Transvenous Embolization of Direct Carotid Cavernous Fistulas

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Of 165 cases of direct carotid cavernous fistula, 14 (8.5%) were treated from a transvenous approach. Twelve of these were treated through the inferior petrosal sinus and one through the superior ophthalmic vein. In one patient, both approaches were used. The embolic agents were as follows: five patients had balloons only, four patients had minicoils alone, three patients had coils and liquid adhesives, one had balloons and coils, and one had balloons and liquid adhesives. Among the patients who were treated from a transvenous approach, three had an occluded carotid artery caused by trauma, nine failed transarterial balloon attempts, and one had a prior trapping procedure. In the remaining patient, who had Ehlers-Danlos syndrome, a transarterial approach was judged to be too dangerous. This patient suffered a fatal pontine hemorrhage after subtotal transvenous occlusion of the carotid cavernous fistula with diversion of flow into cortical veins. Another complication occurred when the inferior petrosal sinus was perforated during catheterization, causing a small subarachnoid hemorrhage. The tear was immediately closed with minicoils, and surgical exposure and embolization resulted in complete cure. Of the remaining 12 patients treated, 11 were completely cured and one showed angiographic and clinical improvement.

Transarterial balloon embolization remains the procedure of choice in the treatment of symptomatic carotid cavernous fistulas; however, transvenous embolization is an alternative when the arterial route fails.

Carotid cavernous fistulas (CCFs) are spontaneous or acquired connections between branches of the carotid artery and the cavernous sinus. Direct connections between the internal carotid artery and the cavernous sinus can occur as a result of trauma, ruptured aneurysms, fibromuscular dysplasia, or collagen deficiency diseases [1, 2].

The earliest treatments included surgical ligation or trapping procedures [3, 4]. Because of the extensive collateral supply involving this region, these treatments were often ineffective at achieving complete closure and could aggravate symptoms such as visual decline [3]. Subsequent embolization treatments have evolved using thrombus, muscle, Gelfoam, coils, balloons, and liquid adhesives [5–8]. Compression therapy has also been shown to be an effective treatment [9]. While the vast majority of CCFs can be obliterated by transarterial embolization techniques, specific vascular anatomy or prior treatments can make this route hazardous or impossible. Of the 165 CCFs treated by us over the past 10 years, 14 (8.5%) were treated by a transvenous route. The results of this treatment approach are summarized below.

Materials and Methods

Of the 165 patients with direct CCF treated by us over the past 10 years, 14 had transvenous embolization. Patients' ages ranged from 19 to 73 years, with a mean age of 38 years. The fistula was located on the left side in eight patients and on the right side in six. A transarterial embolization attempt failed in nine cases. Three patients (cases 5, 6, and 7) had

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occlusion of the carotid artery secondary to trauma and one patient (case 1) had prior surgical trapping of the carotid artery without closure of the fistula. One patient (case 4) had Ehlers-Danlos syndrome and was treated transvenously because the risk of arterial embolization was judged to be excessive. In cases where liquid adhesives were used, the fistula flow was first slowed with coils or balloons. A small-caliber (2-, 2.5-, or 3-French) catheter was then placed into the cavernous sinus and a small injection of IBCA* mixed with Pantopaque was given using real-time digital subtraction control. Standard minicoils[†] were delivered through a 3-French or 5-French catheter. More recently, platinum and gold coils were placed through a 2.5-French Tracker catheter.[‡] Attempts were made to place the minicoils close to the fistula orifice. Because a direct connection exists between the carotid artery and cavernous sinus, care must be taken to prevent placement of a coil into the carotid lumen. In large fistulas, coils were placed at the origin of the sphenoparietal sinus to prevent cortical drainage if subtotal occlusion occurred.

For transvenous placement of balloons, a 7-French catheter [†] was placed into the inferior petrosal sinus. A silicone balloon[§] was attached to a 2-French/4-French coaxial polyethylene catheter system and placed through the guiding 7-French catheter. The balloon was placed uninflated into the cavernous sinus and then inflated to produce occlusion. If in satisfactory position, the balloon was detached by traction or coaxial detachment. In all cases, a small catheter (4- or 5-French) was placed into the ipsilateral common or internal carotid artery for angiographic localization of fistula site and confirmation of fistula closure. The catheter was perfused with heparinized saline between injections.

All patients had angiography at the end of the procedure and follow-up angiography at 1- to 6-month intervals. A cure was defined as both clinical resolution of symptoms related to the fistula and angiographic obliteration. Improvement was defined as clinical improvement in all related symptoms and decrease in the flow within the fistula.

The patients' symptoms, ages, gender, location of and access to fistulas, embolic agent used, outcome, and complications are summarized in Table 1.

Results

Of the 14 patients treated by transvenous embolization, 11 were completely cured and one showed improvement. The follow-up period ranged from 2 months to 6 years, with a mean of 3 years. In the remaining two patients, complications precluded fistula closure. One patient fatally hemorrhaged before complete closure could be achieved and in the other, closure of the inferior petrosal sinus obliterated the transvenous pathway (see Table 1).

Twelve patients had a transfemoral venous approach via the inferior petrosal sinus only. One (case 10) was via a contralateral approach because the ipsilateral sinus was occluded. One patient was successfully treated through the superior ophthalmic vein. In one patient (case 9) a superior ophthalmic vein approach was unsuccessful owing to occlusion of the proximal vein; however, an inferior petrosal approach was successful in closing the fistula. In five patients the fistulas were treated with balloons alone, in four patients

only minicoils were used, three patients had both coils and liquid adhesives, one had balloons and coils, and one had balloons and liquid adhesives.

There were two complications related to transvenous embolization. The first, case 12, was a 62-year-old woman who developed a left CCF following removal of a renal cell carcinoma. A transarterial balloon embolization attempt failed because the size of the fistula orifice was smaller than the deflated balloon. The following day a transvenous approach through the inferior petrosal vein was attempted. A 5-French catheter was placed in the inferior petrosal sinus. A 3-French catheter with a 0.25-in. guidewire was placed into the petrosal vein but could not be negotiated into the cavernous sinus. The patient experienced severe neck pain during the procedure and a contrast injection demonstrated extravasation into the subarachnoid space. The 3-French catheter was immediately placed across the site of rupture and multiple minicoils were deposited at the site of rupture and in the inferior petrosal sinus. The patient's headache abated and she was taken to surgery where the cavernous sinus was directly punctured and several minicoils were placed into the sinus followed by a small injection of liquid adhesive. The patient recovered without deficit.

The second patient, case 4, suffered a fatal pontine hemorrhage following subtotal occlusion of the fistula with diversion of flow into cortical veins.

Representative Case Reports

Case 3 (Fig. 1) is a 73-year-old woman who fell, striking her occiput, and sustained a basal skull fracture. Two months later she developed a bruit and proptosis, and angiography revealed a left CCF (Fig. 1A). A transarterial balloon embolization attempt was unsuccessful because the orifice of the fistula was smaller than the diameter of the deflated balloon. From a transfemoral venous approach a catheter was navigated into the origin of the inferior petrosal sinus. A small, 3-French catheter was placed coaxially into the cavernous sinus (Figs. 1B and 1C). Several Gianturco minicoils were deposited into the cavernous sinus, decreasing the flow. A small injection of IBCA resulted in marked decreased flow in the fistula. An angiogram 1 month later revealed complete closure of the fistula (Fig. 1D).

Case 10 (Fig. 2) is a 33-year-old woman who sustained a gunshot injury to the left mandible. She subsequently developed proptosis, chemosis, severe unilateral headache, and diplopia. An angiogram (Fig. 2A) revealed a lobulated pseudoaneurysm of the ascending cervical carotid artery and a large CCF. Several transarterial embolization attempts were unsuccessful because of the narrowing and turbulence in the pseudoaneurysms. The predominant venous drainage was to the contralateral cavernous sinus through transsellar veins to the inferior petrosal sinus (Fig. 2B). The distal superior ophthalmic vein appeared attenuated. The ipsilateral inferior petrosal sinus was occluded. A small catheter was navigated from a transfemoral venous access into the contralateral inferior petrosal sinus and across the transsellar veins into the left cavernous sinus. Twenty-five gold and platinum wire coils were deposited at this location with marked decrease in the flow within the fistula. A subsequent transarterial embolization was successful because of the decreased flow and turbulence, which resulted in complete fistula obliteration (Fig. 2G).

Case 6 (Fig. 3) is a 29-year-old man who sustained a gunshot injury to the left carotid artery and developed a CCF with occlusion

TABLE 1: Summary of Transvenous CCFs

Patient No.	Major Symptoms	Age	Gender	Etiology	Side	Venous Access	Embolic Agent	Outcome/ Follow-up	Complication
1	Diplopia, headache	32	F	Trauma	R	SOV	Balloons	Cure/7 mos	None
2	Diplopia, bruit, headache	25	F	Trauma	R	IPS	Coils	Cure/4 yrs	None
3	Bruit, headache	73	F	Trauma	R	IPS	Coils, IBCA	Cure/3 yrs	None
4	Diplopia, proptosis, bruit	20	F	Ehlers-Danlos	L	IPS	Balloons	Pontine bleed	Death
5	Diplopia, headache, proptosis	45	F	Trauma	R	IPS	Coils, balloons	Cure/2 yrs	None
6	Headache, visual loss, proptosis	29	M	Trauma	L	IPS	Balloons, IBCA	Cure/2 yrs	None
7	Diplopia, proptosis, bruit	26	M	FMD	L	IPS	Balloons	Cure/1 yr	None
8	Visual loss, proptosis	19	F	Trauma	L	IPS	Balloons	Cure/4 yrs	None
9	Visual loss proptosis	63	M	Trauma	L	IPS, SOV	Balloons	Cure/2 yrs	None
10	Diplopia, headache, proptosis	33	F	Trauma	L	(R) IPS	Coils, IBCA	Improved/2 mos	None
11	Diplopia, headache, proptosis	19	M	Trauma	L	IPS	Coils	Cure/2 yrs	None
12	Proptosis, bruit, headache	62	F	Spontaneous	L	IPS	Coils	Venous rupture/ 2 yrs	Subarachnoid hemorrhage
13	Diplopia, proptosis, bruit	30	F	Trauma	R	IPS	Coils, IBCA	Cure/6 yrs	None
14	Visual loss, diplopia	62	F	Trauma	R	IPS	Coils	Cure/2 mos	None

Note.—R = right, L = left, FMD = fibromuscular dysplasia, SOV = superior ophthalmic vein, IPS = inferior petrosal sinus, IBCA = isobutyl-cyanoacrylate.

of the involved carotid artery (Figs. 3A–3D). The distal petrous carotid was reconstituted from collaterals through the vasa vasorum, but this pathway was too small for balloon navigation. Since a safe transarterial route was not available, a catheter was guided up the inferior petrosal sinus and balloons and liquid adhesives were deposited within the cavernous sinus with complete closure of the fistula. The superior ophthalmic vein approach was not used for several reasons: it requires surgical exposure and the severe tortuosity and kinking would increase the risk of rupture and retroorbital hemorrhage.

Case 4 (Fig. 4) is a 20-year-old woman with Ehlers-Danlos syndrome who developed a spontaneous left CCF. After the diagnostic angiogram the patient suffered massive hemorrhage from the femoral arterial puncture site as a result of her underlying vascular fragility. Because of the risk of arterial damage and hemorrhage associated with transarterial balloon embolization, a transvenous balloon embolization was performed. Following placement of several balloons within the cavernous sinus surrounding the carotid artery (Fig. 4A and 4B) there was decreased flow in the superior ophthalmic vein but increased flow into cortical veins. Forty-eight hours later the patient suffered a fatal pontine and subarachnoid hemorrhage. We presume that diversion of arterialized blood from the fistula into cortical veins was responsible for this devastating complication. Vas-

cular fragility associated with the patient's collagen deficiency disease may have increased this risk.

Discussion

Transarterial embolization has emerged as an effective treatment for carotid cavernous fistulas [10, 11]. In direct CCFs, a detachable balloon can often be placed through the fistula into the cavernous sinus, occluding the fistula with preservation of the parent carotid arterial flow. When the orifice of the fistula is smaller than the uninflated diameter of the balloon, transarterial balloon occlusion with preservation of the carotid artery is often difficult. If proximal carotid occlusion has occurred, a safe transarterial approach may be impossible. A transvenous approach may be effective in these circumstances but is not without risk. Although arterialization of venous structures can occur in long-standing shunts, the draining veins and dural sinuses are still thin-walled and can be perforated by catheter and guidewire manipulations. With the increased pressure and flow of the arterialized blood in
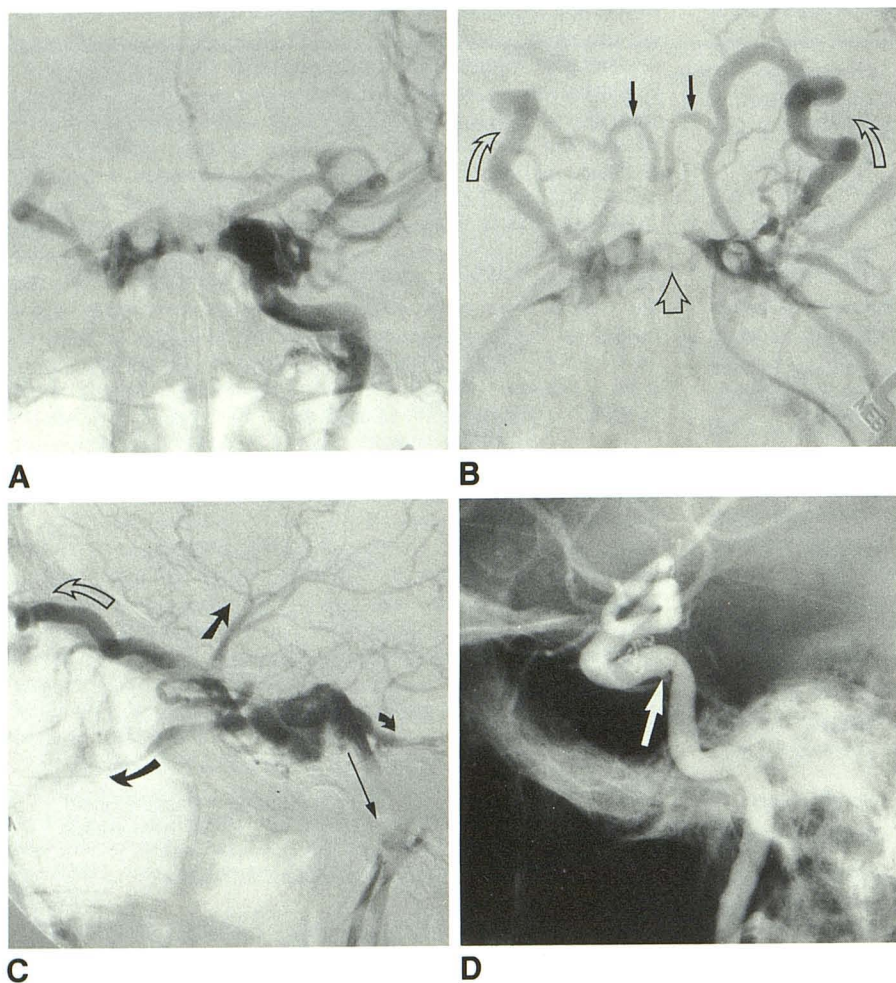
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Fig. 1.—Case 3: 73-year-old woman with head trauma.

A, Left internal carotid artery injection, antero-posterior view, shows carotid cavernous fistula with bilateral drainage. A transarterial approach failed because orifice of fistula was too small.

B, Left cavernous sinus injection, sella view, shows drainage to both superior ophthalmic veins (*curved arrows*) and midline connections at circular sinus (*open arrow*) and glabellar veins (*solid arrows*). Circular filling defects within cavernous sinus are unopacified cavernous carotid arteries.

C, Same injection, lateral view, shows drainage to superior (*curved open arrow*) and inferior (*curved closed arrow*) ophthalmic veins, cortical drainage via sphenoparietal sinus (*oblique solid arrow*), and inferior drainage through superior (*short curved arrow*) and inferior (*long thin arrow*) petrosal sinuses.

D, Postembolization left internal carotid artery injection, lateral view, shows complete closure of fistula by multiple minicoils. Small orifice of fistula is projected inferiorly (*arrow*).

these structures, small perforations can result in rapidly fatal subarachnoid hemorrhage. Shiu et al. [12] reported rupture of pontine veins during injection of contrast material for diagnostic cavernous sinography in a pituitary tumor. In case 12, perforation of the inferior petrosal sinus resulted in subarachnoid hemorrhage. The perforation was sealed within several seconds by advancing the catheter across the rent in the dura. Placement of minicoils across the rent closed the fistula but also the venous access. With the development of softer and smaller catheters and steerable guidewires, the risks of this occurrence can be greatly minimized.

Mullen [13] was the first to report transvenous occlusion of CCFs with closure in one of five patients. A nondetachable balloon was inserted from a jugular vein approach and buried in the soft tissues of the neck. Manelfe and Berenstein [14] treated a posterior draining fistula by a similar technique with a nondetachable Fogarty catheter. Debrun et al. [10] reported a transfemoral venous occlusion of a CCF with a detachable balloon. They noted that the percentage of success is low because partitions within the cavernous sinus preclude placement of the balloon near the fistula orifice. We, too, have experienced difficulty in reaching the orifice site with detachable balloons. If the posterior drainage is occluded without closure of the fistula, aggravation of ocular symptoms may

occur [15]. The development of steerable microcatheters and guidewires has allowed more precise placement of embolic agents within the cavernous sinus near the fistula orifice. Care must be taken to ensure that these embolic agents are not deposited within the carotid artery. If liquid adhesives are used, reflux into the carotid artery and devastating strokes can occur [10]. This risk increases when closure of the fistula is nearly complete and the pressure gradient between the carotid artery and cavernous sinus is lowered. Real-time digital subtraction and slow injections of small volumes of embolic material can avert this potential complication. In our series, either balloons or coils were first used to decrease the flow. If sufficiently slowed, small injections of IBCA were utilized to occlude the fistula.

When a fistula develops between the carotid artery and the cavernous sinus, the flow and pressure within the venous drainage pathways increase and there is reversal of flow within the normal tributaries to the cavernous sinus (Fig. 1). These venous drainage pathways enlarge to accommodate increased flow. Thrombosis can occur as a result of the inciting trauma, spontaneously [17] or as a result of diagnostic [18] or therapeutic intervention. Diversion of flow into the remaining venous pathways can result in alleviation or aggravation of symptoms and increase the morbidity and mortality

Fig. 2.—Case 10: 33-year-old woman with carotid cavernous fistula gunshot injury to left mandible.

A, Left internal carotid artery injection, lateral view, demonstrates a series of lobulated pseudoaneurysms (*horizontal arrows*) in ascending cervical carotid artery that prevented transarterial closure of large carotid cavernous fistula (*oblique arrows*).

B, Same injection, anteroposterior view, shows that ipsilateral inferior petrosal sinus is occluded and that venous drainage is via transsellar veins (*straight arrow*) to contralateral inferior petrosal sinus (*curved arrow*).

C and *D*, Plain films, sella projection (*C*) and lateral view (*D*), with catheter (*arrows*) coursing up inferior petrosal sinus across floor of sella to contralateral cavernous sinus to superior ophthalmic vein.

E and *F*, Cavernous sinus injection, lateral (*E*) and anteroposterior (*F*) projections, demonstrates superior ophthalmic vein drainage. Multiple platinum and gold wire emboli were deposited at this location with marked improvement of ocular symptoms. Catheter course is indicated by *arrows* and sella floor is indicated by *arrowheads*.

G, Postembolization common carotid angiogram, lateral view, shows occlusion of fistula. Ophthalmic artery fills carotid siphon by retrograde flow.
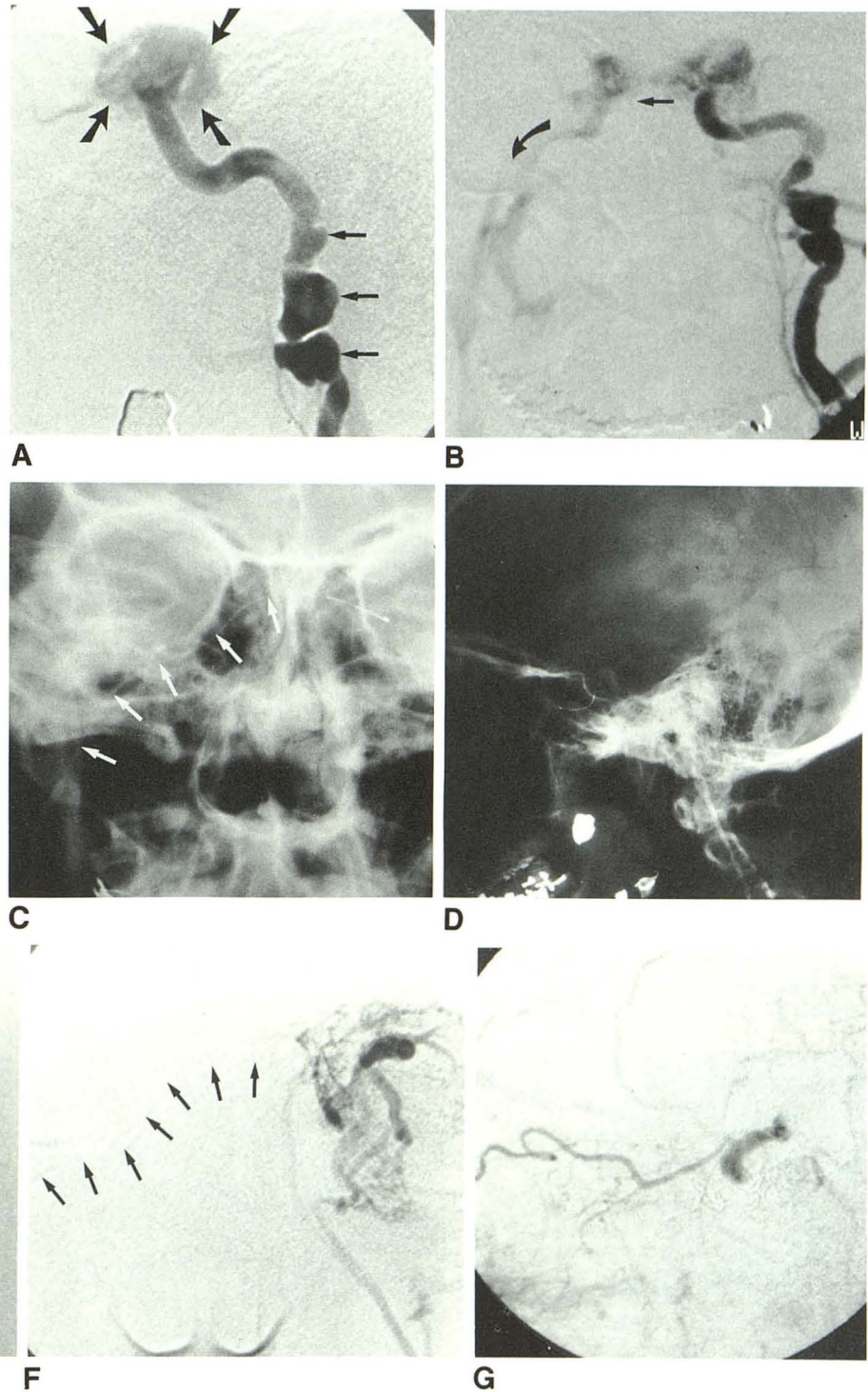
associated with the disease [19]. Diversion of flow into the superior ophthalmic vein may increase proptosis and visual loss. Cortical venous drainage is associated with an increased risk of intracerebral hemorrhage [20]. The fatality that occurred in this series was probably a result of diversion of arterialized fistula flow into cortical veins already compromised by a collagen deficiency disease. In one of the earliest cases, the risk of diversion of flow into cortical veins was not fully appreciated. Because of the difficulty in placing embolic material at the fistula orifice, transvenous treatments may increase fistula flow into remaining pathways. We now prefer to first occlude cerebral venous drainage to prevent hemorrhage.

Our current preferred method of treatment of symptomatic CCFs is transarterial balloon occlusion. If the orifice to the fistula is too small, a transarterial or transvenous approach
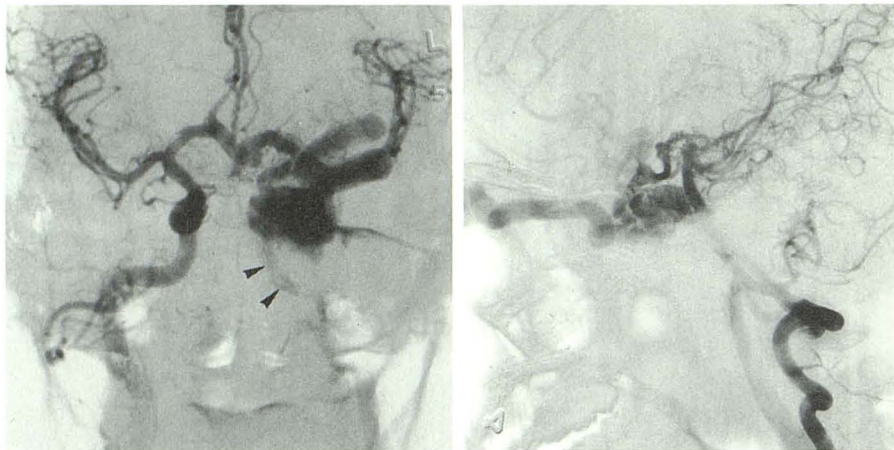
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Fig. 3.—Case 6: 29-year-old man with left carotid injury caused by gunshot injury.

A, Right common carotid artery injection, anteroposterior projection, shows filling of left carotid cavernous fistula from collaterals with retrograde flow in the involved supraclinoid carotid artery. Venous drainage is to superior ophthalmic vein to angular vein (*arrowheads*) and inferior petrosal sinus.

B, Left vertebral artery injection, preembolization, lateral view, shows filling of same fistula via posterior communicating artery.

C and *D*, Left common carotid artery injection, lateral (*C*) and anteroposterior (*D*) views, demonstrates occlusion of petrous internal carotid artery with supply to the fistula from hypertrophied vasa vasorum (*arrow*).

E, Right internal carotid angiogram, anteroposterior view, postembolization, demonstrates complete fistula closure.
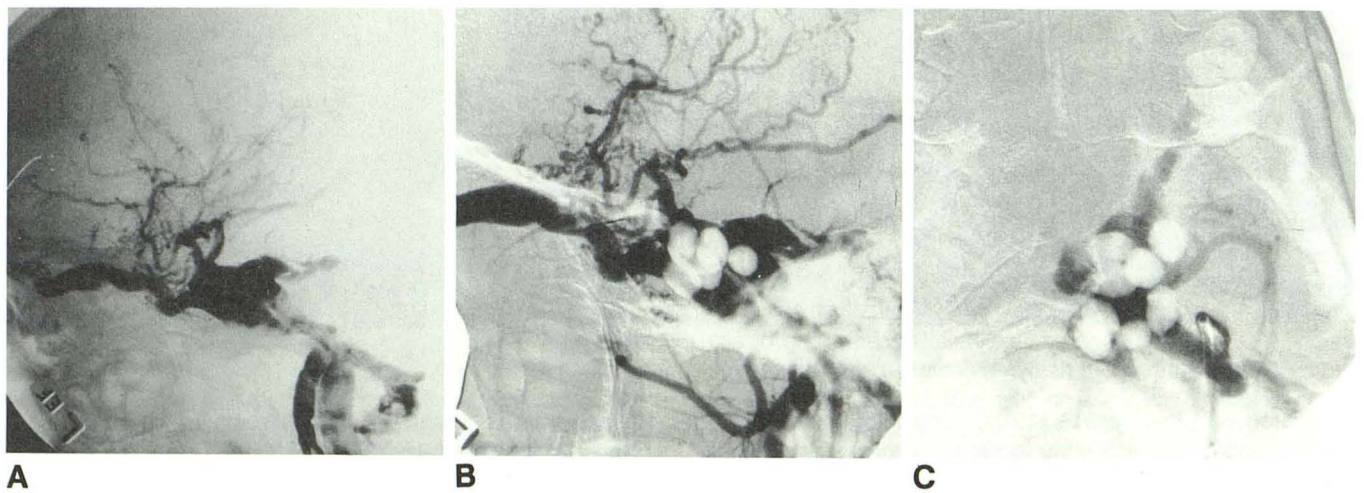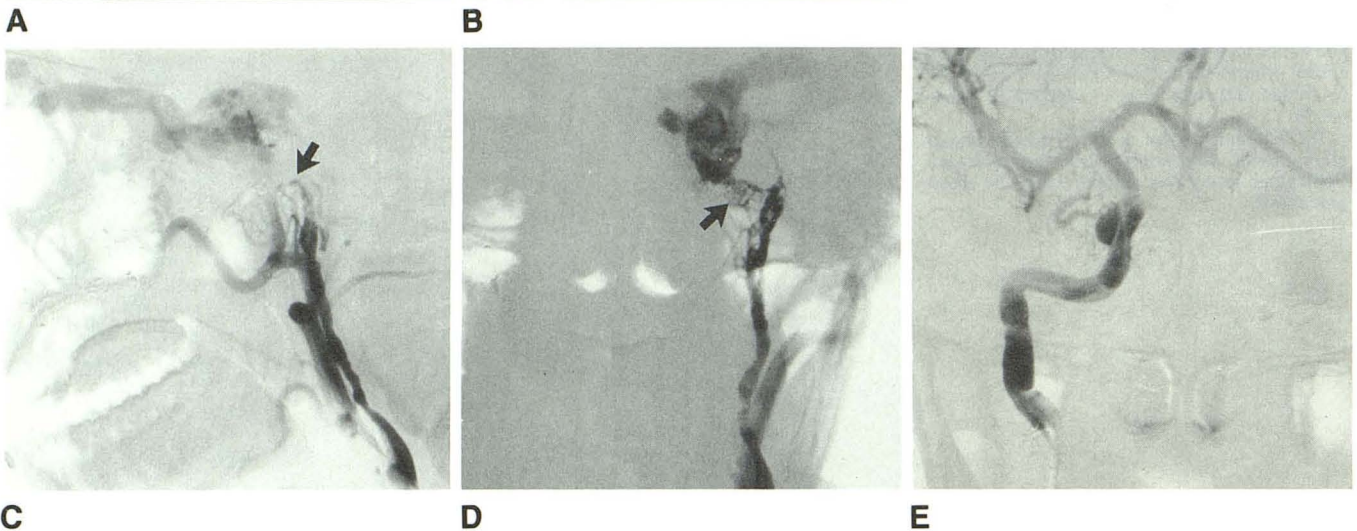

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Fig. 4.—Case 4: 20-year-old woman with Ehlers-Danlos syndrome who developed a spontaneous left carotid cavernous fistula.

A, Left internal carotid injection shows fistula with primary drainage to superior ophthalmic vein and inferior petrosal sinus.

B and *C*, Common carotid artery injection, lateral (*B*) and submental vertex (*C*) projections, after transvenous balloon placement through inferior petrosal sinus demonstrates subtotal occlusion of fistula with venous drainage to cortical and posterior fossa veins.

with a small-caliber catheter is our preferred second choice. If arterial access is difficult or impossible, then a transvenous approach is preferred. Because a direct connection exists between the carotid artery and cavernous sinus, care must be taken that embolic material (coils, glue) are not deposited into the carotid artery. We prefer to use the posterior approach through the inferior petrosal sinus to allow closure of the cortical pathways and reduce the risk of hemorrhage. Coils can be placed directly into the sphenoparietal sinus, occluding this intracranial pathway and preventing diversion of arterialized blood if subtotal occlusion is achieved. If the posterior drainage is closed, a contralateral inferior petrosal sinus or superior ophthalmic vein approach is used. Difficulty can be encountered in exposing the ophthalmic vein, and narrowing or kinking can prevent safe access to the cavernous sinus. More important, if the superior ophthalmic approach fails and the vein is occluded, fistula flow may be diverted into cortical veins, increasing the risk of hemorrhagic complications. In our experience, closure of the distal superior ophthalmic vein is often associated with severe aggravation of ocular symptoms if persistent fistula exists. Last, surgical exposure of the cavernous sinus and direct puncture with embolization remains an alternative when all other routes are impossible.

Transvenous embolization, while not our preferred access for the treatment of CCF, remains an alternative route if the arterial pathway is unsuccessful or inaccessible.

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