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*AJNR Am J Neuroradiol* 1991, 12 (3) 429-433

<http://www.ajnr.org/content/12/3/429>

This information is current as  
of April 9, 2024.

# Transarterial Platinum Coil Embolization of Carotid-Cavernous Fistulas

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Of the 227 embolization procedures performed by our neurointerventional section for symptomatic carotid-cavernous fistulas over the past 10 years, five involved placement of platinum coils in the cavernous sinus from a transarterial route. In four patients, prior transarterial balloon procedures had failed to produce fistula closure. In the fifth patient, with Ehlers-Danlos syndrome, a prior transvenous embolization attempt was unsuccessful. In three patients, complete closure of the carotid-cavernous fistula was achieved with preservation of the parent artery. In one patient, the earliest treated, a portion of a platinum coil projected through the fistula into the parent artery. To eliminate the risk of clot formation and distal embolization, internal carotid occlusion was performed and tolerated without deficits. In the last patient, closure of the anterior drainage was achieved, but complicated by distal migration of the platinum coils with transient aggravation of ocular symptoms. Attempts to occlude the remaining cortical drainage were unsuccessful with platinum coils; therefore, a balloon was used to obliterate the small remaining fistula.

Transarterial platinum coil embolization is an alternative treatment for symptomatic carotid-cavernous fistulas that cannot be closed successfully by other embolization techniques. The development of shorter, more thrombogenic, detachable or retrievable coils may make this technique more promising in the future.

*AJNR* 12:429-433, May/June 1991

Direct carotid-cavernous fistulas (CCFs) are usually solitary connections between the cavernous carotid artery and the cavernous sinus. They most often occur as the result of closed head injury associated with a basal skull fracture, but they also occur with penetrating trauma, collagen deficiency diseases, ruptured cavernous aneurysms, dissections, and iatrogenic injuries [1, 2].

The treatment of these connections has evolved over the past 40 years. The earliest treatments of proximal occlusion or trapping have largely been abandoned because of the high risk of stroke and blindness, often without obliterating the fistula [3, 4]. Prolo and Hanberry [5] described a technique involving the use of a fixed balloon to produce fistula and internal carotid closure. Serbinenko [6] and Debrun et al. [7] described techniques to close fistulas with detachable balloons, often with preservation of the internal carotid artery. Large series have shown the effectiveness of transarterial balloon embolization, which has emerged as the treatment of choice for this disease [7-10]. When transarterial routes are unsuccessful, transvenous embolization [7, 11, 12] or direct surgical exposure and embolization with copper wire [13, 14] or balloons [15] have been described. We describe our early experience with a new technique, transarterial embolization with platinum coils, in five patients with symptomatic CCFs.

## Methods and Representative Case Reports

Five patients with symptomatic CCFs were treated by transarterial placement of platinum coils into the draining venous compartments. Three of these patients had been treated

Received November 8, 1989; revision requested January 2, 1990; revision received December 17, 1990; accepted January 2, 1991.

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0195-6108/91/1203-0429

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unsuccessfully with transarterial balloon techniques; one patient underwent a failed attempt at transvenous embolization, and one patient underwent transarterial and transvenous embolization attempts, which both failed.

Following selective arteriography to delineate the fistula and draining venous pathways, systemic anticoagulation was achieved by administering an IV bolus of heparin (70 units/kg). Following confirmation of the heparin effect with an activated clotting time device (Hemochron), a 5.5-French polyethylene catheter (Cook, Inc., Bloomington, IN) was placed into the proximal internal carotid artery. A 3.2-French Tracker catheter with a 0.016-in. flex tip wire (both from Target Therapeutics, San Jose, CA) were navigated via road-mapping techniques (Diasonic, Inc., Salt Lake City, UT) across the fistula site into the cavernous sinus. The spaces between the platinum guidewire and Tracker, as well as the spaces between the two catheters, were perfused continuously with heparinized saline. Selective angiograms were obtained through the Tracker catheter once it was positioned in the cavernous sinus. In one instance, case 5, a nondetachable balloon assisted in placement of the Tracker catheter into the cavernous sinus.

### Case 3

This patient is a 40-year-old woman with Ehlers-Danlos syndrome who spontaneously developed a right carotid cavernous fistula (Figs. 1A and 1B). Because of the risk of arterial damage and external hemorrhage associated with the use of large-caliber arterial balloon

delivery catheters, a transvenous embolization was attempted. The cavernous sinus could not be reached from the posterior route owing to a constriction in the inferior petrosal sinus. A Tracker catheter was therefore navigated through the ectatic internal carotid artery across the fistula and positioned in the posterior superior ophthalmic vein. Multiple prototype helical platinum coils (Target Therapeutics) were positioned in the posterior superior ophthalmic vein without significant reduction in flow. Short pieces of silk suture were then injected through the Tracker just proximal to the coils to entangle with the platinum coils. Just as the fistula was nearing closure, the silk suture enmeshed with platinum coils migrated distally to the anterior (proximal) superior ophthalmic vein. The patient developed immediate orbital pain, rapidly increasing proptosis, and visual loss secondary to occlusion of the outflow of the fistula distal to orbital venous drainage. Additional coils were immediately positioned at the original site and entangled with more silk suture. The patient's ocular symptoms stabilized, the pain resolved, and the vision returned to normal. A repeat angiogram demonstrated markedly decreased flow to the superior ophthalmic vein but diversion of flow into the cortical veins (Fig. 1C). The Tracker catheter could not be navigated selectively into the sphenoparietal sinus nor could a safe position be found near the fistula orifice to safely deliver additional coils. A detachable balloon was therefore positioned near the fistula orifice within the cavernous sinus and detached, providing complete closure (Fig. 1D). The patient's ocular symptoms resolved completely, but she died 8 months later from complications relating to a bowel perforation, a known complication of Ehlers-Danlos syndrome.

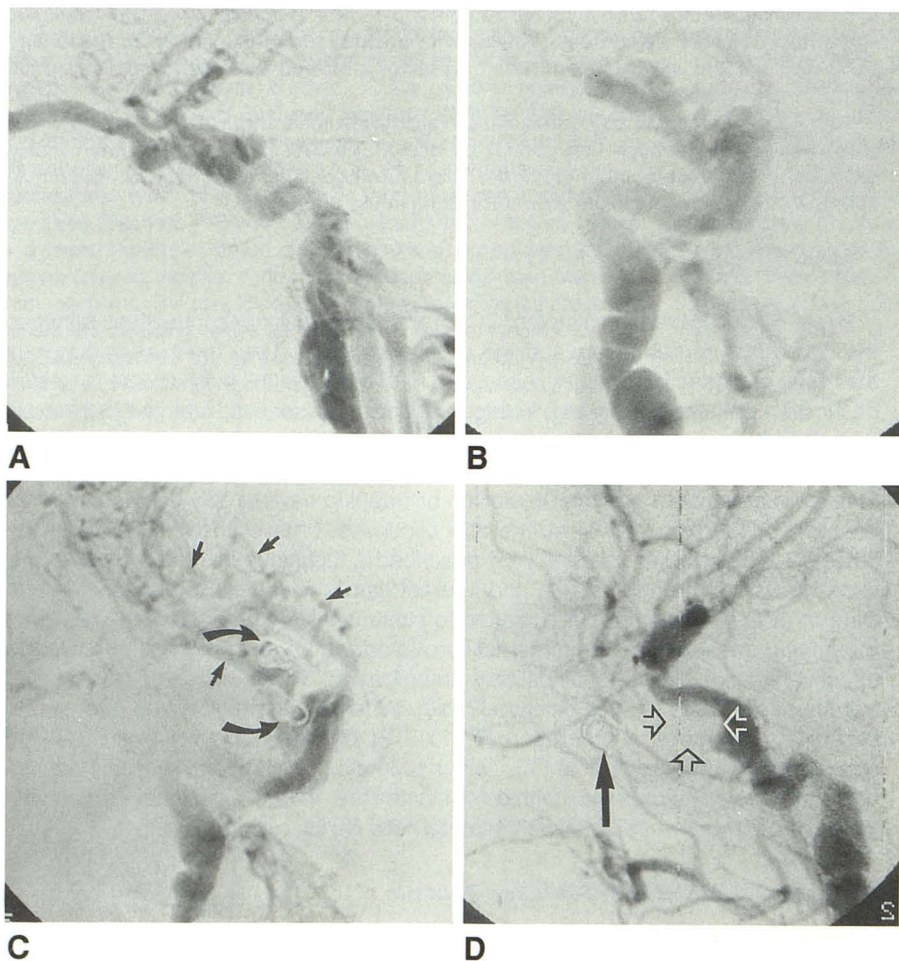
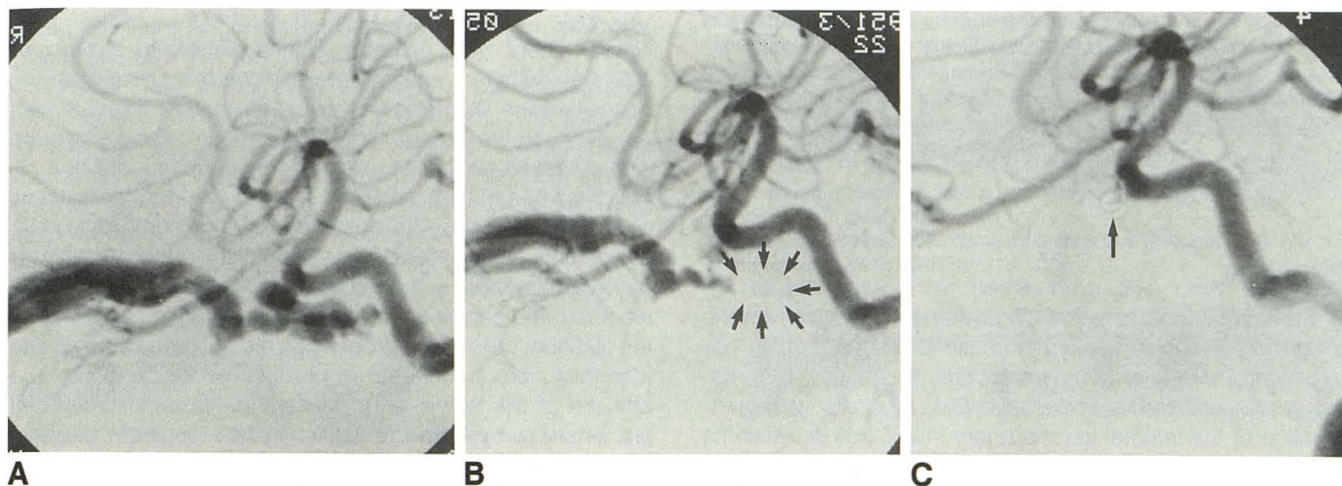


Fig. 1.—Case 3: 40-year-old woman with Ehlers-Danlos syndrome.

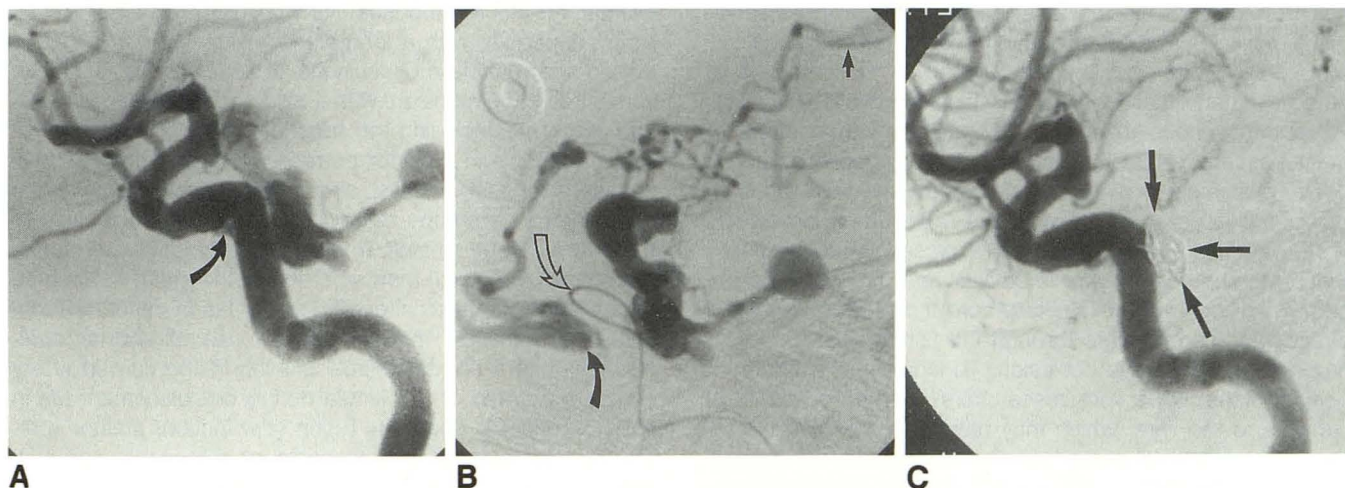
A and B, Right internal carotid angiogram, lateral (A) and anteroposterior (B) projections, shows lobulated ectasia of the distal internal carotid artery and a carotid cavernous fistula draining anteriorly to the superior ophthalmic vein and posteriorly to the inferior petrosal sinus. A transvenous embolization was unsuccessful owing to narrowing of the inferior petrosal sinus drainage.

C, Right internal carotid angiogram, anteroposterior projection, following coil (curved arrows) and silk suture embolization of the proximal and distal superior ophthalmic vein, shows diminished drainage to the eye but diversion of flow into intracerebral veins (straight arrows).

D, Right common carotid angiogram, lateral projection, following platinum coil (long arrow) and detachable balloon (short arrows) embolization, shows complete closure of fistula with preservation of internal carotid artery.



**Fig. 2.**—Case 4: 37-year-old man with large carotid cavernous fistula resulting from motor vehicle accident.  
**A**, Right internal carotid injection, lateral projection, shows carotid cavernous fistula arising from anterior inferior carotid siphon, with drainage to the superior ophthalmic vein.  
**B**, Same injection and projection as **A**, following balloon embolization (arrows), shows occlusion of the posterior compartment. Additional balloons could not be navigated into the fistula site.  
**C**, Same injection and projection as **A** and **B**, following platinum coil placement in fistula site (arrow), shows complete fistula obliteration.



**Fig. 3.**—Case 5: 72-year-old woman with basal skull fracture resulting from a fall.  
**A**, Left internal carotid angiogram, lateral projection, shows a direct carotid cavernous fistula arising from proximal portion of cavernous internal carotid artery (arrow) with posterior cortical drainage.  
**B**, Selective Tracker injection of proximal drainage pathway shows cortical drainage with collaterals to the vein of Galen (small straight arrow) and superior ophthalmic vein (curved closed arrow). Note the acute angle the catheter makes to enter the fistula (curved open arrow).  
**C**, Same injection and projection as **A**, following embolization, shows complete obliteration of the fistula by multiple platinum coils (arrows).

#### Case 4

This patient is a 37-year-old man who developed a large CCF following a motor vehicle accident. The venous drainage anteriorly to the superior ophthalmic vein produced severe proptosis and visual loss (Fig. 2A). A detachable balloon was positioned at the fistula site and detached, but migrated into the posterior cavernous sinus. Additional attempts at fistula closure with a balloon were unsuccessful (Fig. 2B). A series of coils was positioned at the fistula site, producing complete fistula closure, which was confirmed by a follow-up angiogram (Fig. 2C).

#### Case 5

This patient is a 72-year-old woman who sustained a basal skull fracture as a result of a fall. She reported a bruit over the next 2 years and then developed a posterior fossa hemorrhage. Arteriography revealed a direct CCF arising from the interior posterior aspect of the proximal horizontal segment of the cavernous portion of the internal carotid artery draining exclusively to posterior fossa veins (Fig. 3A). A detachable balloon could be made to enter the fistula orifice but could not be navigated into the cavernous sinus. A Tracker catheter with a C curve in the distal segment could engage the orifice

but could not be advanced into the draining vein. A nondetachable balloon was positioned distal to the fistula orifice and transiently inflated while a Tracker catheter bounced off the balloon into the fistula site and into the draining vein (Fig. 3B). Multiple platinum coils were placed in the proximal draining vein along with short segments of silk suture, producing fistula closure, which was confirmed by a follow-up arteriogram (Fig. 3C).

## Discussion

Transarterial balloon embolization has emerged as the treatment of choice for symptomatic CCFs [6, 10]. In our experience with over 200 symptomatic traumatic CCFs, the fistula was completely occluded in 99% of cases with preservation of the internal carotid artery in 88% of the patients [10]. Balloons can usually be flow directed across the fistula into the cavernous sinus and inflated to produce fistula obliteration. The balloon can be inflated to a volume larger than the fistula to preclude balloon migration back into the carotid artery. Rarely, transarterial embolization is unsuccessful: the fistula orifice may be too small to allow entry, the venous compartment may be too small to allow balloon inflation (as in cases 2, 4, and 5), or sharp objects (bone fracture fragments, foreign objects) may puncture the balloon during inflation. In some patients who have had prior balloon embolization with subtotal occlusion, navigation of additional balloons into the fistula is often unsuccessful owing to the presence of embolic material (balloons) partially blocking the fistula orifice. While transvenous techniques [11, 12] can treat some of these patients, venous routes are not always accessible.

The placement of wire coils into the cavernous sinus to produce closure of a CCF was first reported by Hosobuchi [13], who used small copper wire placed intraoperatively. Since the fine copper wire is smaller than the resolution of current intraoperative X-ray equipment, it cannot be visualized directly and can herniate through the fistula site, producing embolization or carotid occlusion. To increase the thrombogenicity of the copper wire, researchers have applied electrical currents to the wire, which may have been responsible for the transient cranial nerve deficits resulting from this treatment. Over the past 3 years, we have treated over 60 patients with neurovascular disorders by delivering platinum coils through small microcatheters [16–19]. Five of these patients had symptomatic CCFs, and all had undergone more traditional embolization techniques, which were unsuccessful. Our earliest platinum coil emboli [16] consisted of the cut ends of steerable microguidewires. These emboli were difficult to shape, would sometimes become impacted in the microcatheter (due to frayed severed ends or overlap with the pushing wire), and were not very thrombogenic. Subsequently, prototype coils have been designed of both platinum and gold materials in a variety of shapes (helical, floral, straight, and curved) and sizes. The recent addition of Dacron fibers to some coils has been advantageous by producing a more thrombogenic device. The development of a specialized pushing wire with a Teflon tip has minimized jamming of coils in the catheter and greatly reduced the risk of proximal migration of coil emboli during placement. Complete fistula closure was achieved with these advanced coils in cases 2, 4, and 5.

In case 1, treated in 1987, only straight platinum coils without fibers were available. During placement of the final coil, the catheter recoiled into the internal carotid artery, depositing the tip of the coil within the parent artery lumen. To eliminate the risk of emboli formation, carotid occlusion with detachable balloons was performed without deficit.

In case 3, a patient with Ehlers-Danlos syndrome, platinum coils were placed in the posterior superior ophthalmic vein, adjacent to the superior orbital fissure. While placement closer to the fistula orifice is more desirable, the risk of coil displacement into the parent artery was considered high. In addition, the platinum coils of the proper size did not contain fibers and therefore were inadequate to produce occlusion alone. The addition of silk suture to produce thrombosis necessitated placement away from the fistula orifice to prevent the non-opaque silk suture from entering the parent artery. Unfortunately, the pulsations of the nearly closed fistula were sufficient to produce distal migration of the coil/silk suture mass, resulting in an ocular emergency. Possible contributing factors that resulted in coil migration include the decreased tensile strength of the superior ophthalmic vein in a patient with a collagen deficiency disease as well as the increasing diameter as the vein courses more anteriorly.

Closure of carotid cavernous fistulas with platinum coils from an arterial route poses many problems. The cavernous sinus, especially with a long-standing fistula, may be quite dilated and variable in dimensions. In addition, the fistula can immediately communicate with a wide variety of venous drainage pathways, including the superior and inferior ophthalmic veins, inferior and superior petrosal sinuses, sphenoparietal and sphenobasal sinuses, and midline connections to the contralateral cavernous sinus. Closure of the fistula close to the orifice can be difficult. If the microcatheter recoils during placement of the coil, then a portion or the entire coil can be deposited in the internal carotid artery (as in case 1). Techniques to minimize this include the use of shorter coils, placement of a nondetachable balloon in the carotid artery across the origin of the fistula during coil placement (as in case 5), and the use of a Teflon (low-friction) pusher wire. The development of a detachable or retrievable coil may reduce this risk. An alternative to closing the fistula orifice is to occlude the proximal draining pathways (as in cases 2, 3, and 5). This was successful in cases 2 and 5 but unsuccessful in case 3 because of the inability to selectively catheterize the sphenoparietal sinus.

Occlusion of one venous outflow can redirect the flow into the remaining pathways, causing aggravation of ocular symptoms (superior ophthalmic vein) or hemorrhage (cortical drainage). Fortunately, in case 3, the remaining venous compartment was large enough to allow placement of a balloon to eliminate the remaining drainage. Another unique problem in occluding a draining venous pathway is the high compliance of a vein or sinus, which can allow dilatation and subsequent migration of emboli. The soft platinum coils exert little force on the surrounding structures and therefore could be displaced in a high-flow fistula. Proper sizing of a coil is essential, too small a coil would embolize distally and too large a coil would fail to assume its desired configuration and not produce the desired occlusion. The superior ophthalmic vein dilates

anteriorly, thereby increasing the risk of migration of emboli placed posteriorly in this structure.

Despite these drawbacks, transarterial coil embolization may play an important role in the management of symptomatic fistulas that fail to respond to or are poor candidates for traditional embolization techniques. The development of shorter, more thrombogenic, retrievable or detachable coils such as the prototype electrothrombosis coils (Guglielmi G, et al. Paper presented at annual meeting of American Society of Neuroradiology, Los Angeles, March 1990) may make this a safer technique in the future.

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