Percutaneous Transvenous Embolization of Intracranial Dural Arteriovenous Fistulas with Detachable Coils and/or in Combination with Onyx

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Key words: arteriovenous fistula, cavernous sinus, dural arteriovenous malformation, transvenous embolization

Summary

This study evaluated angiographic and clinical results in patients with a dural arteriovenous fistula (DAVF) who underwent percutaneous transvenous embolization.

Retrospective chart analysis and radiographic studies were performed in 23 patients (aged 11-70 yrs) with a DAVF treated with percutaneous transvenous embolization in the past five years. Lesions were located in the anterior cranial fossa, cerebellar tentorium, transverse-sigmoid sinus and cavernous sinus. All procedures were analyzed with regard to presentation, delivery, angiographical and clinical outcome.

Data for 23 patients (age range, 11-70 yrs, mean age 49.5yrs) with DAVFs (cavernous sinus[CS], n=17; transverse-sigmoid sinus, n=3; anterior cranial fossa, n=2; cerebellar tentorium, n=1) were retrospectively reviewed. The DAVFs were treated with coils or a combination with Onyx via different transvenous approaches, in 28 procedures. Cerebral angiography was performed to confirm the treatment.

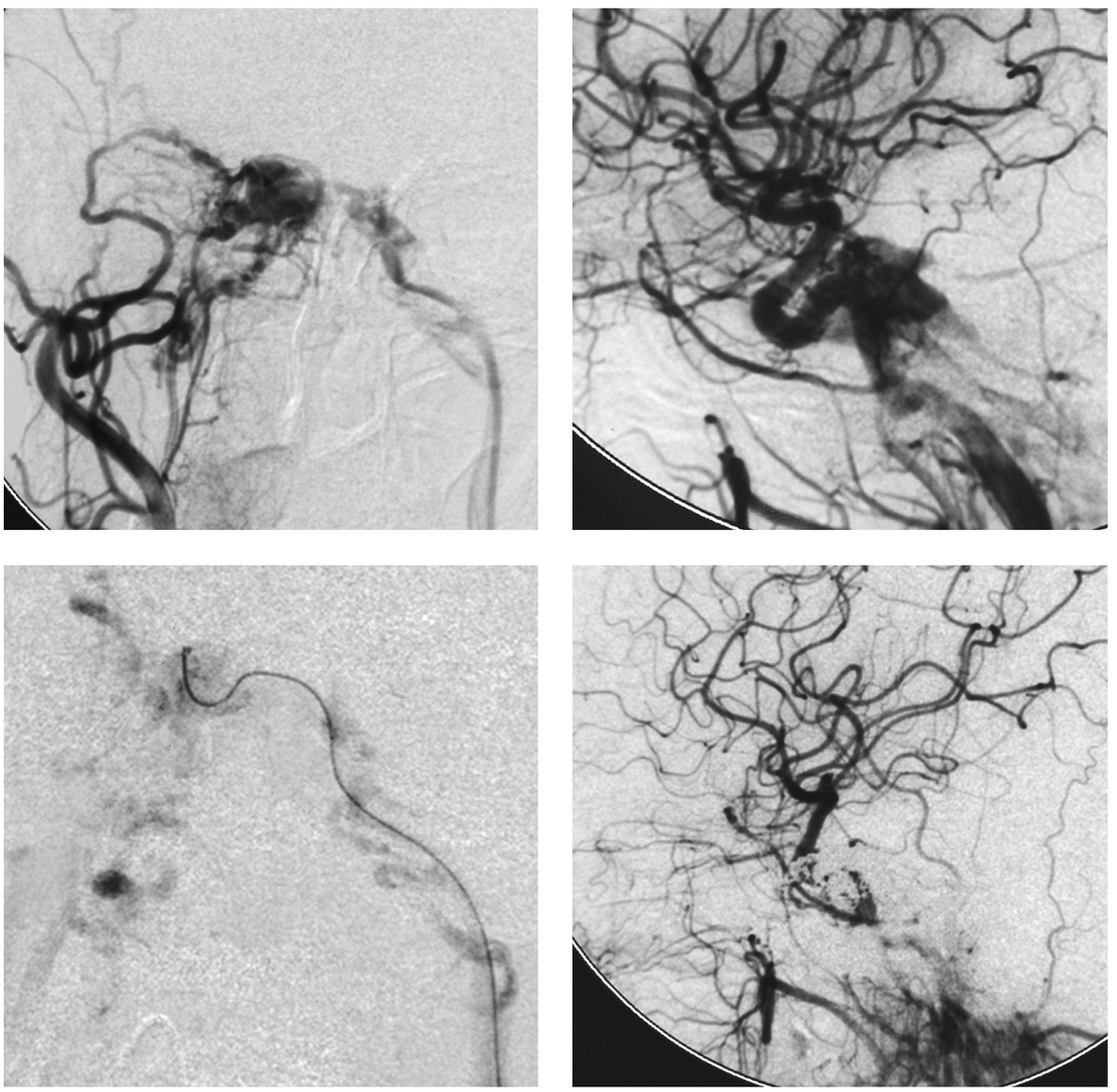
The mean clinical follow-up period was 22.1 months.

Transvenous treatment of intracranial DAVFs can be safe and effective if various transvenous approaches are attempted. Percutaneous transvenous embolization with detachable platinum coils or a combination with Onyx is effective in the treatment of DAVFs.

Introduction

DAVFs represent 10 to 15% of intracranial arteriovenous malformations [46,48,56]. Their classification is determined on the basis of the arterial supply or the venous drainage pattern [46,48,53,56]. Carotid cavernous fistulae (CCFs) are classified as direct (Barrow Type A) fistulae, which are often posttraumatic high-flow shunts between the cavernous portion of the internal carotid artery (ICA) and the cavernous sinus (CS), or indirect dural fistulae (Barrow Type B-D). Multiple arterial feeders arise from the ICA (Barrow Type B), the external carotid artery (ECA) (Barrow Type C), or both (Barrow Type D), with numerous microfistulae within the sinus wall [4]. Recently published classifications of DAVFs (e.g., Cognard's classification) are based on the pattern of drainage for estimation of bleeding risks [8]. Depending on the DAVFs location and the venous drainage, clinical presentations range from asymptomatic to symptomatic [1,7,15,16,26,36,38], with pulse-synchronous bruit, headaches, neurological deficits, venous hypertensive encephalopathy with dementia, or intracranial hemorrhage resulting from venous hypertension.

The decision to treat is based on the venous drainage pattern, the natural history of the lesion, the severity of presenting symptoms, the patient's general condition, angiographic features, the location of the DAVF, and the mor-



bidity and mortality rates of the procedure being considered. The goals of treatment are the prevention of risks and the elimination of symptoms caused by the arteriovenous shunt. Because of the bleeding risk, intracranial DAVFs with retrograde cortical drainage often require an anatomic cure. They can be treated with different modalities, such as endovascular procedures with transvenous and transarterial [1,11,17,19-25,33,35,37,42,43,49-57], surgery [7,10,12,13,16,18,29,41,55,58], gamma knife surgery [39,40,44,45,51], or combinations of the three [15,30,31,33]; in selected cases, the lesions can be treated conservatively [22].

Transvenous embolization with coils has become the standard treatment for DAVFs [27,47,48]. Today, transarterial Onyx embolization has been used preoperatively or as additional therapy to prompt the cure rate. This study presents our experience of different transvenous embolization techniques for the treatment of intracranial DAVFs and transvenous administration of Onyx.

Patient and Methods

Between February 2003 and February 2008, 23 patients (nine females, 14 males) with DAVFs involving the anterior cranial fossa

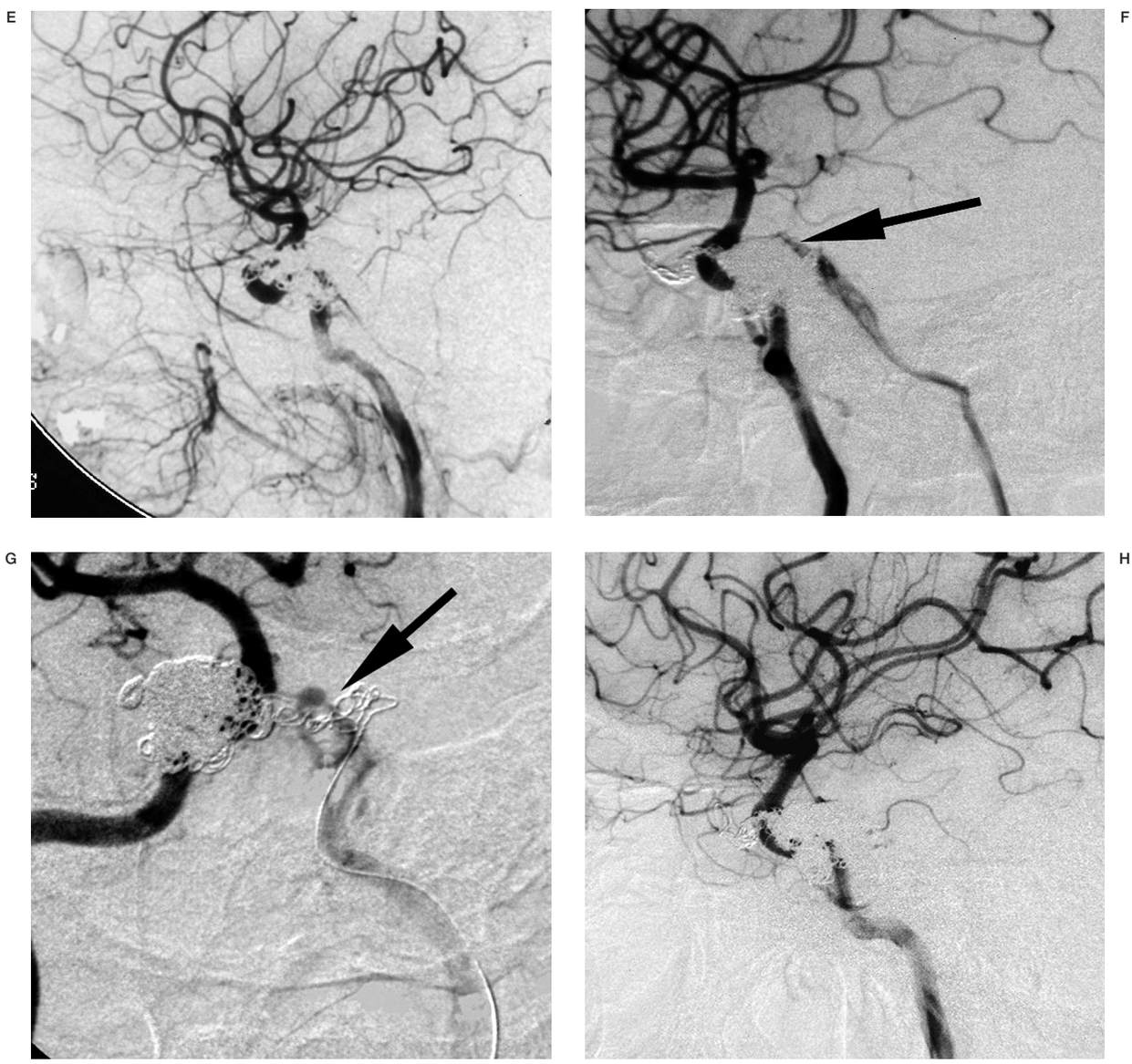
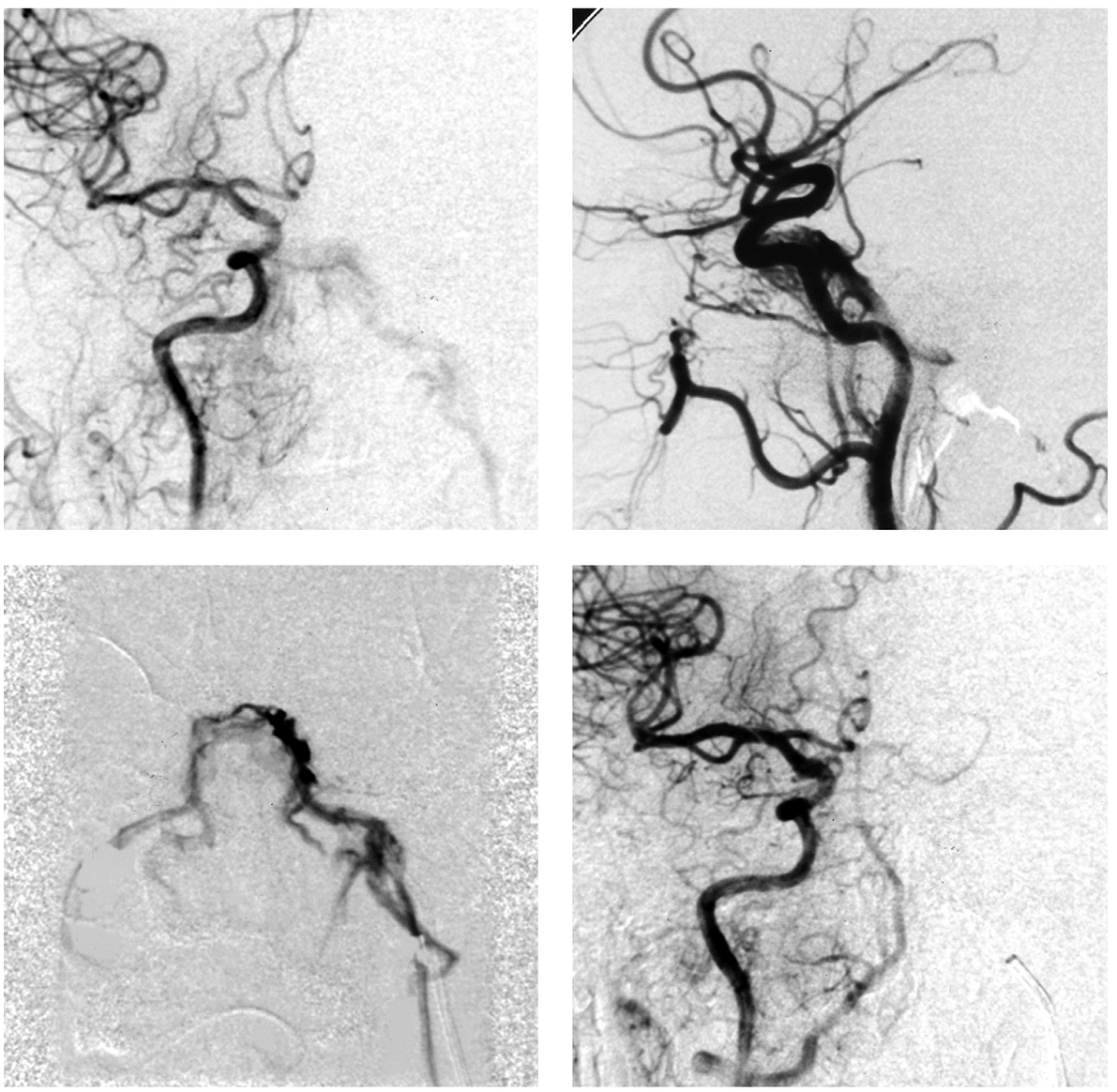


Figure 1 Patient 9, a 44-year-old woman demonstrated a cavernous DAVF of Barrow Type D/Cognard Type IIa. Right CCA angiogram, anteroposterior projection (A), left CCA angiogram, lateral projection (B) showing a CDAVF fed by both internal and external carotid arteries, mainly drained to the left InfPS and the right SOV. Frontal superselective angiogram of the right CS (C) showing the microcatheter positioned close to the fistula site. After embolization, anterograms of the right common carotid artery (lateral view, D) and left common carotid artery (lateral view, E) demonstrating complete occlusion of the fistula. F) Six months later, lateral angiogram of the right ICA showing persistent filling of the residual fistula (arrow). G) Occlusion of the intercavernous sinus (arrow) with several standard coils. H) Arteriogram of the right ICA (lateral view) after complete embolization of the right-side fistula.

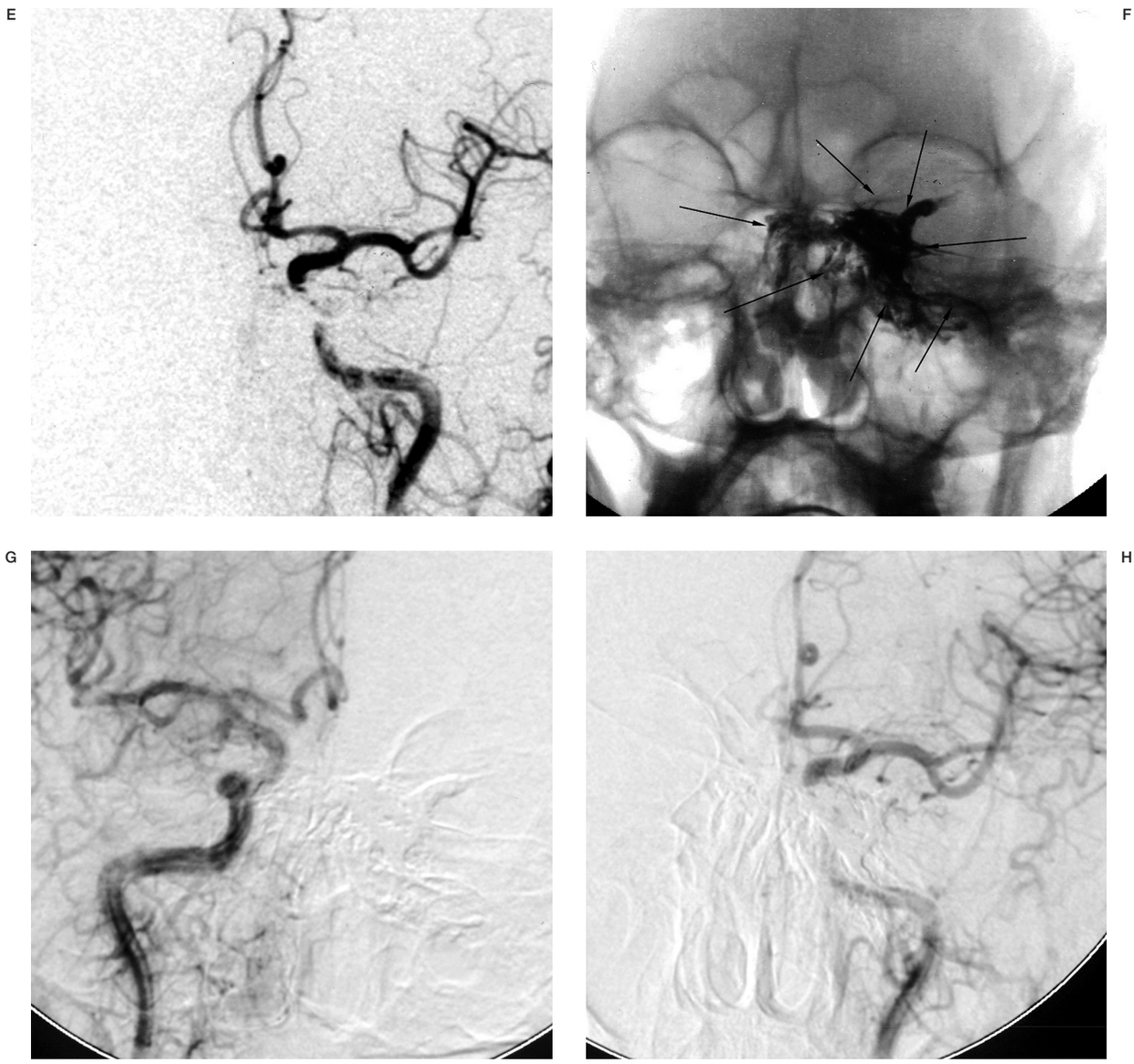
(ACF), cerebellar tentorium, transverse-sigmoid sinus (TSS) and cavernous sinus (CS) were treated by percutaneous transvenous embolization at Beijing Tiantan Hosptial. Symptoms, locations of DAVFs, and access routes of venous embolization in each case are presented in Tables 1 and 2.

Bilateral selective ICA and ECA angiography and vertebral artery angiography were performed for all patients, for assessment of the feeding arteries, fistula sites and venous drainage. The arteriovenous shunts were approached via the venous route. We first placed 6-French sheaths in the femoral artery and



vein. A 5-French catheter in the carotid artery allowed observation of the shunt, acquisition of roadmaps, and angiographic monitoring of the procedure. A second 5-French catheter was placed in the jugular vein. A microcatheter (Marathon/Echelon, MTI-EV3, Irvine, CA, USA) was navigated coaxially via different venous approaches. The microguidewire (Mirage/Silverspeed 10, MTI-EV3, Irvine, CA, USA; Transend 0.014, Boston Scientific, USA) was then carefully introduced and advanced to the fistula portion, followed by the microcatheter. Subsequently, the draining vein or sinus was packed using detachable platinum coils or a combination with Onyx, using real-time digital subtraction fluoroscopic mapping.

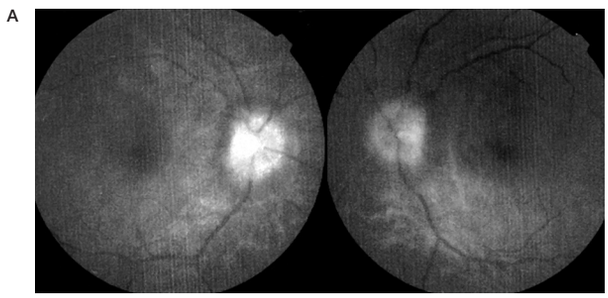
Seventeen patients (nine female and eight male patients; age range, 11-69 yrs, mean age 47.6 yrs) presented with spontaneous DAVFs of the CS of Barrow Types D. Symptoms included chemosis and proptosis (n=12), pulsatile tinnitus (n=9), VI cranial palsy (n=5), III cranial nerve palsy (n=3), blurred vision (n=1). According to the classification described by Cognard et Al[21], the 17 CDAVFs were Type II (n=14) and Type III (n=3). Nine patients underwent angiographic follow-up (range three to eight months; mean 6.3 months). The ratio-

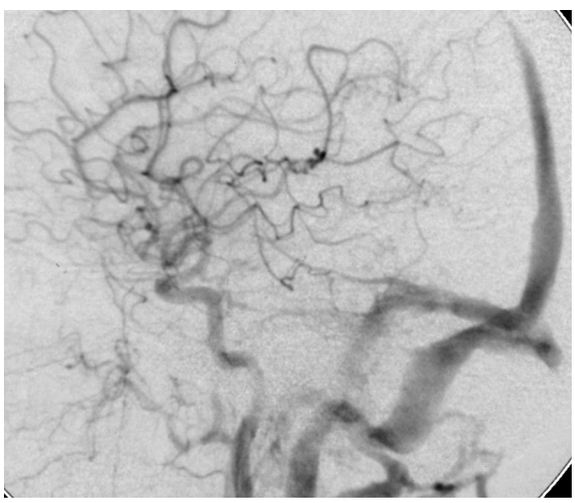


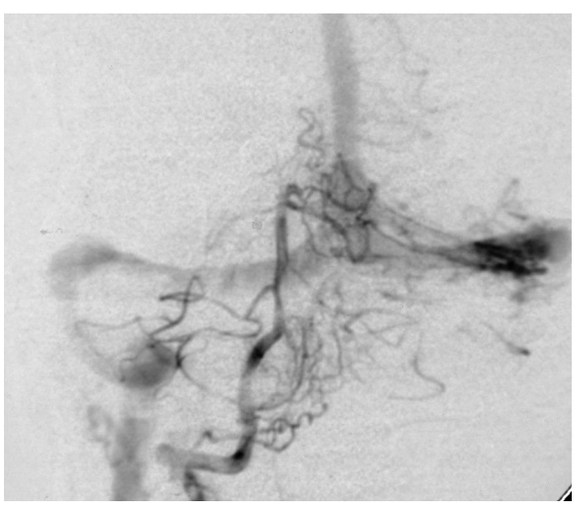
nale for not requiring angiographic follow-up was clinical cure (without any symptoms). Clinical follow-up status was supplemented by telephone interviews and follow-up periods ranged from two to 62 months (mean 25.3 months).

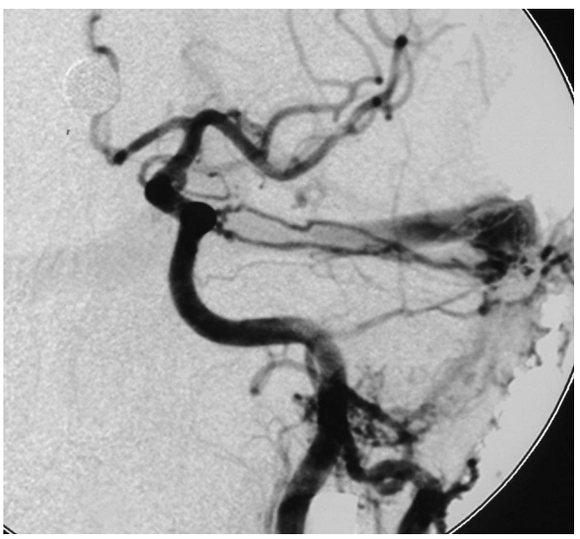
Six male patients (age range 40-70 yrs; mean age 54.8 yrs) demonstrated DAVFs located in TSS (n=3), ACF (n=2) and cerebellar tentorium (n=1). Symptoms included headaches (n=3), pulsatile tinnitus (n=2), seizure (n=1), visual disturbances (n=1), dementia (n=1), and SAH (n=1). According to the classification described by Cognard et Al [21], the DAVFs were of Type IIa (n=2), Type II[a]+b (n=1), Type III (n=2) and Type

Figure 2 Patient 12, a 54-year-old man with a Barrow Type D/Cognard Type IIa DAVF. Right common carotid artery (CCA) angiogram, anteroposterior projection (A), left CCA angiogram, anteroposterior projection (B) showing a DAVF fed by both internal carotid arteries, mainly drained to the left inferior petrosal sinus and the left superior ophthalmic vein. Superselective angiogram (C) showing the tip of microcatheter in the left cavernous sinus. Right CCA angiogram, anteroposterior projection (D) and left CCA angiogram, anteroposterior projedtion (E) after embolization showing the DAVF is completely occluded. Skull X-ray film (F) after embolization, anteroposterior projection, showing the left CS and paracavernous sinuses were completely occluded (arrows). Seven months later, control angiograms of the right CCA (anteroposterior view, G) and left CCA (H), demonstrating no recanalization of the fistula points.









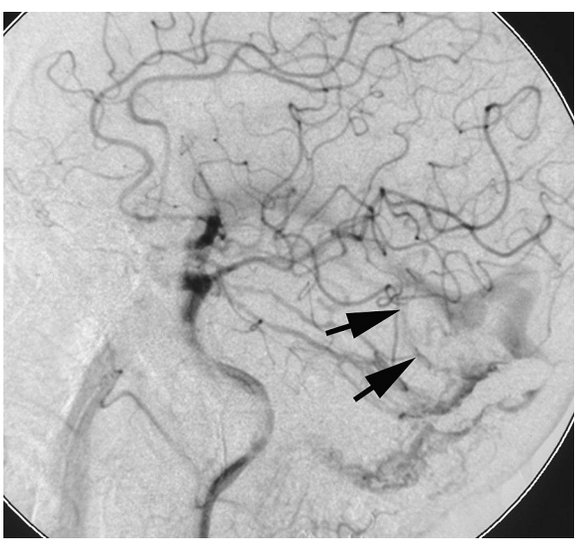


Figure 3 Patient 23, a 56-year-old man with a left Cognard Type IIa DAVF, with SSS reflux. A) An ophthalmological examination revealed bilateral papilledema. B) Arteriogram of the left CCA (arterial phase, lateral view), showing multiple feeders arising from the ICA and ECA. C) Arteriogram of the right VA (arterial phase, frontal view), showing multiple feeders arising from the VA. D) The microcatheter was navigated into the left TSS via the right IJV-TSS. E,F) Arteriograms (lateral view) of the left common carotid artery (E) and left VA. The residual fistula was Cognard Type I with parallel venous channel was coiled and the parent sinus was patent, with preservation of the venous outflow (arrows) of the temporal lobe through the vein of Labbe.

IV (n=1). The fistulae were spontaneous. Clinical follow-up periods for this group ranged from two to 36 months (mean, 13 months).

Results

Twenty-three patients with DAVFs were reviewed in this series. Twenty-one DAVFs were completely embolized with detachable platinum coils or a combination with Onyx. The clinical data, and the angiographic results are summarized in Tables 1 and 2.

Transvenous embolization of the CS.

Twenty-two transvenous and two transarterial approaches were performed for the group of 17 DAVFs of the CS. Sixteen patients with DAVFs were initially treated with a transvenous route while one patient was treated with a transarterial route first. If the drainage was to the ipsilateral CS and/or predominantly posteriorly, then we first approached via the internal jugular vein (IJV)-inferior petrosal sinus (InfPS)-CS (n=13). If the InfPS could be passed (n=13), then the success rate was high, with complete occlusion in 16 cases. The more invasive direct SOV approach was chosen only if alternative endovascular transvenous routes had failed (one out of 17 cases) to yield complete occlusion of the fistula. The transvenous approach via the facial vein (FV) was possible in two cases with complete occlusion of the fistula. An alternative approach via the superior petrosal sinus was performed in one case but failed.

Follow-up outcome

Sixteen of the 17 DAVFs (94.1%) of the CS were cured anatomically and clinically. One patient (5.9%) with initial left VIth cranial nerve palsy did not completely resolve and developed brain infarction at 30-month follow-up. We encountered complications in five cases (29.4%): one patient developed local alopecia on the right side due to X-ray radiation, two patients developed reflexive bradyarrythmia and two patients demonstrated CNVI palsy after transvenous treatment. Angiographic follow-up (4-7 months; mean five months) was obtained in six patients. There was one recanalization in one patient; additional coil embolization was performed in five patients with residual fistulae. Residual aneurysm resolved in four patients with one failure.

Illustrative cases

Patient 9

A 44-year-old woman demonstrated right proptosis and IVth cranial nerve palsy and excessive pulsatile bruits. Cerebral angiography revealed a DAVF of the right CS. Angiography of the right CCA demonstrated persistent filling of the left InfPS (Figure 1A). Therefore, a transvenous approach was chosen. The microcatheter was navigated through the left InfPS and the intercavernous sinus to the right CS (Figure 1C). The right CS was occluded with 28 standard coils (Figure 1D,E). However, the pulsatile tinnitus was still persistent at six-month follow-up study. Control angiography demonstrated recurrence of the fistula (Figure 1F) and the same procedure was performed (Figure 1G). The residual fistula was occluded completely by another six standard coils (Figure 1H).

Patient 12

A 54-year-old man presented with blepharotosis, diplopia and chemosis. Cerebral angiograms showed a cavernous DAVF (Figure 2A,B). Recommendation was made for transvenous embolization of this lesion. Onyx injection was performed after three standard coils (two 5x12, one 6x15) were introduced until control angiogram revealed complete occlusion of the DAVF. The patient's symptoms resolved within three months, there was no recanalization on seven-month follow-up angiograms (Figure 2 G,H).

Transvenous embolization in other locations

For the group of DAVFs in other locations, clinical symptoms included headaches (n=3), pulsatile tinnitus (n=2), seizure (n=1), visual disturbances (n=1), dementia (n=1), and SAH (n=1).

Five DAVFs experienced cures, and one patient (1/6) experienced improvement. We performed six transvenous approaches usually via the IJV-saggital sinus (SS), IJV-TSS and leptomeningeal routes. The technical success rate was 100% (six out of six cases), with complete occlusion in 83.33% of cases (five out of six cases). The rate of incomplete occlusion was 16.67% (one out of six cases). For four patients, we performed the transarterial approach prior to transarterial embolization.

Table 1 **Clinical features of patients with CDAVFs who underwent transvenous embolization with detachable coils and Onyx.**

Patient No.	Age(yr)/ Sex	Location	Type*	Feeders	Drainage	Symptoms	Endovascular technique	Complications	Outcome	Follow-up period
1.	17/M	R	Barrow D/ Cognard IIa	Right ICA and ECA	Right SOV	Right proptosis	1. TVE: right SOV; coils; success; complete	None	Cure	62 mths
2.	68/F	R	Barrow D/ Cognard IIa	Right ICA and ECA	Both SOVs	Bilateral proptosis, Pulsatile tinnitus	1. TVE: right FV, coils; success; complete	None	Cure	59 mths
3.	64/F	R	Barrow D/ Cognard IIa	Right ICA and ECA	Right SOV and InfPS	Right chemosis, Right CNVI palsy, Pulsatile tinnitus	1. TVE: right InfPS, coils; success; complete	None	Right CNVI palsy resovled within 6 mths	54 mths
4.	38/F	L	Barrow D/ Cognard IIa	Right ICA and ECA	Right SOV	Right proptosis	1. TVE: right InfPS; coils; success; complete	None	Cure	50 mths
5.	11/M	L	Barrow D/ Cognard IIa	Both ICAs and ECAs	Left SOV, SupPS, and InfPS	Left proptosis, Left CNVI palsy, Pulsatile tinnitus	1. TVE: left InfPS; coils; success; incomplete 2. TVE: left InfPS; coils; success; complete	None None	left CNVI palsy resolved within 2 mo	42 mths
6.	39/M	L	Barrow D/ Cognard IIa	Both ICAs and left ECA	Left SOV and InfPS	Right chemosis	1. TVE: left InfPS; coils; success; complete	None	Cure	41 mths
7.	68/F	L	Barrow D/ Cognard IIa	Right ICA, both ECAs	Right SOV, both InfPS	Bilateral chemosis, Left CNVI palsy Pulsatile tinnitus	1. TVE: left InfPS, coils; success; incomplete 2. TAE: right MMA, coils; success; complete	None	Left CNVI palsy and developed brain infarction at follow-up	30 mths
8	64/F	B	Barrow D/ Cognard III	Both ICAs and ECAs	Both SOV, SupPS, InfPS and right SphS	Bilateral blurred vision	1. TVE: left InfPS; coils; success; incomplete 2.TVE: left SupPS; failed	Left CNVI palsy None	Left CNVI palsy resolved within 6 mths	20 mths
9.	44/F	R	Barrow D/ Cognard IIa	Both ICAs and ECAs	Right SOV, both InfPS	Right proptosis, Right CNVI, Pulsatile tinnitus	1. TVE: left InfPS, coils; success; incomplete 2.TVE: left InfPS, coils; success; complete	None None	Left CNVI palsy resolved within 6 mths	12 mths

Patient No.	Age(yr)/ Sex	Location	Type*	Feeders	Drainage	Symptoms	Endovascular technique	Complications	Outcome	Follow-up period
10.	46/F	B	Barrow D/ Cognard IIa	Both ICAs and ECAs	Both SOV, and InfPS	Bilateral chemosis, Pulsatile tinnitus	1. TVE: right InfPS, coils; success; incomplete 2. TVE: left InfPS, coils; success; complete	None None	Cure	12 mths
11.	37/F	R	Barrow D/ Cognard III	Right ICA and ECA	Right SOV, InfPS and SphS	Right chemosis, Pulsatile tinnitus	1. TVE: right InfPS, coils; success; complete	Local alopecie on the right side	Cure	3 mths
12	54/M	L	Barrow D/ Cognard IIa	Both ICAs	Left InfPS	Left CNIII palsy	1. TVE: left InfPS; Coils and Onyx; success complete	TCR	Left CNIII palsy resolved within 3 mths	13 mths
13.	36/M	L	Barrow D/ Cognard IIa	Right ICA and ECA	Right SOV	Right proptosis and chemosis	1. TAE: Incomplete; 2. TVE: right FV Onyx; success;complete	None	Cure	12 mths
14.	69/F	R	Barrow D/ Cognard IIa	Both ICAs	Right SOV	Right CNIII palsy	1. TVE: right FV; Coils and Onyx; success; complete	None	Right CNIII palsy resoved within 3 mths	9 mths
15.	57/M	R	Barrow D/ Cognard IIa	Both ICAs and ECAs	Both InfPS	Right CNIII palsy	1. TVE: right InfPS; Coils and Onyx; success; complete	TCR	Right CNIII palsy resolved within 2 mths	5 mths
16.	54/M	L	Barrow D/ Cognard IIa	Both ICAs and ECAs	Left InfPS	Pulsatile tinnitus Left CNVI palsy	1. TVE: left InfPS; Coils and Onyx; success complete	None	Left CNVI palsy resolved	4 mths
17.	43/M	B	Barrow D/ Cognard IIa	Both ICAs and ECA	Left SOV and both InfPS	Left proptosis, Chemosis and Pulsatile tinnitus	1. TVE: left InfPS, coils and Onyx, Incomplet 2.TVE: right InfPS, Coils and Onyx; success complete	None Right CNVI palsy	Right CNVI palsy resolved	2 mths

**.Barrow type and Cognard classification. R, right; L, left; F, female; M, male; SOV, superior ophthalmic vein; mo, months; InfPS, inferior petrosal sinus; FV, facial vein; SupPS, superior petrosal sinus; ICA:internal carotid artery; ECA:external carotid artery; CNIII, the third cranial nerve; CNVI, the sixth cranial nerve; TCR, trigeminocardiac reflex; TAE, transarterial embolization; TVE, transvenous embolization. 2, two sessions.*

Table 2 **Clinical features of patients with DAVFs in other locations who underwent transvenous embolization with detachable coils.**

Patient No.	Age(yr)/ Sex	Location	Type*	Feeders	Drainage	Symptoms	Endovascular technique	Complications	Outcome	Follow-up period
18.	65/M	ACF	Cognard III	Left EA and ECA	FPV	Dementia seizure	1. TAE: left OA, Onyx-18, success, incomplete 2.TVE: SSS; coils; success; complete	None None	Cure	9 mths
19	48/M	ACF	Cognard III	Both EAs and ECAs	Both FPVs	Headaches, right? visual disturbance	1. TVE:SSS, coils; success; complete	None	Cure	3 mths
20.	70/M	Tentoium(R)	Cognard IV	Right ICA and ECA	Right BVR	SAH	1. TAE: right MMA coils, success, incomplete 2. TVE: right BVR, coils; success; complete	None	Cure	4 mths
21.	50/M	TSS(L)	Cognard IIa	Left ICA, ECA and VA	Right TSS	Headaches	1. TVE:left TSS; coils; success; complete	None	Cure	36 mths
22.	40/M	TSS(R)	Cognard IIa+b	Right ICA, ECA and both VAs vein	Left TSS, right Labbe	Headaches, Pulsatile tinnitus,	1. TAE: right ECA; coils; success; incomplete 2. TVE: left TSS coils, success, complete	None None	Cure	24 mths
23.	56/M	TSS(L)	Cognard IIa	Left ICA Both ECAs and VAs	Right TSS	Pulsatile tinnitus	1. TAEl:left ECA; coils; success; incomplete 2. TVE: right TSS coils; success; incomplete	None	Pulsatile tinnitus	2 mths

**.Cognard classification.*
R, right; L, left; M, male;AFC, anterior cranial fossa; EA, ethmoidal artery; FPV, frontal polar vein; OA, ophthalmal artery; ICA:internal carotid artery; ECA:external carotid artery; SSS, superior sagittal sinus; BVR, basal vein of Rosenthal; TSS, transverse-sigmoid sinus; mo, moths; TAE, transarterial embolization; TVE, transvenous embolization.

Follow-up outcome

Angiographic follow-up was obtained in two patients with cure. For one patient, patency of residual DAVF after endovascular treatment of a TSS DAVF on the left side and tinnitus was stable, another five patients were cured at clinical follow-up.

Illustrative cases

Patient 23

A 56-year-old man with headaches and pulsatile tinnitus demonstrated a left TSS Cognard Type IIa DAVF (Figure 3). An ophthalmological examination revealed bilateral papilledema (Figure 3A). Cerebral angiography demonstrated multiple feeders arising from the left ECA and ICA (Figure 3B) and basal artery system (Figure 3C) with a parallel venous channel. One transarterial and one transvenous embolization of the TSS DAVF were performed. These procedures and occlusion of the ECA feeders significantly reduced the size of the fistula (Figure 3E,F). After transvenous embolization of the left TSS, control angiography demonstrated obliteration of the parallel channel, with preservation of the patent parent sinus (Cognard Type I). During the subsequent months the patient?s tinnitus was in stable condition and no further neurological symptoms were noted, ophthalmological examination was not available.

Discussion

Depending on their venous drainage patterns, intracranial DAVFs can cause headaches, dementia, chemosis, protosis, bruit, and, rarely, infarction or hemorrhage. The data of our patients confirmed previous studies [7,12,27,38,40,50,56]. The clinical presentation is closely related to the degree of shunting, cerebral venous hypertension, and the pattern of venous drainage, with or without impaired cortical function [46]. Despite spontaneous remission, which occurs in 9.4 to 50% of cases [22], treatment is indicated in cases with cortical drainage (Cognard Type IIb or greater), hemorrhage, progressive neurological deficits, or intractable headaches or tinnitus. Although the cure rate of DAVFs by transarterial embolization has been promoted by Onyx, it is limited in smaller arteriovenous fistula DAVFs [53]. Transvenous embolization is still a good option for DAVFs with multiple feeding arteries, especially as they cannot be cured by transarterial embolization [19-21]. Our 23 patients represent 32.76% (the remaining patients were treated with transarterial embolization or neurosurgery) of the patients who underwent embolization for treatment of DAVFs at our institution in the past ten years. This reflects the evolution of transvenous approaches at a single institution in a period of five years. In our series, the anatomic cure rates were 94.1% (16/17) for DAVFs of the CS and 83.3% (1/6) for DAVFs at other locations. All patients, including those without anatomic cures, experienced improvement.

When catheterization is possible, transvenous embolization is associated with a high rate of permanent long-term occlusion. Occlusion can be achieved with placement of coils via a transvenous route.

Transvenous embolization of CS

There are different transvenous routes to the CS, i.e., by way of the InfPS, contralateral InfPS, basilar plexus or circular sinus, through the FV, angular vein, and SOV, or through the pterygoid plexus [2-6,9,14,19,25,27,35,36,42,43,47,52]. To achieve complete occlusion, the cavernous sinus was tightly packed with GDC. This tight packing may have accounted for the intense nausea and vomiting. Transient VIth or IIIrd nerve palsy following coil embolization for cavernous DAVF are well known events [2]. The complex nature of the fistula, the unexpected difficulty in the placement of detachable coils, and our previous experience with Onyx in the treatment of DAVFs promoted us to use Onyx in the treatment of our patien [19,20,38].

Transvenous embolization of DAVFs in other locations

For DAVFs in the ACF, we prefer the transvenous procedure with the softest EDC and free coils to fit the draining frontal veins and to minimize the risk of damage and rupture of the frontal veins, appreciating the risk of visual compromise from embolic occlusion of the central retinal artery. Although the venous approach through the elongated, ectactic and potentially fragile pial veins is considered difficult and risky, several cases of tentorial DAVF have been treated by transvenous embolization [9,21,23].

If the affected TSS is isolated or exhibits prominent retrograde drainage to the cortical

veins and is not a functional part of the venous circulation, then sinus occlusion can be performed via an endovascular procedure. There was anterograde flow in the vein of Labbe in one case of a lateral sinus fistula, after transvenous embolization of the TSS with sparing of the vein of Labbe.

Kubo et Al [30] concluded, on the basis of their three cases and a review of the literature, that second fistulae can occur after complete embolization, with latency periods of more than one year and this finding was confirmed by Kiyosue et Al [26]. For this reason, we occluded all main feeding arteries prior to obliteration of the affected sinus in our cases with DAVFs of the tentorium and TSS to prevent development of cortical venous reflux and intracranial hemorrhage. In one patient with a TSS DAVF with a parallel venous channel of the transverse/sigmoid sinus converted a Cognard Type IIa DAVF into a Cognard Type I DAVF with a patent parent sinus.

Conclusions

Transvenous treatment of intracranial DAVFs can be a highly effective method if various transvenous approaches are attempted. Onyx is a promising embolic agent for the transvenous treatment of DAVFs, and its physical properties warrant further appraisal in larger series of patients. The advantages make this an attractive alternative to various platinum coils already described.

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