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Original Investigation

Transarterial ONYX Embolization of Intracranial Dural Arteriovenous Fistulas in Adults

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ABSTRACT

AIM: To present our experience on transarterial treatment of dural arteriovenous fistulas (DAVFs) with ONYX in adult patients.

MATERIAL and METHODS: Between March 2008 and November 2012, 27 adult patients with DAVFs treated by transarterial ONYX embolization were included. Clinical data, including hospital records, operative reports, and angiograms, were reviewed and analyzed.

RESULTS: Complete obliteration of the fistula was achieved in 16/27 (59.3%) patients after 32 intra-arterial embolizations. One complication (3.7%) was transient hemiparesis. Follow-up imaging, which was available for 16 fistulas with angiographic cures, showed no evidence of recurrence. At mean 14.5 months follow-up, 26 patients (96.3%) had GOS score of 5 and 1 patient (3.7%) had GOS score of 3.

CONCLUSION: Transarterial ONYX embolization has become the main treatment for adult intracranial DAVFs and is associated with high safety and efficacy.

KEYWORDS: Dural arteriovenous fistula, Embolization, ONYX, Radiosurgery

ABBREVIATIONS: AVF: Arteriovenous fistula, **CT:** Computed tomography, **CVR:** Cortical venous reflux, **DAVF:** Dural arteriovenous fistula, **DCF:** Dural cavernous fistula, **ECA:** External carotid artery, **ICA:** Internal carotid artery, **IPS:** Inferior petrosal sinus, **MMA:** Middle meningeal artery, **VA:** Vertebral artery, **DAVF:** Dural arteriovenous fistula, **GOS:** Glasgow Outcome Scale.

■ INTRODUCTION

In adults, it has been shown that dural arteriovenous fistulas (DAVFs) are an acquired disease. The term dural arteriovenous fistula (DAVF) should therefore be used in adults, rather than in children (34).

The arterial supply of the DAVFs is from the dural arteries and the dural branches of cerebral arteries. This is directly shunted into a venous sinus and/or arterialized leptomeningeal veins. The nidus of the DAVF is usually located within the dura mater (3,19). The venous drainage of DVAF is the most important predictor of the clinical behavior. DAVFs with cortical venous reflux (CVR) exhibit a much higher incidence of hemorrhage or venous infarction (29). The annual mortality rate for DAVFs with CVR may be as high as 10.4%, whereas the annual risk for hemorrhage or non-hemorrhagic neurological deficits during follow-up period are 8.1% and 6.9%, respectively, resulting in an annual event rate of 15% (29,42).

In addition, re-bleeding rates are as high as 35% during the first 2 weeks after the first hemorrhage (10). Therefore, DVAFs need careful evaluation for the best therapeutic option (29).

The current endovascular treatment of DAVFs is sometimes a complex strategy, including not only transarterial injection of any liquid embolic agent but also transvenous approaches and also surgical elements (16).

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With the advent of ONYX (Covidien, Irvine, CA), most intracranial DAVFs can be successfully managed with transarterial ONYX embolization via their supply from the external carotid artery (ECA) branches, which can be safely embolized (29).

In this study, we report our experience with a series of 27 adult patients who underwent intra-arterial embolization for intracranial DAVFs.

MATERIAL and METHODS

Between March 2008 and November 2012, 27 (20 males, 7 females) consecutive adult patients with DAVFs treated using transarterial ONYX embolization (Tables I, II). The mean age was 46.3 years (range, 29-70 years).

Clinical presentations included hemorrhage in 11 patients (40.7%), chemosis in 4 patients (14.8%), bruit in 9 patients (33.3%), headaches in 5 patients (18.5%), blurred vision in 1

Table I: Demographic Characteristics of the 27 Patients

Patient No.	Age (years)	Sex	Presentation	Location	Suppliers	Borden Type	Approach
1	44	M	Bruits	BL, TS Torcula	R, ECA/VA, L, OA	II	R, MMA; L, OA
2	40	F	Chemosis, bruits, blurred vision	R, CS	R, ICA/ECA	II	R, MMA
3	42	F	Headaches	R, TS	R, VA; BL, ECA	II	R, MMA
4	70	M	Headaches, bruits, chemosis	L, TS	L, ICA/MMA/VA	II	L, MMA
5	50	F	Bruits	L, TS	L, OA/MHT/MMA	II	L, MMA; L, OA
6	36	F	Headaches, blurred vison	R, TS	BL, ECA	II	BL, MMA; R, OA
7	31	M	Chemosis, bruits	R, TS	R, ICA/ECA	II	R, MMA
8	46	M	Chemosis	L, CS	L, ICA/ECA	II	L, MMA
9	44	M	ICH	R, Fronto-parietal	R, MMA	III	R, MMA
10	40	M	Chemosis	R, TS	BL, ECA	III	R, MMA
11	29	M	ICH	R, TS	R, ECA/VA; L, OA	III	R, MMA
12	61	M	Trigeminal neuralgia	Meckel Cave	R, ECA/ICA	III	R, MMA
13	38	M	ICH	Ethmoidal	BL, ICA; L, ECA	III	R, Opha
14	63	M	Headaches	R, tentorial	L, MMA; R, ECA/ICA	III	L, MMA
15	59	M	ICH	R, tentorial	BL, ECA/ICA	III	BL, MMA
16	56	M	ICH	R, tentorial	R, ICA/ECA/AICA	III	R, MMA
17	47	M	ICH	R, tentorial	R, ICA/ECA	III	R, MMA
18	43	F	ICH	R, tentorial	R, ECA/ICA	III	R, MMA
19	35	M	ICH	R, tentorial	R, SCA/MMA/MHT	III	R, MMA
20	35	M	Hypoesthesia	R, tentorial	R, MHT/SCA	III	R, SCA
21	51	F	ICH	Craniocervical junction	L, VA	III	L, PMA
22	52	M	Bruits	Middle cranial fossa	L, ECA	III	L, MMA
23	31	F	Bruits	L, TS SSS R, fronto-parietal	BL, ECA L, MCA	II III III	BL, MMA
24	38	M	Bruits	L, TS	L, ECA/ICA; R, OA	III	R, OA
25	69	M	Bruits	L, fronto-parietal	BL, MMA	III	L, MMA
26	43	M	ICH, headaches, bruits	L, tentorial	L, ECA/ICA	III	L, MMA
27	56	M	ICH	L, clival	L, MHT	III	L, MHT

***M:** Male; **F:** Female, **ICH:** Intracranial hemorrhage, **CN:** Cranial nerve, **TS:** Transverse sigmoid, **ECA:** External carotid artery, **ICA:** Internal carotid artery, **OA:** Occipital artery, **VA:** Vertebral artery, **CS:** Cavernous sinus, **Opha:** Ophthalmic artery, **SSS:** Superior sagittal sinus, **MMA:** Middle meningeal artery, **SCA:** Superior cerebellar artery, **MHT:** Meningohypophyseal trunk, **PMA:** Posterior meningeal artery.*

patient (3.7%), hypoesthesia in 1 patient (3.7%), and trigeminal neuralgia in 1 patient (3.7%). Multiple dural fistulas occurred in 2 patients (7.4%).

The locations of the lesions were transverse-sigmoid sinus in 10 patients (37.0%), cavernous sinus in 1 patients (3.7%), tentorium in 8 patients (29.6%), ethmoidal in 1 patients (3.7%), frontoparietal in 3 patients (11.1%), saggital sinus in 1 patients (3.7%), Meckel cave in 1 patient (3.7%), middle fossa dura in 1 patients (3.7%), clivus in 1 patient (3.7%), craniocervical junction in 1 patient (3.7%) and torcula in 1 patient (3.7%).

According to Borden classification (4), 8 fistulas (29.6%) were type II, and 19 (70.4%) were type III.

All endovascular approaches were performed under general anesthesia. Diagnostic angiography was performed including six vessels. Cervical branches of the subclavian artery were

Table II: Treatment and Follow-Up of the 27 Patients

Patient No.	Injection time (minutes)	Material	Adjunct treatment	Angiographic result	Complications	Follow-up (months)	Clinical outcome (GOS) score
1	110	ONYX	NO	Incomplete	no	24	5
2	20	ONYX	Radiosurgery	Incomplete	no	10	5
3	40	ONYX	NO	Incomplete	no	25	5
4	55	ONYX	NO	Complete	no	7	5
5	75	ONYX	NO	Incomplete	no	15	5
6	80	ONYX	NO	Incomplete	no	9	5
7	30	ONYX	NO	Incomplete	no	13	5
8	15	ONYX	NO	Incomplete	no	16	5
9	40	ONYX	NO	Complete	no	29	5
10	20	ONYX	NO	Complete	no	4	5
11	15	ONYX	NO	Complete	no	5	5
12	33	ONYX	Radiosurgery	Incomplete	no	1	5
13	30	ONYX	NO	Incomplete	no	1	5
14	50	ONYX	NO	Complete	no	25	5
15	45	ONYX	NO	Complete	no	12	3
16	20	ONYX	NO	Complete	no	16	5
17	25	ONYX	NO	Complete	no	3	5
18	15	ONYX	NO	Complete	no	20	5
19	15	ONYX	NO	Complete	R, ICA stenosis, hemiparesis	13	5
20	15	ONYX	NO	Complete	no	24	5
21	25	ONYX	NO	Complete	no	12	5
22	10	ONYX	NO	Complete	no	25	5
23	44	ONYX	NO	Incomplete	no	20	5
24	30	ONYX	NO	Complete	no	21	5
25	25	ONYX	NO	Complete	no	16	5
26	15	ONYX	Radiosurgery	Incomplete	no	24	5
27	4	ONYX	Balloon assistance	Complete	no	1	5

***GOS:** Glasgow outcome scale.*

included in selected cases. The decision of embolization, the route, and the embolizing material were chosen based on the angiographic findings (29). After transfemoral access and sheath placement, the patient was heparinized, with 3000 units intravenously and 1000 units per hour of intravenous heparin, to maintain an activated coagulation time of between 250 and 300 seconds (29). Standard coaxial techniques were used for embolization. Guide catheters were navigated into the appropriate parent vessel (external carotid artery, internal carotid artery, or vertebral artery) (38). A DMSO compatible microcatheter (Marathon or Echelon; Covidien) with a microwire (Mirage or Silverspeed; Covidien) was then advanced into the selective branches as close to the nidus as possible and allowing for an adequate distance for reflux of the embolic agent, and superselective angiography was performed on the target branch or branches for embolization (29,38). When there were multiple feeders, the feeder with maximum reflux distance from the skull base was chosen to decrease the chances of cranial nerve palsies (29). Embolization of the DAVF was then performed with ONYX-18 in the manner previously described (26-28). If the meningohypophyseal trunk was catheterized, ONYX embolization was performed with balloon assistance. The end point of the embolization was the angiographic obliteration of the fistula, with some filling of the draining veins (Figure 1A, B).

Clinical follow-up (mean 13.2 months, range 1–29 months) data were supplemented by telephonic interviews and graded according to the Glasgow Outcome Scale (GOS) (18). An excellent outcome was defined as the resumption of normal life despite minor deficits (GOS Score 5). A good outcome was a moderate disability, but the patient was independent (GOS Score 4). A fair outcome was a severe disability, and the patient was dependent on the care of others (GOS Score 3). A poor outcome was a persistent vegetative state (GOS Score 2) or death (GOS Score 1). Most patients had follow-up angiograms approximately 6-11 months after the embolization procedure.

The angiographic results of treatment were classified as incomplete or complete, based on the evidence of remnant fistula on the post-treatment angiogram.

■ RESULTS

Thirty-two intra-arterial ONYX embolization procedures were performed to treat dural fistulas in 27 patients (Table I). There were 32 transarterial approaches, 1 of which was performed with balloon assistance. Thirty-two ONYX injections were performed in 32 vessel branches, including 28 ECA branches, posterior meningeal artery (n=1), ophthalmic artery (n=1), meningohypophyseal artery (n=1), superior cerebellar artery (n=1).

Twenty-three branches of the middle meningeal artery (MMA) were embolized along with 5 branches of the occipital artery. Thirteen lesions were cured with transarterial treatment via the MMA alone (Figure 1). Three fistulas were cured with transarterial treatment via the superior cerebellar artery, meningohypophyseal artery and posterior meningeal artery.

Three patients underwent Gamma Knife radiosurgery, which was performed after incomplete embolization. Only one technical complication was associated with the transarterial ONYX embolization, resulting in a complication rate of 3.1%. A 35-year-old man presented with subarachnoid hemorrhage caused by a tentorial DAVF with supply from the right meningohypophyseal trunk, the right superior cerebellar artery and the right middle meningeal artery. The patient underwent transarterial ONYX embolization via the MMA. At the final stage, a small amount of ONYX appeared to reflux into the right internal carotid artery (ICA) via the meningophypophyseal trunk. Therefore, ONYX embolization was aborted, and the catheter was removed. Then, immediate angiography revealed complete occlusion of the fistula. The patient experienced left hemiparesis just after the procedure and discharged home on postoperative day 5. The hemiparesis had almost resolved completely at the fifteenth day after the embolization.

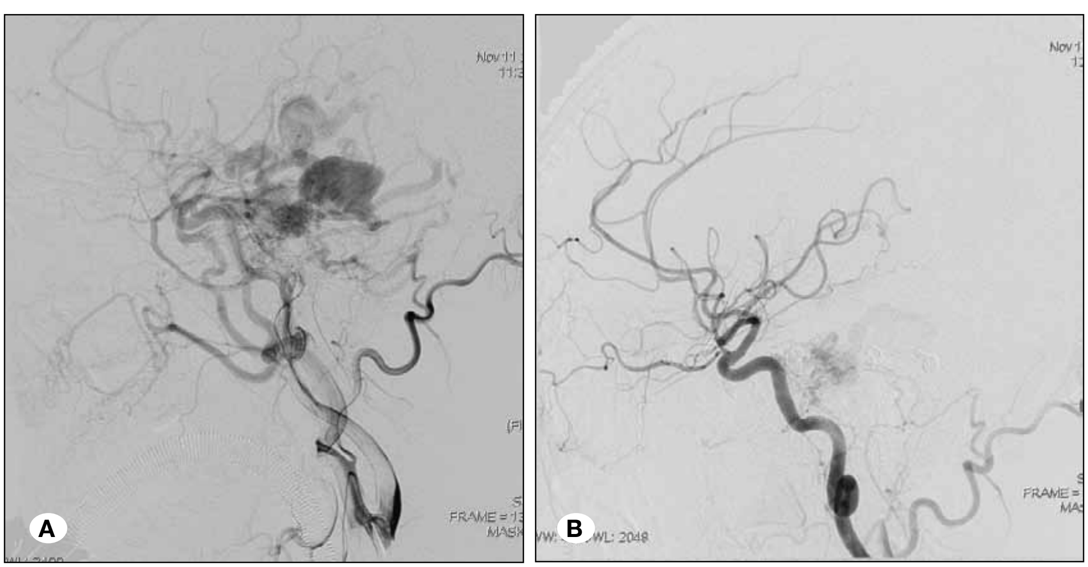

Figure 1: A) left carotid artery angiogram (lateral view) demonstrating a left tentorial DAVF with supply from the left MMA and occipital artery and venous drainage into a cortical vein with a dilated venous varix that drains into the lateral mesencephalic veins. **B)** post-embolization left ICA angiogram (lateral view) showing residual fistula supplied by the meningeal hypophyseal trunk.

Of the 27 patients who had endovascular treatment, 16 (59.3 %) had complete obliteration of the fistula after embolization. Of the 11 fistulas, in which endovascular treatment was incomplete, 3 underwent radiosurgery. In the remaining 8 fistulas, the fistula was treated nearly complete obliteration or the post-embolization fistula was Borden type I, and the residual fistula remained stable on the follow-up angiogram, and no further treatment was performed.

Of the 3 fistulas that underwent Gamma Knife radiosurgery, complete fistula obliteration was confirmed by 2-year follow-up angiogram in 2 and 1 will have follow-up angiography 2 years post-treatment.

Twenty-six of 27 patients (96.3%) had a favorable outcome (GOS score 5) during the follow-up period. One patient with GOS score 3, the cause for the poor outcome was the initial insult of the hemorrhage. In our series, there was no procedure-related mortality.

■ DISCUSSION

The pathogenesis of DAVFs is still unclear, with a congenital and an acquired etiology having been proposed (19, 29). Lasjaunias et al. (19) proposed that a primary structural weakness of the dura coincides with a trigger factor and results in the formation of a DAVF (29). The common predisposing factor appears to be venous sinus thrombosis, with the body compensating for this by attempts at recanalization (12,13,17,29). In our series, sinus occlusion was observed in 8 patients. There were 2 patients with multifocal complex DAVFs in adults; and in 26 patients, no specific cause could be identified. We have a male predominance (76.9%) in our patients and this may suggest that it tends to have a more aggressive course in men (16, 34, 41).

The incidence of DAVF by location, as reported in the literature, is as follows: transverse sigmoid sinus, 50%; cavernous sinus, 16%; tentorium, 12%; superior sagittal sinus, 8%, and anterior fossa, 2% (2, 4, 8, 25, 29).

A patient's first hemorrhage from a DAVF is associated with 20% to 30% mortality, emphasizing the importance of early recognition and treatment of patients at highest risk (5,29). The natural history of DAVFs has been poorly documented until recently and has been based on retrospective reviews (2,8,29). Van Dijk et al. (42) had a 4.3 years follow-up on their 14 non-treated patients and 6 partially-treated patients. They found that persistence of the CVR in cranial DAVFs yielded an annual mortality rate of 10.4%.

Recent studies demonstrate evidence that the risk of bleeding for a DAVF with CVR is less when the patient does not present with a hemorrhage or a nonhemorrhagic neurologic deficit (29,37,39). Strom et al. (39) report that asymptomatic versus symptomatic DAVFs (in patients presenting with hemorrhage or neurologic deficit) have annual hemorrhage rates of 1.4% versus 19%, respectively. Although small in size, these studies make the important point that the natural history may depend on the type of presentation (29,39). Nevertheless, lower annual hemorrhage rates of asymptomatic type II and III DAVFs (up to 1.5% per year) (29,37) still pose significant long-term risk to patients, thereby justifying treatment in appropriately selected patients (29). Our patients belonged to the high-risk category (Borden types II or III) and required active intervention to prevent risk of hemorrhage.

At our institution, we perform aggressive treatment for symptomatic type II/III DAVFs. We also recommend treatment in asymptomatic type II/III DAVFs if the patient is a good candidate for embolization on the basis of their age, lifetime hemorrhage risk profile, and willingness or unwillingness to accept the natural history.

Currently, several series have established a high degree of safety and efficacy of ONYX used intra-arterially and intra-venously in the treatment of intracranial DAVFs (1,6,9,29,31,32,40). The complete obliteration rate in arterial ONYX embolization was 61.3%-91.6% (22,31-33,40) and that in venous ONYX embolization was 100% (21,23). The efficiency of access through the MMA, even when the diameter was very small, than through other more dilated feeders (eg, occipital and posterior auricular arteries) due to the superior flow control and reliability of target vessel embolization has been described well in literatures (15,20,29,38). ONYX offers the possibility of venous sinus packing/occlusion from an arterial side approach, which may be quite helpful in cases with previous occlusion of the draining venous structures (14,29).

Post-embolization complication rates of approximately 2% to 10% have been reported in most series (11,22,24,29,30). Complications associated with arterial embolization include cranial nerve deficits, draining vein occlusion or venous ONYX migration, brain infarction, reflexive bradycardia, brain infraction and microcatheter gluing (22,24). On our experience, complications associated with venous embolization were reflexive bradycardia and transient cranial nerve deficits. Our success rate of 63.9% seems comparable with previously reported results of 50% to 90% (6,7,9,31) and our complication rate was as low as 2.8%.

The petrous branch of the middle meningeal trunk supplies the cranial nerves at the skull base (29). We avoid this branch and select another distal tentorial branch to embolize the fistula, even if that is not a direct feeder. The arterial or venous balloon assistance technique provides an adjunctive method in the transarterial and transvenous ONYX embolization of complex DAVFs (36). The balloon can be inflated in the ICA or vertebral arteries at the site of the meningeal feeding arteries, which have anastomotic connections with the target vessel being embolized (36). This technique prevented the untoward passage of ONYX into the ICA via the meningophypophyseal branch and vertebral artery via the posterior meningeal artery. It can thus prevent the embolic material from occluding the intracranial artery and/or causing distal embolism via those anastomotic channels (36). This technique is especially useful in DAVFs because of the rapid tapering, small-diameter feeding arteries resulting in early reflux during ONYX injection (36).

Shi et al. have used the venous balloon assistance technique to prevent ONYX from inadvertently occluding the lumen of a functioning venous sinus and migrating into adjacent key cortical or deep veins when the balloon occludes the recipient venous structure (36).

Radiosurgery is inefficient for DAVFs and it may be tried where embolization has failed and surgery appears to carry a high risk (25, 29, 44). Wu et al. reported a 75% angiographic obliteration rate at 24 months (43). In our series Gamma Knife radiosurgery was used in 3 patients. Complete obliteration has been achieved in 2 with 1 awaited for 2-year follow-up angiogram.

Surgery is indicated for high-risk DAVFs with leptomeningeal retrograde venous drainage when embolization is technically difficult or has resulted in incomplete occlusion (29, 35).

■ CONCLUSION

Transarterial ONYX embolization has become the main treatment for adult intracranial DAVFs and is associated with high safety and efficacy.

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