

Dural arteriovenous fistulas with direct cortical venous drainage treated with Onyx®

A case series

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ABSTRACT

Dural arteriovenous fistulas (DAVFs) may have aggressive symptoms, especially if there is direct cortical venous drainage. We report our preliminary experience in transarterial embolization of DAVFs with direct cortical venous drainage (CVR) using Onyx®. **Method:** Nine patients with DAVFs with direct cortical venous drainage were treated: eight type IV and one type III (Cognard). Treatment consisted of transarterial embolization using Onyx-18®. Immediate post treatment angiographies, clinical outcome and late follow-up angiographies were studied. **Results:** Complete occlusion of the fistula was achieved in all patients with only one procedure and injection in only one arterial pedicle. On follow-up, eight patients became free from symptoms, one improved and no one deteriorated. Late angiographies showed no evidence of recurrent DAVF. **Conclusion:** We recommend that transarterial Onyx® embolization of DAVFs with direct cortical venous drainage be considered as a treatment option, while it showed to be feasible, safe and effective.

Key words: dural arteriovenous fistula, dural arteriovenous malformation, embolization, endovascular, Onyx®, transarterial.

Fístulas arteriovenosas durais com drenagem cortical direta tratadas com Onyx®: casuística

RESUMO

As fistulas arteriovenosas durais (FAVDs) podem se manifestar com sintomas agressivos, especialmente se existe drenagem cortical direta. Relatamos nossa experiência preliminar na embolização transarterial de FAVDs com drenagem cortical direta usando Onyx®. **Método:** Nove pacientes com FAVDs com drenagem cortical direta foram tratados: oito do tipo IV e uma do tipo III (Cognard). O tratamento consistiu na embolização transarterial usando Onyx-18®. Angiografias imediatas pós-tratamento, evolução clínica e angiografias de controle tardias foram estudadas. **Resultados:** A oclusão completa da fístula foi alcançada em todos pacientes através de um só procedimento e injeção em apenas um pedículo arterial. No seguimento, oito pacientes ficaram livres de sintomas, um melhorou e nenhum deteriorou. Angiografias tardias de controle não mostraram evidência de FAVD recorrente. **Conclusão:** Nós recomendamos que a embolização transarterial com Onyx® das FAVDs com drenagem cortical direta, seja considerada como uma opção terapêutica, uma vez que mostrou ser factível, segura e efetiva.

Palavras-chave: fistula arteriovenosa dural, malformação arteriovenosa dural, embolização, endovascular, Onyx®, transarterial.

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Intracranial dural arteriovenous fistulas (DAVFs) are considered an acquired abnormality, characterized by abnormal shunting of blood inside the dura between the arterial and the venous systems. The true incidence of DAVFs is difficult to determine. Earlier case series reported from large single tertiary academic centers estimated that DAVFs represented only 10% to 15% of all cerebral arteriovenous malformations diagnosed with angiography¹.

There are numerous classification schemes for DAVFs dating back to the initial scheme proposed by Djindjian and Merland in 1978.² The most useful and modern are the revised Djindjian classification proposed by Cognard et al.³ and the classification proposed by Borden et al.⁴, both of which are based on the initial scheme. Cognard defined five types of DAVFs based exclusively upon the pattern of venous outflow: type I, located in the main sinus, with antegrade flow; type II, in the main sinus, with reflux into the sinus (IIa), cortical veins (IIb), or both (IIa+b); type III, with direct cortical venous drainage without venous ectasia; type IV, with direct cortical venous drainage with venous ectasia; and type V, with spinal venous drainage. No matter the classification system, they all focus on the patterns of venous drainage.

DAVFs draining retrogradely into cortical veins exhibit a much higher incidence of hemorrhage or venous infarction⁵. The annual mortality rate for cortical venous reflux may be as high as 10.4%, whereas the annual risk for hemorrhage or nonhemorrhagic neurologic deficits during follow-up are 8.1% and 6.9%, respectively, resulting in an annual event rate of 15%⁵.

We present our experience in endovascular embolization of intracranial DAVFs with direct cortical venous drainage using transarterial ethylene vinyl alcohol (Onyx-18®).

METHOD

From October 2005 to May 2009, 9 consecutive previously untreated patients with intracranial DAVFs with direct cortical venous drainage (Cognard types III-IV) underwent endovascular treatment with Onyx-18® at three different institutions. There were 7 (77.7%) men and 2 women. The mean age of these patients was 50.77±12.26 years (median, 52 years; range 31-71 years) (Table). Clinical presentation included intracranial hemorrhage in 5 patients (55.5%), ocular symptoms in 2 (22.2%), focal neurological deficit in 1 (11.1%), seizures in 1 and pulsatile tinnitus in 1. Symptoms were developed in an acute fashion in six patients and chronic in three patients (mean duration, 50 months; range 6-96 months). Patients were questioned about medical history to identify etiologic factors such as thrombophlebitis, otitis or sinusitis, cranial trauma, neurosurgery, or phlebitis of the lower limb. None patient presented these conditions.

Three (33.3%) DAVFs were located at the dural con-

vexity, 3 (33,3%) at the tentorial region, 2 at the anterior fossa and one (11.1%) at the lesser sphenoid wing. According to San Millan-Ruiz et al.⁶ DAVFs located at the lesser sphenoid wing region can be classified according to the involvement of either the superficial middle cerebral vein or the lesser sphenoid wing sinus. Only one patient at our study presented a DAVF located at the lesser sphenoid wing region. The fistula was drained by superficial middle cerebral vein. Picard et al.⁷ divided the venous tributaries in the tentorium into three regions: the lateral tentorial sinus group lie adjacent to the lateral sinus and receive supratentorial drainage from the lateral and inferior surfaces of the temporal and occipital lobes. The medial tentorial sinus group are situated adjacent to the torcula and drain into it or the lateral or straight sinus. They primarily receive infratentorial venous drainage from the cerebellar hemispheres and vermis. Finally, lesions along the free edge of the tentorium, which receive venous drainage from the basilar and lateral mesencephalic veins and may have infra or supratentorial drainage or even drain into spinal veins (Cognard Type V). Three patients presented DAVFs located at the tentorial region. All of them drained primarily to cortical cerebellar veins, cortical occipital veins or to the lateral pontomesencephalic vein. There was an average of 2.66±1.11 arterial feeders for each DAVF (median, 3; range, 1-5). The middle meningeal artery was involved in 7 cases (77.7%), combined or isolated, the occipital artery in 3 and the ophthalmic artery in 3. Eight (88.8%) lesions were classified as Cognard IV and one (11.1%) lesion as Cognard III. Onyx injection was used as the single treatment modality in all cases.

An immediate post-treatment angiogram was performed in all patients. Follow-up angiography was obtained 6 months after the initial treatment.

Endovascular procedure

The interventions were performed under general anesthesia. An intravenous bolus of 3,000 UI of heparin was given at the beginning of the procedure. Vascular access was obtained via the right common femoral artery. A complete cerebral angiogram including both internal carotid arteries, both external carotid arteries and ipsilateral vertebral artery was performed before the treatment to determine the DAVF angioarchitecture. A 6F guiding catheter was placed into the parent artery. A microcatheter (Ultraflow, Micro Therapeutics, Irvine, Calif.) was advanced over a 0.008-inch microguidewire (Mirage, Micro Therapeutics) into the meningeal branch responsible for the DAVF supply, always trying to reach the fistulous zone as close as possible or at least wedged into position. The microcatheter was flushed with dimethyl sulfoxide (DMSO) and the dead space was filled with Onyx-18® for 40 seconds. Under continuous subtraction fluoros-

Table. Summary of 9 patients with DAVFs with direct cortical venous drainage treated with transarterial Onyx®-18 injection.

Case No.	Age (yrs), Sex	Presentation (duration)	Localization	Type Cognard ³	Arterial supply	Drainage	Onyx® injection	Length of injection	Complications	Immediate angiography	Clinical outcome (follow-up)
1	39, F	Seizures (acute)	Rt temporo-occipital convexity	IV	Rt MMA (psb), rt oph (recurrent meningeal branch), lt MMA, rt STA, lt PCA (pial branch)	Rt cortical temporo-occipital vein	2.6 cc via MMA (direct puncture)	41 min	None	Anatomical exclusion	Asymptomatic (10 mos)
2	71, M	Retro-orbital pain (4 yr)	Lt lesser sphenoid wing	IV	Lt MMA	Lt superficial middle cerebral vein	1.3 cc via MMA	31 min	None	Anatomical exclusion	Asymptomatic (10 mos)
3	52, M	Pulsatile tinnitus, intermittent rt hemiparesis (6 mos)	Lt tentorial	IV	Lt MMA (tentorial branches), lt ICA (tentorial branches of C4 segment), lt PMA	Lateral pontomesencephalic vein	1.7 cc via MMA	42 min	None	Anatomical exclusion	Asymptomatic (20 mos)
4	49, M	Hemorrhage (acute)	Lt tentorial	IV	Lt MMA, lt occ (tob), lt MHT	Cortical cerebellar veins toward deep and superficial systems	3.5 cc via MMA	47 min	None	Anatomical exclusion	Asymptomatic (8 mos)
5	53, M	Lt eye proptosis, hyperemia, VI nerve palsy (8 yrs)	Lt parietal convexity	IV	Bilateral MMA, lt STA (tob)	Lt cortical parietal vein	2.0 cc via MMA	37 min	None	Anatomical exclusion	Partial improvement (8 mos)
6	62, M	Hemorrhage (acute)	Rt occipital convexity	III	Rt MMA, rt occ (tob)	Rt cortical occipital vein	1.5 cc via MMA	35 min	None	Anatomical exclusion	Asymptomatic (12 mos)
7	58, M	Hemorrhage (acute)	Anterior fossa	IV	Lt oph (ethmoidal branches), lt IMA	Lt frontobasal vein	1.5 cc via AETHA	35 min	None	Anatomical exclusion	Asymptomatic (6 mos)
8	42, F	Hemorrhage (acute)	Lt tentorial	IV	Lt MMA, lt occ (tob), lt PMA	Lt cortical occipital vein	2.6 mL via MMA	42 min	None	Anatomical exclusion	Asymptomatic (5 mos)
9	31, M	Hemorrhage (acute)	Anterior fossa	IV	Rt oph (ethmoidal branches), Lt oph (ethmoidal branches)	Lt frontobasal vein	1.6 cc via AETHA	32 min	None	Anatomical exclusion	Asymptomatic (6 mos)

DAVFs: dural arteriovenous fistulas; F: female; M: male; Lt: left; Rt: right; AETHA: anterior ethmoidal artery; ICA: internal carotid artery; IMA: internal maxillary artery; MHT: meningohypophyseal trunk; MMA: middle meningeal artery; psb: petrosquamous branch; STA: superficial temporal artery; PMA: posterior cerebral artery; PCA: posterior meningeal artery; Occ: occipital artery; Oph: ophthalmic artery; Tob: transosseous branches.

copy, very slow Onyx® injections were performed, avoiding excessive reflux.

Each treatment consisted of a single Onyx® injection, after one unique feeder catheterization. One patient demanded a direct access through a small temporal craniotomy to the right middle meningeal artery because of difficult endovascular navigation (the middle meningeal artery originated from ophthalmic artery).

RESULTS

Immediate post-treatment angiographic results

Complete angiographic occlusion with anatomical exclusion of the fistula was achieved in all patients, with isolated arterial Onyx® injection, after one procedure, demonstrated on angiography performed immediately after the intervention.

All Onyx® injections were performed via a meningeal branch. The volume of Onyx® injected ranged from 1.3 to 3.5 mL per procedure (mean, 2.03 mL). The duration of the injection per pedicle ranged from 31 to 47 minutes, with a mean of 38 minutes.

All patients complained of headache in the first days after embolization that resolved with a short course of corticosteroids. No catheter was glued. No complication was observed.

Follow-up

Patients were followed-up in a period ranging from 5 to 20 months after intervention. After treatment, 8 (88.8%) patients were free from symptoms related to the DAVF and 1 (11.1%) patient improved. No patient deteriorated.

Control angiographies after 6 months of the treatment showed no evidence of residual or recurrent DAVF in any patient.

DISCUSSION

The main goal of the treatment of type III/IV DAVFs is to eliminate the cortical venous drainage and the resulting risks. Optimal treatment aims at occluding the origin of the draining vein. Many options have been used: surgery⁸⁻¹⁰, transvenous¹¹, or transarterial embolization¹²⁻¹⁴.

Arterial feeder ligation is not an effective treatment because it frequently leads to recruitment of an extensive collateral network^{10,14}.

One option is surgical clipping of the draining vein, especially if it is unique and easily approached⁸⁻¹⁰.

Transvenous endovascular approach consists of retrograde catheterization and sacrifice of the involved venous structure^{15,16}. For DAVFs with direct CVR (types III-IV), dural sinus occlusion is not an option. Retrograde catheterization of the cortical vein draining the DAVF and its occlusion was performed in a few cases¹¹. This is very difficult and risky, with severe complications, in-

cluding vessel rupture or perforation, venous infarct and hemorrhage^{10,17}.

Since the initial description of therapeutic embolization of DAVFs in the early 1970s¹⁸, various embolic agents such as particles, liquid silicone, ethyl alcohol, platinum microcoils and cyano-acrylates have been used by transarterial approach. Polyvinyl alcohol particles (PVA) are easy to handle but they often promote proximal occlusion. Reduction of the shunting flow can be obtained but obliteration of the shunt itself is rather difficult. DAVFs treated with PVA frequently recanalize^{12,13}. The use of this temporary embolic suspension was supplanted by liquid embolic embolization. It is generally accepted that recanalization rate is lower with cyano-acrylate liquid adhesives. The possibility of reaching the site of fistulous communication is greater. Complete cure is achieved when all veins exiting the DAVF are occluded¹⁴. The use of N-butyl-cyano-acrylate (NBCA) necessitates experience in both its preparation and delivery. Because of some chemical and physical properties such polymerization rate, binding and viscosity, its effects are not always predictable, at times producing proximal feeder occlusion or venous obstruction even in normal territories¹⁹. Sometimes NBCA may not traverse the fistulous connection into the venous side permitting the re-appearance of smaller collaterals, which may be more difficult to catheterize selectively.

In 2007, van Rooij et al.²⁰, published the experience of their group in the management of DAVFs with CVR. Surgery was the treatment of choice for anterior fossa DAVFs. For all other DAVFs, embolization with glue was the first treatment option, with the aim of complete cure. Five patients with an anterior fossa DAVF underwent successful surgery. In 14 patients, the DAVF was completely occluded with embolization alone, and in 7 patients, embolization was followed by surgery. Complete occlusion was angiographically confirmed in 28 of 29 DAVFs. There were no complications of surgery; embolization was complicated by postembolization hemorrhage in 1 patient (3%). In a series of 21 DAVFs (9 type III-IV Cognard) treated transarterially under flow-arrest conditions, cures were demonstrated in all fistulae without complications.¹⁴ Although the definite curative embolization occurred under flow-arrest conditions, a significant portion of these patients underwent adjunctive embolization with polyvinyl alcohol or NBCA or previous transvenous coiling of the recipient venous structure. This served to devascularize the collateral inflow to minimize NBCA fragmentation, prevent systemic venous embolization, and increase the probability of polymerization within the pathologic shunt itself.

These studies illustrate the complex angioarchitectural spectrum of DAVFs and the expertise in multimodal-

ity treatments required to engender treatment safe and effective.

Ethylene vinyl alcohol (Onyx®), a polymer which is dissolved in DMSO, is an alternative embolic agent. In comparison with NBCA, Onyx does not polymerize but the copolymer precipitates as the DMSO diffuses under aqueous conditions, and thus mechanically occludes the vessel^{19,21-28}. The application of the ethylene-vinyl alcohol copolymer (EVOH) in the endovascular treatment of intracranial arteriovenous malformations (AVMs) was first described by Taki et al.²¹ and Terada et al.²² in the early 1990s. The FDA approved the intravascular use of Onyx for embolization of intracranial AVMs in July 2005. Since that, some series were published reporting the efficacy of Onyx® in the management of intracranial AVMs. The major advantage to the use of Onyx® compared with cyanoacrylates is the ease of injection. The catheter should be placed in the same wedge situation as for intranidal glue injection^{23,24}. The injection should be very slow, as well. It may be stopped for a few seconds or minutes to wait for precipitation of Onyx® in order to avoid reflux, and then resumed. Control angiography may be performed during Onyx® injection for a better understanding of material progression and of nidus and vein occlusion. Onyx® always behaves as a column, and the formation of small drops flowing into the vein that may be seen when glue is injected too fast, normally do not occur. The injection may last for several minutes or even tens of minutes^{23,24}. The total amount of Onyx® injected at one time in one single pedicle may therefore be much more than with glue. It reduces the number of catheters used and the total number of procedures needed to achieve a complete cure of the AVM²³. The other major advantage is that injection is more prolonged and the decision to stop or continue the injection does not have to be made immediately, as it does for glue injection.

DAVF closure with Onyx® was first reported by Rezende et al.²⁵ in 2006, in a patient with a lesser sphenoid wing region fistula with direct cortical venous drainage. After that, few other reports and case series were published^{19,26-28}.

Cognard et al.¹⁹ presented a series of 30 patients with DAVFs, 20 of those with direct cortical venous drainage. Complete cure was achieved in 23 (92%) of 25 patients who were not previously treated, with no recidive on follow-up. It took only 1 procedure for 20 patients. One patient with tentorial DAVF presented with ophthalmoplegia and facial pain after partial embolization due to foramen spinosum Onyx® reflux and rebled 2 years later. Another patient with tentorial DAVF had a cerebellar syndrome and hemorrhage after treatment secondary to extensive thrombosis of the draining vein. Nogueira et al.²⁷ reported 91.7% rate of cure in a 12 patient series with no significant morbidity or mortality. Ten of those had direct

cortical venous drainage. They had 1 (11%) recidive in 9 patients followed-up angiographically.

Similarly to the mentioned series above, we achieved complete occlusion of the fistula in all patients solely with Onyx®. Only one procedure and injection in only one pedicle (middle meningeal artery or anterior ethmoidal artery) was sufficient to close the fistula in these patients. Additionally, we had no complications and no patient deteriorated after treatment. All patients improved or had their symptoms resolved. One case at our series presented very tortuous feeders. It was not possible to navigate the microcatheter to reach a satisfactory position to inject Onyx. Based on previous reports, we decided to perform a small craniectomy to obtain access to the middle meningeal artery²⁹. We recognize that on these situations, a direct surgical approach could be an alternative.

Our series included only dural arteriovenous fistulas with direct cortical venous drainage (without venous sinus involvement) treated with Onyx®. We achieved a high rate of cure following some steps: [1] performing detailed angiographic study of the fistula (feeding artery, fistula point and draining vein well visualized), [2] selecting only dural arteriovenous fistulas with direct cortical venous drainage, [3] performing embolizations via a meningeal branch, [4] trying to reach the fistulous zone as close as possible or at least wedged into position, [5] performing very slow, intermittent injections, resulting in enhanced penetration into the fistula point and [6] avoiding reflux toward cranial base foramina. These points are critical for successful embolization.

Based on these findings, Onyx® showed to be effective and safe. While it allows a prolonged time of larger volume injections and predictable effect, its penetration reaches the feeding vessel more distally, occluding the exit vein and other feeders retrogradely. Despite its advantages, adverse effects may happen, such as catheter rupture or entrapment, angiotoxicity and undesired reflux^{23,24}.

According to Cognard et al.¹⁹, Onyx® injections were easier to control than NBCA injections. A much larger volume could be injected over a longer time period. Injection in a single feeder allowed obtaining arterioarterial reflux and avoided embolization of other feeders. Access through the meningeal artery was more efficient even if the size was very small. They suggested that Onyx can be used as a primary treatment option for most cases of DAVFs with direct CVR. Nogueira et al.²⁷ described that Onyx® appears to allow for embolization from more proximal locations than cyanoacrylate. This may be accomplished without compromising the Onyx® penetration into the fistula. They have used this technique in cases where unfavorable vascular anatomy prevents more distal microcatheterization. Another potential advantage of Onyx® over cyanoacrylate is that Onyx embolization may allow for the

occlusion of several different vessel feeders from a single pedicle. This avoids the time and repeated risk of subsequent catheterizations that may be required with NBCA.

For DAVFs with direct CVR (type III-IV) the transarterial approach with Onyx® is a new option.

In conclusion, we consider Onyx® a promising option in the management of dural arteriovenous fistulas with direct cortical venous drainage. It showed to be feasible, safe and effective. Long term follow-up and comparative studies are necessary to allow drawing conclusions on the superiority of this technique.

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