jack

Bharat A. Mehta

Roushdy S. Boulos

Suresh C. Patel

James I. Ausman

See next page for additional authors

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Interventional Neuroradiology: Henry Ford Hospital Experience with Nonembolization Procedures

Clifford R. Jack, Jr, MD,* Bharat A. Mehta, MD,* Roushdy S. Boulos, MD, PhD,* Suresh C. Patel, MD,* James I. Ausman, MD, PhD,† and Ghaus M. Malik, MD†

Innovative technical developments over the past two decades have resulted in the development of a variety of useful interventional procedures for minimally invasive treatment of a variety of head and neck lesions. We have had experience with four different types of nonembolization interventional neuroradiologic procedures at Henry Ford Hospital from 1981 through 1985.

Percutaneous transluminal angioplasty of six external carotid artery stenoses has been performed in five patients. Five were successful, and the artery became occluded in one patient. Intracarotid BCNU infusion was performed successfully in five patients with recurrent astrocytoma. Intraarterial streptokinase infusion was performed in one patient with acute thrombosis of an ectatic basilar artery. A traumatic carotid cavernous fistula was successfully closed by detachable silicone balloon technique. (Henry Ford Hosp Med J 1986;34:11-18)

The search for less invasive ways to treat a variety of abnormalities involving virtually every organ system has led to rapid growth in the field of interventional radiology. In recent years, interventional radiologic techniques have played an increasingly important role in the treatment of a variety of lesions of the head, neck, and spine, giving rise to the high subspecialized field of interventional neuroradiology.

A number of technical innovations within the past two decades have stimulated the development of a variety of useful and increasingly successful interventional neuroradiologic procedures. The list of therapeutic procedures that have been applied to the treatment of head and neck abnormalities include: percutaneous transcatheter embolization of vascular tumors and vascular malformation (1,2); percutaneous transluminal angioplasty (PTA) (3-9); transluminal detachable, occlusive, and leak-calibrated balloons (10-15); and intracranial drug infusion made possible by better catheter delivery systems (16-20).

In this paper we discuss only the nonembolization interventional neuroradiologic procedures performed at Henry Ford Hospital. Indications, benefits, risks, and technical guidelines are discussed for each procedure.

Patients, Methods, and Results

Twelve patients have undergone nonembolization interventional neuroradiologic procedures at Henry Ford Hospital from 1981 through 1985. All procedures were performed by one of the authors (Mehta) in the Department of Radiology, Division of Neuroradiology. To date, we have experience with four different types of nonembolization procedures.

Percutaneous transluminal angioplasty (PTA) of the external carotid artery (ECA)

Patients—Six such procedures have been performed in five patients. Bilateral ECA-PTA was performed in the same sitting in one patient. All patients were elderly, with atherosclerotic occlusion of the ipsilateral internal carotid artery (ICA) and atherosclerotic stenosis at the origin of the ipsilateral ECA. These patients were to undergo superficial temporal artery to middle cerebral artery bypass procedures but had ipsilateral external carotid stenoses. The PTA was performed to eliminate the need for external carotid endarterectomy before the bypass operation.

Technique—The procedure was performed via the femoral approach in all but one patient, in whom a direct common carotid artery puncture was performed. A constant intravenous heparin infusion was maintained throughout each procedure. A 5 French polyethylene Dotter Balloon Dilatation Catheter (Cook, Bloomington, IN) with a 4 mm (inflated diameter) balloon was positioned across the stenotic ECA lesion under fluoroscopic guidance. The balloon was inflated three times for 30 seconds each. The balloon catheter was then withdrawn into the common carotid artery, and a postdilatation angiogram was performed.

Results—Increase in lumen size of the affected segment of 50% to 70% was achieved in five arteries (Fig 1). No neurologic complications were encountered in any of these patients.

The ECA became occluded in the patient who underwent direct carotid artery puncture. She developed a mild contralateral hemiparesis following the procedure, which resolved in two months. This patient was shown at subsequent endarterectomy to have had a large, heavily calcified atherosclerotic plaque producing the stenosis.

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*Department of Diagnostic Radiology, Division of Neuroradiology, Henry Ford Hospital.
†Department of Neurosurgery, Henry Ford Hospital.
Address correspondence to Dr Mehta, Department of Diagnostic Radiology, Henry Ford Hospital, 2799 W Grand Blvd, Detroit, MI 48202.

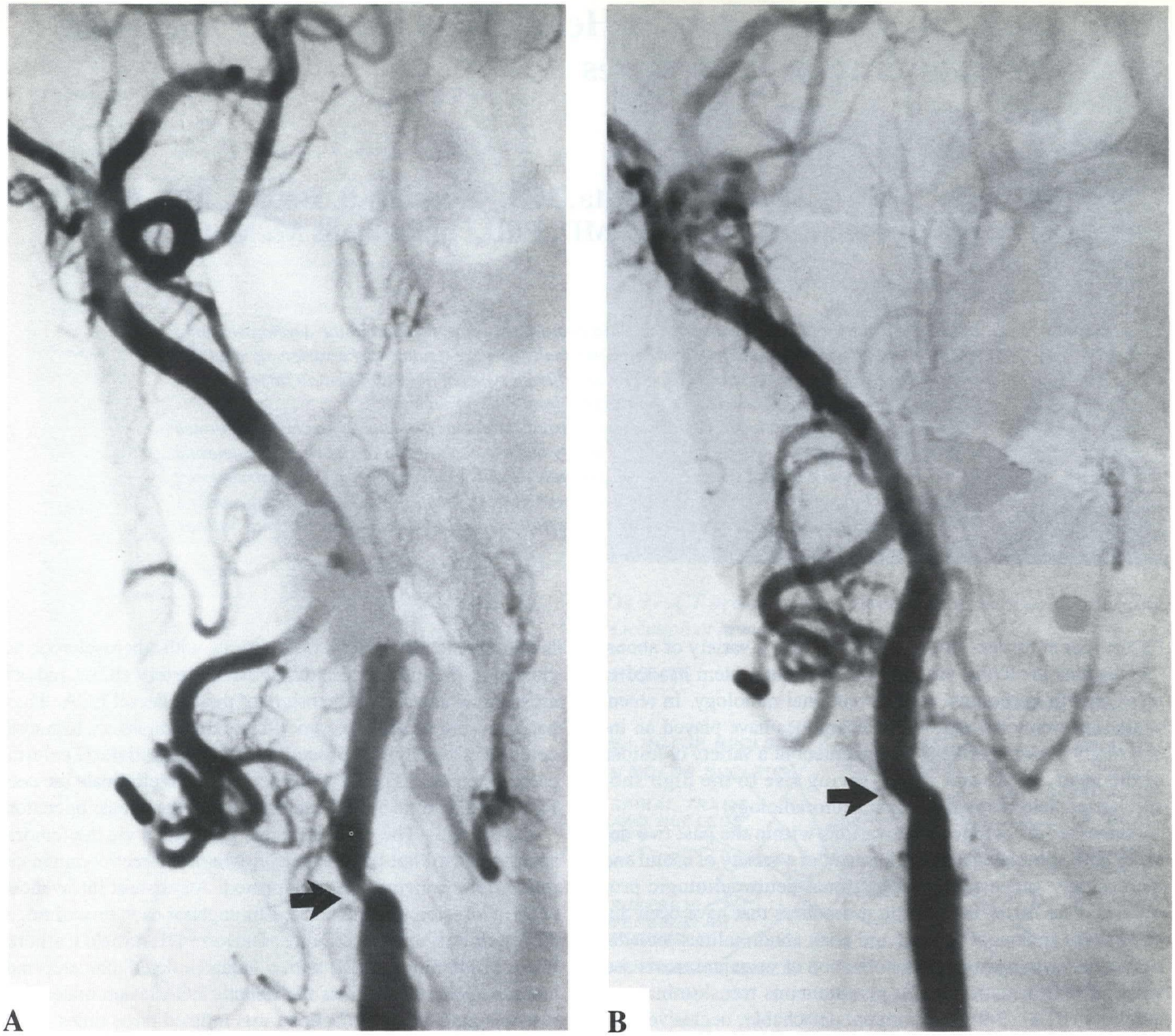

Fig 1—External carotid PTA in patients with occluded ipsilateral ICA. (A) Predilatation and (B) postdilatation AP view right carotid injection showing 50% increase in size of stenotic ECA segment (arrow).

Intracarotid 1,3-Bis(2-chloroethyl)-1-nitrosourea (BCNU) infusion

Patients—Six such procedures have been performed in five patients. These patients ranged in age from 27 to 60. All patients had end stage, grade 3 to 4, unilateral supratentorial astrocytomas. All tumors were recurrent (postsurgical resection), and all were then treated with a combined radiation therapy-intracarotid chemotherapy approach.

Technique—Via transfemoral approach, a 5 French catheter was placed in the petrosal segment of the ICA ipsilateral to the tumor. Twenty-five grams of mannitol in saline were infused through the catheter rapidly. A solution of 100 mg/m^2 BCNU in 49 mL of normal saline and 1 mL absolute ethanol (solvent for BCNU) was then infused through the catheter via a micropump (Sigma Motor, Inc, Middleport, NY) over 15 minutes. The patients were carefully monitored for signs of neurologic and ocular toxicity during infusion.

Results—No neurologic deficit, seizure activity, vision loss, myelosuppression, or GI toxicity was produced. One patient did experience retro-orbital pain during infusion with no permanent sequelae.

Results concerning survivorship or improved neurologic status are inconclusive in comparison to other chemotherapeutic regimes due to the small number of patients included. All

Fig 2(A)—Intraarterial streptokinase infusion for basilar artery thrombosis. AP view of left vertebral artery injection showing massive ectasia of basilar artery. A 3 cm thrombus partially occludes rostral basilar artery (arrow).

patients did eventually die. Well-controlled data with documentation of the effect of intraarterial BCNU on tumor size by computed tomography (CT) are not available.

Intraarterial streptokinase infusion for basilar artery thrombosis

Patients—This procedure was performed on an emergency basis in one patient. This 66-year-old man presented with rapidly progressing multiple cranial nerve deficits and decreased level of consciousness over the course of several hours. Emergency cerebral angiography demonstrated marked diffuse ectasia of the basilar and the intracranial left vertebral artery with nearly complete occlusion of the rostral basilar artery by a 3 cm intraluminal thrombus.

Technique—Twelve to 14 hours after onset of symptoms, the interventional procedure was begun. A Berenstein catheter (USCI, Bellerica, MA) was placed transfemorally into the cervical left vertebral artery at the C2 level. Through this, a 0.038 removable core hollow wire (USCI) was coaxially placed into the basilar artery, just proximal to the thrombus. Through the hollow wire 350,000 units of streptokinase (Streptase, Hoechst-Roussel, NS) was infused over three hours using a microdrip pump (Sigma Motor, Inc). This was accompanied by low-dose systemic heparinization. The entire procedure was performed on the angiography table, with constant monitoring of the patient's clinical status. Three angiographic studies were performed to assess morphologic change in the thrombus.

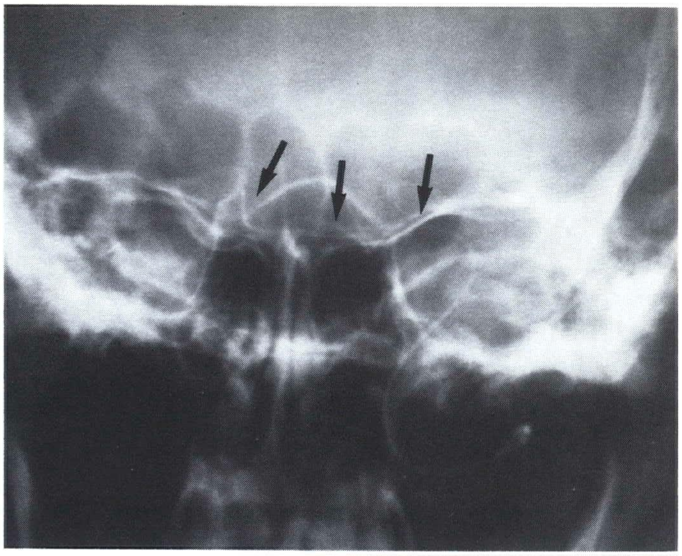

Fig 2(B)—Intraarterial streptokinase infusion for basilar artery thrombosis. AP scout radiograph showing position of hollow wire tip in midbasilar artery (arrows).

Results—Slow but progressive improvement in the patient's level of sensorium was noted over the first three hours of infusion. At three hours, however, a sudden decreased level of consciousness was noted, and the infusion was terminated. Diagnostic angiographic studies performed over the course of the streptokinase infusion demonstrated no change in thrombus size.

The patient unfortunately died two days later. Autopsy revealed extensive brain stem and cerebellar infarction, producing marked posterior fossa mass effect and tonsillar herniation, with no evidence of intracranial hemorrhage (Fig 2). A recent embolus was also present in the left posterior cerebral artery, producing infarction of the left occipital lobe. The basilar artery was markedly ectatic with little evidence of atherosclerosis and uniformly absent internal elastic lamina. The thrombus appeared to have formed without an atherosclerotic substrate, due to stasis within the basilar artery.

Detachable balloon occlusion of carotid-cavernous fistula

Patient—This procedure has been performed in one patient to date, a 64-year-old man who presented with a posttraumatic high-flow carotid-cavernous fistula on the right. He was symptomatic from a constant loud bruit that interfered with sleep and a cavernous sinus syndrome consisting of ipsilateral cranial nerve 3, 4, and 6 palsy.

Technique—The procedure was performed using a Becton-Dickinson (Rutherford, NJ) detachable silicone balloon system that comes premade from the manufacturer (12). The cylindric silicone rubber balloon (2 x 7 mm uninflated) is attached to a 150 cm 3 French polyurethane catheter via a stainless steel pressure-activated valve pin. This balloon-tipped catheter was introduced coaxially through a 9 French straight catheter that had been placed transfemorally into the proximal right ICA. The balloon was flushed with normal saline into the fistula via flow direction technique (12). The balloon was inflated with 0.6 mL of 210% Amipaque (Winthrope-Breon Lab, New York, NY). A DSA run

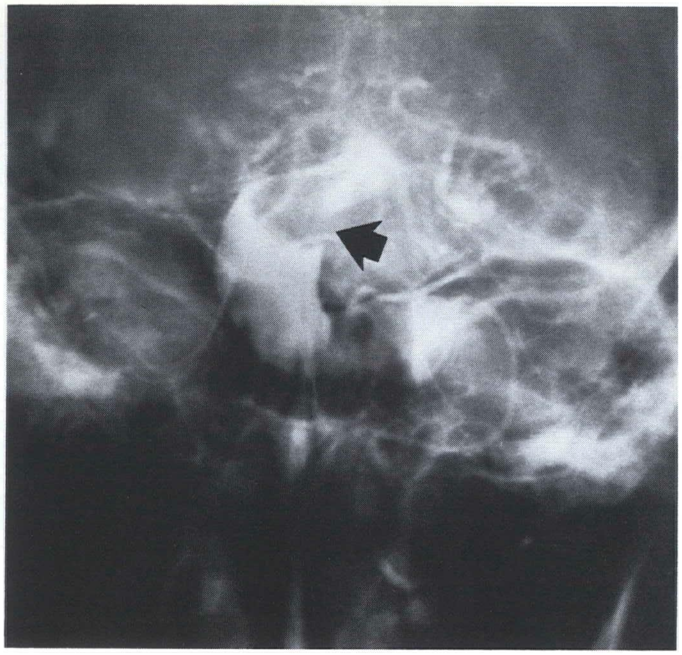

Fig 2(C)—Intraarterial streptokinase infusion for basilar artery thrombosis. AP left vertebral injection after two and one half hours of streptokinase infusion shows no change in size of basilar thrombus (arrow), although the patient was improved clinically at this point.

was taken to document satisfactory balloon position, effect on fistula flow, and morphology of the adjacent carotid siphon. When the aforementioned criteria had been met, the balloon was detached. Two detachable silicone balloons were placed by this technique.

Results—The first balloon was successfully placed into the fistulous opening, resulting in immediate subjective cessation of the bruit. After one hour, the bruit returned suddenly. A DSA study was performed that revealed migration of the balloon from the fistulous opening into the cavernous sinus with reopening of flow through the fistula. A second balloon was then successfully placed into the fistulous opening, again with subjective relief of the bruit. At one month follow-up, neither balloon had changed position, and the patient remained asymptomatic (Fig 3). No complications were encountered during placement of either balloon. Marked clinical improvement in the right cavernous sinus syndrome was noted within 24 hours.

Discussion

In recent years, interventional neuroradiologic procedures have increasingly been employed with much success in the management of a variety of head and neck conditions. This paper is limited to a discussion of the four types of nonembolization interventional neuroradiologic procedures to date at this institution.

Percutaneous transluminal angioplasty of the external carotid artery

The technique of PTA was pioneered by Gruntzig in the 1970s and has since been applied extensively in treatment of local areas

Fig 2(D)—Intraarterial streptokinase infusion for basilar artery thrombosis. Gross specimen of ectatic basilar circulation at autopsy.

of arterial stenosis involving many organ systems (6,7). This technique has proved to be especially useful in the treatment of coronary artery disease, peripheral vascular disease, and renovascular hypertension (6,7).

Several authors have reported the application of PTA in the treatment of stenotic arterial lesions of the extracranial carotid and vertebral circulation. Successful dilatation of cervical ICA stenoses due to fibromuscular dysplasia (8) and of carotid and vertebral artery atherosclerotic stenoses (3,4) has been reported. Atherosclerotic stenosis of the cavernous-carotid artery has also been dilated successfully (9). Due to the risk of distal embolization and possible stroke, PTA for atherosclerotic ICA lesions is recommended only for patients who are not surgical candidates (3,4).

The risk of stroke is minimized in dilatation of ECA stenoses in patients with ipsilateral ICA occlusion. Successful dilatation of ECA stenosis in nine patients before superficial temporal to middle cerebral artery bypass for ICA stenosis without neurologic complication has been reported by Vitek (5).

This procedure is not without risk. An intimal tear or intramural hematoma may be produced that could lead to ECA occlu-

Fig 2(E)—Intraarterial streptokinase infusion for basilar artery thrombosis. Cross section of basilar artery showing intraluminal thrombus.

sion, as happened in one of our cases. Wide fluctuations in blood pressure are also possible due to pressure on chemoreceptor cells in the adjacent carotid bulb (3). Emboli may reach the intracranial circulation even with cervical ICA occlusion in patients with retrograde ophthalmic collateral flow.

Poor results have been reported in attempting to dilate heavily calcified stenotic plaques (4). Both the poor results reported in the literature as well as our experience with one patient in whom PTA failed leads us to concur that patients with calcified plaques are not candidates for this procedure.

Intracarotid BCNU infusion in recurrent astrocytoma

Anaplastic glioma accounts for approximately one fourth of all adult cerebral neoplasms and includes glioblastoma multiform, anaplastic astrocytoma, and malignant astrocytomas. These tumors have a uniformly fatal course with less than 10% survivorship at two years (21). A mean survival of 17 weeks is reported with surgical resection alone (22). With the addition of radiation therapy, mean survival is extended to 37.5 weeks (22). The best result reported in patients treated with resection, radiation therapy, plus systemic BCNU is a survival of 51 weeks (22). Although this combined approach has resulted in prolonged survival and improved neurologic function, the long-term prognosis remains poor (23-28).

BCNU does cross the blood-brain barrier and has been shown to be the most effective single chemotherapeutic agent against glioma (17,21). A response rate of 50% with a mean duration of

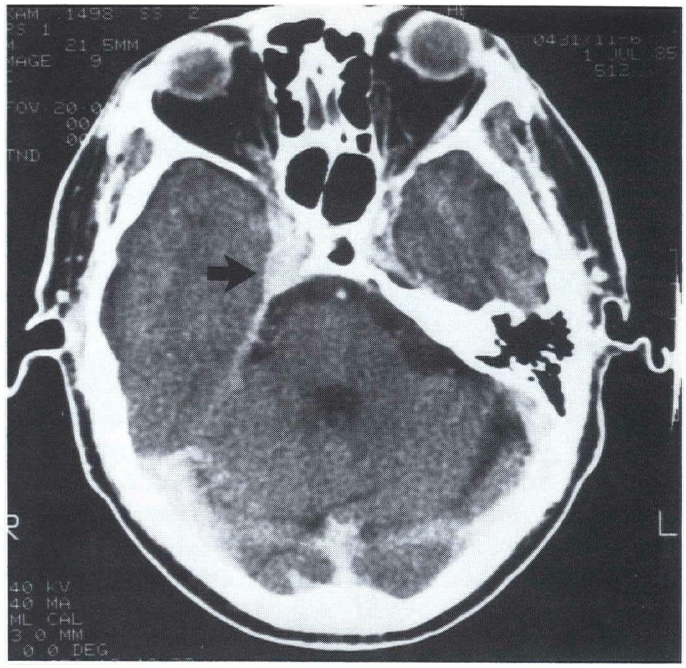

Fig 3(A)—Detachable balloon occlusion of carotid cavernous fistula. CT scan showing enlargement of right cavernous sinus (arrow) due to high-flow CC fistula.

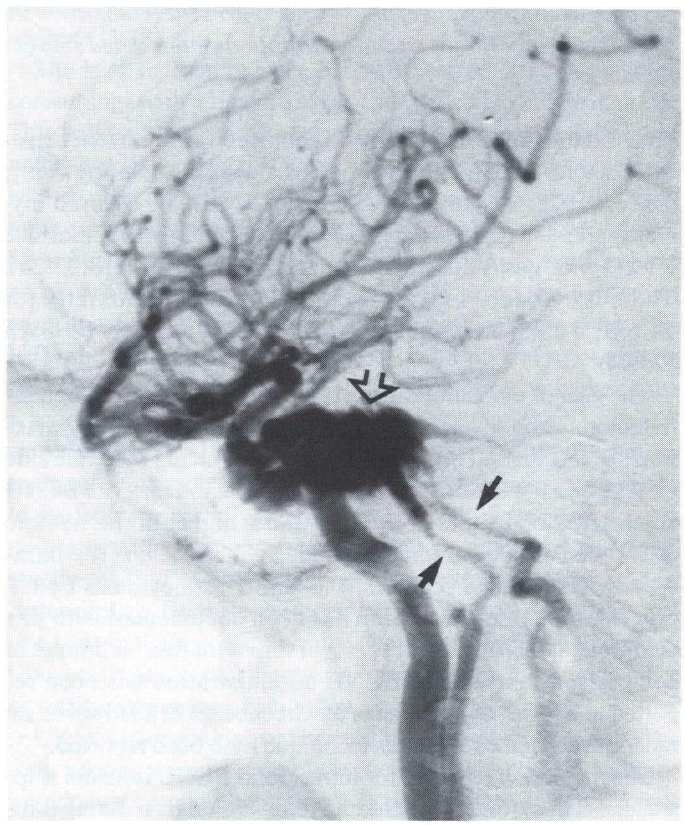

Fig 3(B)—Detachable balloon occlusion of carotid cavernous fistula. Lateral view of right ICA injection showing opacification of right cavernous sinus (hollow arrow) by flow through fistula. Venous drainage is via inferior petrosal sinuses bilaterally (solid arrows).

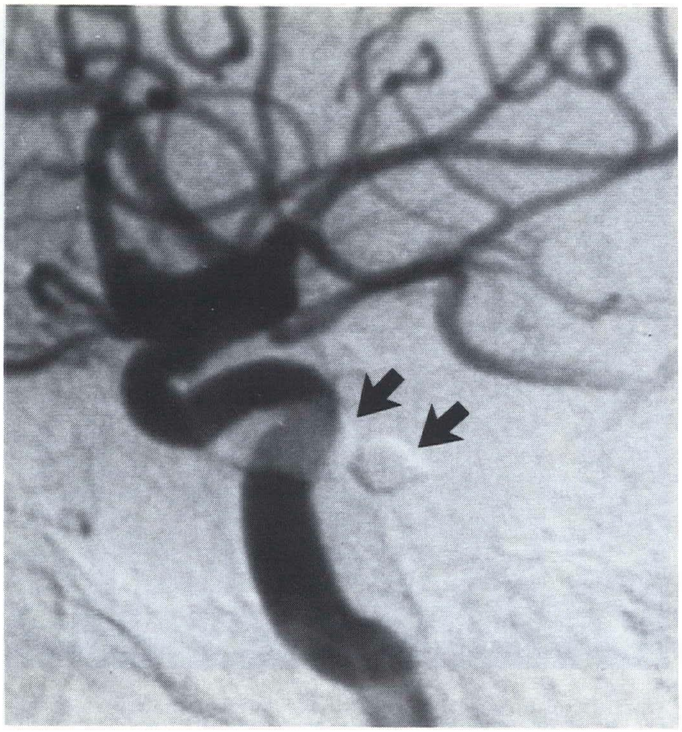

Fig 3(C)—Detachable balloon occlusion of carotid cavernous fistula. Lateral view of right ICA injection after fistula closure. No opacification of cavernous sinus is present (compare with Fig 3B). Two balloons are identifiable as subtracted images (arrows).

nine months' response has been reported for recurrent astrocytoma with systemic BCNU therapy alone (23). Unfortunately, side effects of systemic treatment can be severe. Delayed myelosuppression (particularly thrombocytopenia) is the chief side effect, with gastrointestinal toxicity also reported (18,23,24). There is evidence indicating cumulative myelotoxicity for BCNU, a problem limiting the total amount that may be given (23,24).

The goal of intracarotid BCNU infusion is to achieve high intratumoral drug levels with low systemic levels, thereby maximizing antitumoral drug activity and minimizing systemic side effects. Work with monkeys has shown that intraarterial BCNU administration results in 190% to 280% higher brain, nucleic acid-bound drug levels than systemic administration (17). Intracarotid BCNU has been shown to shrink astrocytomas by CT criteria, though no remission has been documented with this technique (20). Improved survivorship with this technique in comparison to systemic BCNU administration has been reported in a series of 30 patients by Greenberg (22). However, no randomized studies with this technique have been reported.

The major risk reported for intracarotid BCNU infusion is ipsilateral retinal toxicity, including retro-orbital pain during infusion, retinal vasculitis, and even blindness (20,27). This is because the ophthalmic artery receives high drug concentration with high cervical ICA catheter tip placement. Decreasing the ethanol concentration of the mixture seems to decrease the severity of retinal toxicity; however, it is not yet clear whether the offending agent is ethanol alone, or BCNU as well (21,27). Ipsilateral cerebral infarction is a less widely reported complication (16, 18).

Supraophthalmic BCNU infusion through a microballoon or hollow wire threaded coaxially through a polyurethane catheter with its tip in the cervical ICA is possible (14,15). Successful supraophthalmic BCNU infusion has been reported using calibrated leak microballoons with no retinal toxicity (28). Superselective catheterization of the specific intracranial vessels supplying the tumor may also be possible, in which case much of the normal brain parenchyma ipsilateral to the tumor may be spared exposure to high concentrations of BCNU. However, the safety and efficacy of superselective intraarterial BCNU infusion directly into tumor vessels have not been definitively established, and this approach must, at this point, be regarded as experimental.

Intracarotid mannitol was given in our series of patients to temporarily modify the blood-brain barrier and to increase delivery of BCNU to tumor tissue in our protocol (29). However, the efficacy of this step in achieving greater delivery of BCNU to tumor tissue has recently been questioned (27).

Intraarterial streptokinase infusion for basilar artery thrombosis

Basilar artery thrombosis has been a very poor prognosis. In a series of 22 cases of angiographically proven basilar artery occlusion by Thompson et al, 44% of these patients died within three months (30). Archer and Hornstein published 20 cases of angiographically proven basilar artery occlusion; 70% of these patients died within three and a half months (31). Those patients with rostral basilar artery thrombosis had an even poorer prognosis than those with more proximal occlusion (31). To date, no effective surgical therapy is available for basilar artery thrombosis.

Successful intraarterial clot lysis has been achieved using both intravenous (IV) and intraarterial (IA) streptokinase (19,32-35). IV streptokinase in doses of 100,000 units/hr results in successful intravascular clot lysis (34). However, maintenance of systemic streptokinase levels in this therapeutic range regularly results in unwanted bleeding at distal sites, particularly recent surgical incisions and needle puncture sites (34).

The purpose of IA administration is to maximize drug levels at the target site, while minimizing systemic levels. IA streptokinase in doses of 10,000 units/hr results in the same degree of intravascular clot lysis as 100,000 units/hr administered systemically, without the unwanted systemic side effects (34). IA streptokinase infusion has been proven effective in clot lysis (without distal hemorrhagic complications) at a number of different locations, including peripheral and pulmonary arterial circulation (32), peripheral arterial grafts, renal dialysis accesses (33), and coronary circulation (35).

The catheter used for streptokinase infusion may lie for a fairly long period within the relatively stagnant column of blood proximal to an obstructing thrombus. Simultaneous systemic heparinization is therefore recommended to prevent new thrombus formation on the catheter (33).

Zeumer et al have reported five cases of IA streptokinase infusion for angiographically proven basilar artery thrombosis (19). Three of these five patients demonstrated dramatic functional improvement and prevention of further ischemic necrosis. One patient died, and one remained "locked in," unchanged from the preinfusion state. A dose of 100,000 units/hr for two hours was used in all patients with no CT evidence of intracranial hemorrhage (19).

In the case we report, autopsy revealed no evidence of significant atherosclerotic plaque formation in the intracranial vertebrobasilar system. Therefore, we postulate that the most likely cause of thrombus formation is stasis due to massive basilar ectasia (33). Because of the grave nature of this patient's problem and the rapid rate of clinical deterioration, we felt that anything less than a maximally aggressive therapeutic approach would produce a certainly fatal outcome. At autopsy, embolic occlusion of the left posterior cerebral artery and extensive brain stem infarction were found. We postulate that the large basilar thrombus was "broken up" by streptokinase infusion into multiple smaller clots which embolized distally.

Because of the small number of cases reported, risks have not been established for this procedure, but certainly embolization of basilar branches due to clot "break up" would be a major theoretical risk. Intracranial hemorrhage would be a second major theoretical risk; however, this was not seen in our case, nor in the cases reported by Zeumer (19).

The goal in intracranial arterial clot lysis must be dissolution of the clot exterior, layer by layer, peeling it like an "onion skin." Formation of smaller clot fragments, which migrate distally, producing embolic tissue infarction may be tolerated in the peripheral vasculature but not in the central nervous system. Further experimental work must be done to suitably modify this technique for widespread use in central nervous system intraarterial thrombolysis.

Transluminal detachable balloon occlusion of carotid-cavernous fistula

The term carotid-cavernous (CC) fistula is used to describe two anatomically distinct vascular abnormalities. In both cases, an abnormal fistulous connection exists between arteries adjacent to the cavernous sinus and the sinus itself. This fistulous channel produces abnormal shunting of arterial blood directly into the cavernous sinus (10).

When the arterial supply to the fistula is from small dural branches of the ICA or the ECA, the rate and volume of flow is often minimal. This type of carotid-cavernous fistula usually does not pose a serious clinical problem, and often is merely an incidental finding at cerebral angiography. Spontaneous closure of this type of fistula is the rule and, therefore, no form of treatment is recommended (10).

If, however, the arterial supply to the fistula is through a tear in the cavernous ICA itself, then flow through the fistula is often of high rate and volume. This type of CC fistula may produce severe clinical symptoms. The rapid arterial to venous shunting elevates the pressure within the cavernous sinus and the venous channels which normally drain into or out of the sinus (10). Elevation of pressure within the cavernous sinus may result in dysfunction of cranial nerves 3, 4, 6, and 5 (particularly the first division). Elevation of venous pressure within the orbit may produce exophthalmus and, more importantly, vision loss. These symptoms are most commonly seen ipsilateral to the fistula but due to normally present transcavernous venous channels may be bilateral or rarely contralateral to the fistula. This high-flow type of CC fistula most commonly results from trauma or from spontaneous rupture of a cavernous ICA aneurysm. These, in general, do not close spontaneously, and treatment is recommended because of the danger of permanent blindness and/or ocular palsy (10). Carotid-cavernous fistulas that drain predominantly posteriorly may produce a cavernous sinus syndrome and a loud bruit, without significant orbital symptoms.

A variety of approaches have been used to treat high-flow CC fistulae. The list includes simple ligation of the ipsilateral ICA or common carotid artery in the neck, trapping of the ICA with or without fistula embolization, or intraluminal balloon occlusion of the cavernous ICA (11,36). Copper wires have been placed into the cavernous sinus with or without electric current to induce thrombosis (36). A procedure recently described by Diaz et al involves ICA trapping combined with an ipsilateral bypass of the superficial temporal to the middle cerebral artery in the sylvian fissure (11,36).

Detachable balloon occlusion of the fistula itself is theoretically the best procedure for treatment of this condition because the fistula is closed without occluding the ipsilateral ICA (11).

Two different types of detachable balloons have been developed. Latex balloons were developed first but have been supplanted in many centers by the silicone balloon we have described (11,12).

The latex balloon must be hand-tied (often difficult and time consuming) with a ligature at the end of a single lumen catheter. This balloon must be maneuvered into the fistula and detached with a coaxially placed 8 French outer single lumen catheter. It is often difficult to maneuver an 8 French catheter into the cavernous carotid artery, and the risk of damage to the vessel wall from a catheter this large is significant. A second catheter must be placed in the opposite groin and placed in the ipsilateral carotid artery to perform diagnostic angiographic runs. The balloon ligature is inherently weak, and partial or complete balloon deflation is a problem. Latex balloons also incite tissue reaction (12).

We prefer the silicone detachable balloons because they are more maneuverable, have less premature deflation, come ready to use from the manufacturer, do not require placement of a second catheter in the opposite groin, and incite little if any tissue reaction (12). The one advantage latex balloons have is greater distensibility. Because they can be inflated to larger diameter, one latex balloon is usually sufficient to achieve fistula closure. Conversely, up to six silicone balloons may be required to close or sufficiently reduce fistula flow.

Use of either silicone or latex balloons is not without risk. The most serious potential complication is distal embolization of the intracranial carotid circulation by a prematurely detached or deflated balloon, which may produce stroke. Palsy of cranial nerves 3, 4, 6, 5 (first division), and 7 have been reported (11-13). These are nearly always temporary when they do occur. If a balloon is overinflated in the cavernous sinus and later deflates, a false aneurysm may be produced. Trauma to the low cervical ICA by the outer 9 French coaxial catheter may rarely cause perforation, false aneurysm, dissection, or occlusion (11,12).

Angiographically complete fistula closure is not commonly achieved. Silicone balloons are individually placed until the fistula flow is slowed significantly, and the subjective bruit experienced by the patient disappears. When this end point is achieved, the cavernous sinus will usually thrombos spontaneously within weeks. The fistula will then not recur, even with balloon deflation. This instant and dramatic resolution in symptoms can be one of the most elegant and gratifying procedures in medicine.

Summary

We have had experience with four different types of nonembolization interventional neuroradiologic procedures at Henry Ford Hospital. Detachable balloon occlusion of CC fistula is an elegant procedure with well-documented clinical efficacy. PTA of the ECA, intracarotid BCNU infusion for glioblastoma, and intraarterial streptokinase for basilar thrombosis are relatively new or experimental procedures and, therefore, not widely reported in the literature. The full range of clinical applicability of the latter three procedures has yet to be realized.

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