Available online at www.sciencedirect.com

ScienceDirect

Journal of the Chinese Medical Association 77 (2014) 184−189

www.jcma-online.com

Original Article

Transarterial Onyx embolization of intracranial dural arteriovenous fistulas: A single center experience

Chao-Bao Luo [a,b,c,*], Feng-Chi Chang [a,b], Michael Mu-Huo Teng [a,b], Chung-Jung Lin [a,b], Hsiu-Mei Wu [a,b], Wan-Yuo Guo [a,b], Cheng-Yen Chang [a,b]

[a] *Department of Radiology, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[b] *Department of Radiology, National Yang-Ming University School of Medicine, Taipei, Taiwan, ROC*
[c] *Department of Radiology, National Defense Medical Center, Taipei, Taiwan, ROC*

Received October 25, 2012; accepted October 30, 2013

Abstract

Background: Transarterial embolization of intracranial dural arteriovenous fistulas (DAVFs) is usually associated with inadequate embolization. The purpose of this study was to report our experience of transarterial Onyx embolization of intracranial DAVFs with an emphasis on treatment outcome with this new embolic agent in different types of DAVFs.
Methods: In the past 3 years, a total of 14 intracranial DAVFs have been treated by transarterial Onyx embolization. Among these, there were nine males and five females, aged from 30 years to 82 years (mean = 62 years). We retrospectively analyzed the injection volume and time of Onyx embolization as well as outcomes in different types of DAVFs.
Results: The locations of the DAVFs were sigmoid sinus ($n = 6$), tentorium ($n = 3$), sinus confluence ($n = 2$), transverse−sigmoid sinus ($n = 1$), sigmoid sinus−jugular bulb ($n = 1$) and the superior petrous sinus ($n = 1$). The mean volume and time of Onyx injection were 3.4 mL and 28 minutes, respectively (Cognard type I: 4.9 mL, 40 minutes; type II: 4.5 mL, 34 minutes; type III: 2.2 mL, 21 minutes; type IV: 2 mL, 22 minutes). Total fistula occlusion was achieved in six out of seven patients of type III and type IV DAVFs, and in four out of seven patients of type I and type II DAVFs. Nine patients had total resolution of their symptoms, whereas partial regression occurred in five patients. No significant periprocedural complication was found. Mean clinical follow-up period was 16 months.
Conclusion: Transarterial Onyx embolization of intracranial DAVFs is safe and effective. This technique is particularly useful in type III and type IV DAVFs with a high cure rate, and lower volume of Onyx as well as a short injection time.

Keywords: dural arteriovenous fistula; endovascular embolization; Onyx

1. Introduction

Intracranial dural arteriovenous fistulas (DAVFs) are uncommon lesions, comprising only 15% of all cerebrovascular malformations.[1] The symptoms and natural history of DAVFs are determined by lesion locations and patterns of venous drainage. Aggressive DAVFs with cortical venous drainage are high-risk lesions usually presenting with nonhemorrhagic or hemorrhagic neurological deficits.[2,3] The goal of treatment of aggressive DAVFs is total fistula occlusion. On the contrary, benign DAVFs with antegrade dural sinus flow often present with a seemingly benign course, such as pulsatile tinnitus, and are typically managed by conservative or symptomatic treatment. Since the advent of the Onyx, transarterial Onyx embolization (TAOE) of DAVFs with morphologic cure has become feasible[4−8]. However, the effect of TAOE in different types of intracranial DAVFs has not yet been sufficiently evaluated.

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Chao-Bao Luo, Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: cbluo@vghtpe.gov.tw (C.-B. Luo).

1726-4901/$ - see front matter
http://dx.doi.org/10.1016/j.jcma.2014.01.004

The purpose of this study was to report our experiences with TAOE involving intracranial DAVFs, highlighting the use of this new embolic agent.

2. Methods

From February 2009 to August 2012, a series of 43 patients with 49 intracranial DAVFs were referred to our institute for endovascular embolization. Within this patient database, there were 35 DAVFs (cavernous sinus DAVF = 25, lateral dural sinus = 10) that underwent transvenous coil packing. TAOE was performed on the other 14 DAVFs involving sinus confluence, transverse, sigmoid sinus, or jugular bulb, or involving two locations. Final treatment decision regarding procedural access routes and selection of embolic materials depended on angioarchitecture analysis and hemodynamic of the DAVFs. If the affected dural sinus was nonfunctional arising from venous drainage or occlusion, we opted for transvenous coil packing. By contrast, if the involved dural sinus was patent and/or functional, TAOE was selected. Of these 14 patients, there were nine males and five females, aged from 30 years to 82 years (mean = 62 years). Prior to initiation of this article, informed consent was obtained from all 14 patients. The clinical manifestations were headache (n = 4), cognitive decline (n = 4), tinnitus (n = 4), intracerebral hemorrhage (n = 2), facial numbness (n = 1), limb weakness (n = 1), and seizure (n = 1), as well as consciousness change (n = 1).

TAOE procedures of the DAVFs were performed by a transfemoral artery approach under general anesthesia. Systemic intravenous heparinization was achieved by administering an intravenous bolus of heparin (3000 International Units). Activated clotting time measurements were performed every 30 minutes during the procedure and clotting time was maintained at a value that was approximately twice the baseline. A 5- or 6-F guiding catheter was positioned in the external carotid artery. An Onyx-compatible microcatheter (Rebar, Echelon, or Marathon, ev3 Inc., Irvine, CA, USA) was coaxially advanced into a feeding artery as close as possible to the fistula site. We used Onyx-18, the least viscous preparation, for all patients. Onyx injection was performed according to the plug-creating technique as mentioned in previously published articles.[4–7] Prior to Onyx embolization, the microcatheter lumen was flushed with dimethyl sulfoxide (DMSO, ev3 Inc.). Then, Onyx was slowly injected into the parent artery under a fluoroscopic monitor. When Onyx reflux occurred, the injection was paused for 30 seconds–2 minutes. Usually, reflux may occur several times prior to Onyx advancing into the fistula site. Once Onyx advanced to the fistula site, it was slowly and continually injected. When the Onyx cast stopped advancement, we used small and short pulses of injection until the proximal draining veins were filled and all feeders were retrograde filled by Onyx casts. During the Onyx injection, digital subtraction angiography (DSA) was performed to check the fistula flow and intracranial hemodynamics. The end point of the procedure was complete fistula occlusion or Onyx reflux longer than 3–4 cm to the microcatheter without evidence of further advancement of Onyx into the fistula. An immediate post-embolization DSA was done after the procedure was completed to check the occlusion of the fistula. In terms of post-embolization follow-up, all patients were recommended to clinically follow-up every 1–2 months for 1 year. Imaging follow-up by magnetic resonance imaging (MRI) and angiography (MRA) were recommended every 6–12 months for 2 years and catheter angiography annually for 2 years.

3. Results

The clinical findings and treatment outcome of the 14 patients are summarized in Table 1. The locations of the fistulas were sigmoid sinus (n = 6, Fig. 1), tentorium (n = 3, Fig. 2), sinus confluence (n = 2), transverse–sigmoid sinus (n = 1), sigmoid sinus–jugular bulb (n = 1), and superior petrous sinus (n = 1). Regarding the type of DAVFs that were observed, Cognard type IB was found in two patients, type IIA in one patient, type IIA+B in five patients (Fig. 1), type III in four patients, and type IV in three patients (Fig. 2). All DAVFs were embolized in a single session. Single feeder injection was performed in 11 patients, whereas three patients underwent two-feeder injections. The injection feeding pedicle was the occipital artery (n = 11), middle meningeal artery (MMA, n = 5) and/or ascending pharyngeal artery (n = 1). The mean volume and injection time of Onyx were 3.4 mL and 28 minutes, respectively. In terms of mean volume/time of injection of individual DAVFs, type I was in 4.9 mL/40 minutes, type II was 4.5 mL/34 minutes, type III was in 2.2 mL/21 minutes, and type IV was in 2 mL/22 minutes (Table 2). In 12 cases, removal of the microcatheter was uneventful; in two patients with longer injection time (45 minutes, 38 minutes) with long segments of Onyx reflux (4 cm, 3.5 cm), asymptomatic disruption and retention of the distal segment of the microcatheter to feeders of external carotid arteries were found. Complete fistula occlusion was achieved in 10 patients (Figs. 1 and 2), whereas partial embolization occurred in four patients. Of the four partial embolizations, two were type IIA+B, and after embolization one was regraded to type IIA. Another one was regraded to type IA; an additional two patients underwent radiosurgery (Gamma Knife) and one was cured by the 24-month follow-up, whereas one patient was still waiting for the effect of radiosurgery. Regressive clinical manifestation was found in all patients, with complete regression in eight patients and partial regression in six patients. No significant procedure-related neurological complications, such as intracranial hemorrhage or infarction or cranial nerve impairment, were observed in any of the 14 patients. No recurrent or new DAVFs were demonstrated in the follow-up MRI/MRA (n = 12). Only one patient had follow-up DSA and showed no evidence of recurrent DAVFs. All patients were clinically followed up for an average of 16 months (range = 6–36 months).

4. Discussion

Previous series have shown that the cure rate of DAVFs varied from 62.5% to 100% by TAOE.[4–8] The injection time

Table 1
Demographic and clinical outcomes in 14 patients with intracranial DAVFs after transarterial Onyx embolization.

Patient/sex/age (y)	Clinical manifestations	Cognard DAVF grading	DAVF location	Injection artery	Volume of Onyx injection (mL)	Injection time (min)	Angiographic outcome	Complication	Clinical follow-up (mo)
1/M/37	Headache, dizziness, pulsatile tinnitus	IIA+B	Sigmoid sinus	OA	5.1	30	Morphologic cure	Nil	11
2/M/82	Cognitive decline	III	Sinus confluence	OA	2.8	13	Morphologic cure	Nil	5
3/M/58	Facial numbness	IV	Tentorium	MMA	1.4	19	Morphologic cure	Nil	8
4/M/79	Tinnitus	III	Sigmoid sinus	OA	3	25	Morphologic cure	Nil	19
5/M/30	Tinnitus	IIA	Sigmoid sinus	OA	3.5	39	Morphologic cure	Nil	14
6/M/58	Limb weakness	IV	Tentorium	MMA	2.9	22	Morphologic cure	Nil	10
7/F/73	Cognitive decline	IIA+B	Sigmoid sinus	OA	3.4	31	Morphologic cure	Nil	15
8/F/68	Headache	III	Transverse−sigmoid sinus	MMA	0.8	16	Morphologic cure	Nil	24
9/M/49	Conscious change, ICH	IV	Superior petrous sinus	MMA, OA	1.8	25	Partial embolization	Nil	24
10/F/74	Headache, pulsatile tinnitus	IB	Sigmoid sinus, Jugular bulb	APA, OA	5.6	38	Morphologic cure	Catheter disruption	17
11/F/65	Headache	IB	Sigmoid sinus	OA	4.2	42	Partial embolization	Nil	12
12/M/75	Cognitive decline, ICH	IIA+B	Sigmoid sinus	OA	2.8	25	Partial embolization	Nil	31
13/M/73	Cognitive decline	IIA+B	Sinus confluence	Bilateral OA	7.5	45	Partial embolization	Catheter disruption	24
14/F/48	Seizure	III	Tentorium	MMA	2.1	28	Morphologic cure	Nil	6

APA = ascending pharyngeal artery; DAVF = dural arteriovenous fistula; ICH = intracerebral hemorrhage; MMA = middle meningeal artery; OA = occipital artery.

varied from 17 minutes to 29 minutes.[8] In our series, the total fistula occlusion was achieved in 10 out of 14 patients (71%), which is comparable with previously reported outcomes; particularly, in type III and type IV DAVFs, in which six out of seven DAVFs were cured. One failure to achieve total fistula occlusion was presumed to be insufficient reflux of Onyx because of inexperience in the first case of this series. On the contrary, in seven DAVFs with type I and type II, only four fistulas achieved total occlusion. Relatively, the lower cure rate was assumed to be due to more dural feeders and larger fistula flow than those in type III and type IV. Another factor is the aim of TAOE to embolize the fistula retaining affected sinus patency, particularly in type I, or to reverse aggressive DAVFs to more benign behavior. We usually stop the procedure when Onyx advances to sinus after many attempts. Regarding the injection volume and TAOE time, these were largely dependent on the number of feeders and fistula flow. In our series, the mean volume and time of Onyx injection in type I and type II are significantly higher than those in type III and type IV (4.6 mL vs. 2.1 mL, 36 minutes vs. 21 minutes, respectively). These results were attributed to more dural feeders, larger fistula flow in type I and type II than those in type III and type IV.

The definitive treatment of DAVFs requires the occlusion of the arteriovenous shunt without interfering with the normal venous drains. The treatment can be performed by conventional open neurosurgery, radiosurgery, or endovascular embolization. The main goal of endovascular treatment of DAVFs is total fistula occlusion or the elimination of high-risk features such as cortical vein drains or symptomatic treatment in benign DAVFs. In the past, to achieve an angiographic-proven cure with complete fistula occlusion, a transvenous approach with coil packing of affected dural sinus was selected. This technique is appropriate as long as the diseased segment of the sinus is occluded completely or does not participate in normal venous return. However, transvenous embolization is not always possible in cases with difficult fistula anatomy such as in isolated or high-grade stenotic dural sinus.[9,10] Transarterial approaches consist of superselective catheterization of the dural branches supplying the DAVF and by delivering the embolic agent (e.g., liquid adhesives or particles). However, the angiographic cure rate is low owing to numerous arterial feeders and the limited volume of injection of embolic materials.[11]

Onyx, a nonadhesive liquid embolic material, was initially introduced to treat brain arteriovenous malformation in 1999. In 2006, the first case of a DAVF successfully occluded by Onyx was reported.[12] Subsequently, other case reports and case series were published.[6−10,13] We started to use Onyx to embolize DAVFs in 2009; prior to this, we had several experiences with Onyx to embolize brain arteriovenous

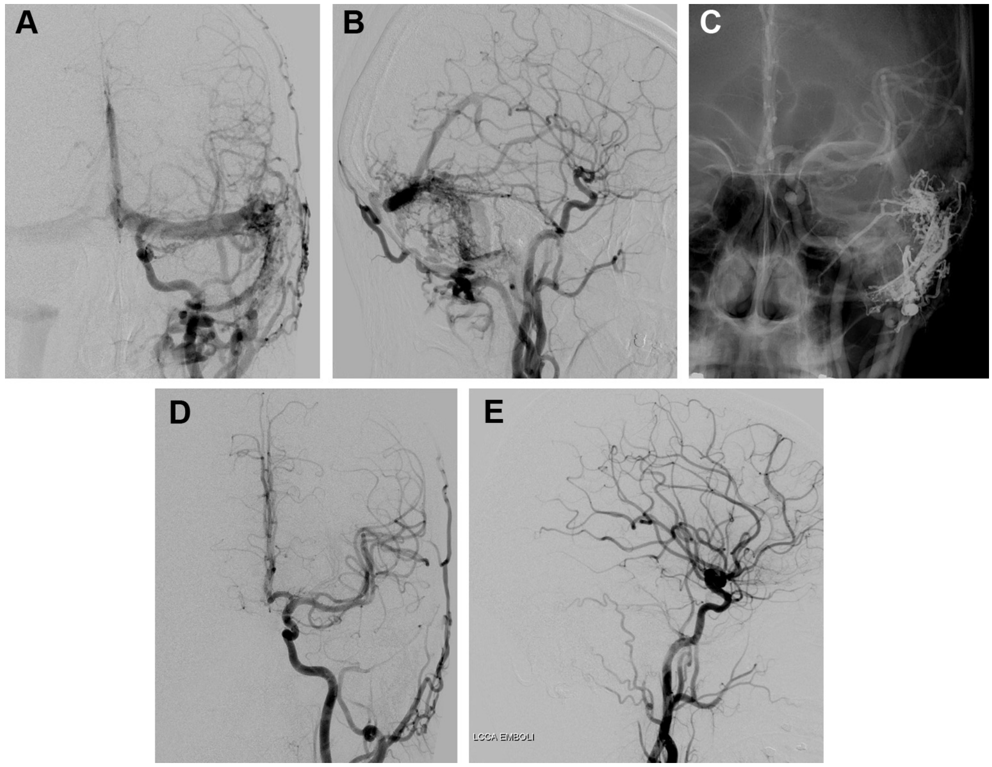

Fig. 1. A 37-year-old male had headache, dizziness, and pulsatile tinnitus. (A, B) Left carotid angiography revealed Cognard type II A+B dural arteriovenous fistulas (DAVFs) at the left sigmoid sinus mainly supplied by the occipital artery with retrograde reflux to the dural sinus and cortical vein. (C−E) Post-embolization angiography demonstrated Onyx cast with total occlusion of the DAVFs. The total volume and injection time of Onyx were 5.1 mL and 30 minutes, respectively.

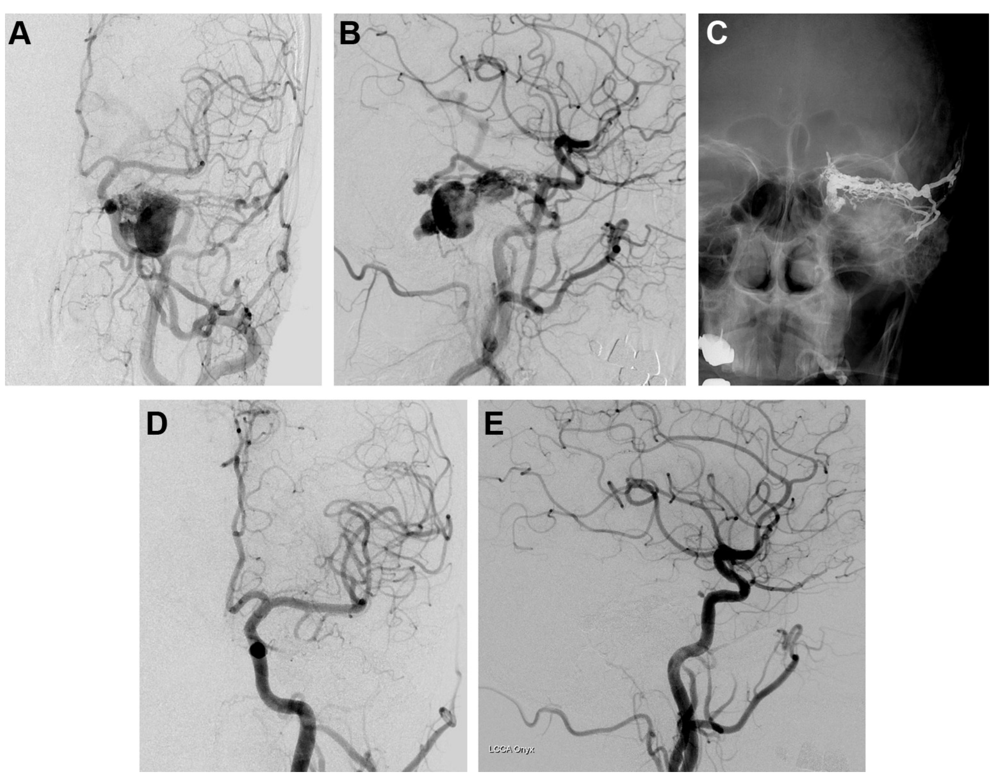

Fig. 2. A 58-year-old male had lower limb weakness. (A,B) Left carotid angiography revealed Cognard type IV dural arteriovenous fistulas (DAVFs) in the left tentorium fed by the middle meningeal artery and meningohypophyseal trunk with deep venous reflux associated with venous pouch. (C−E) Post-embolization angiography demonstrated Onyx cast with total occlusion of the DAVFs. The total volume and injection time of Onyx were 2.9 mL and 22 minutes, respectively.

Table 2
Mean volume and injection time of transarterial Onyx embolization in different types of DAVFs.

Type and number of DAVFs	Volume (mL)	Time (min)
Type I ($n = 2$)	4.9	40
Type II ($n = 5$)	4.5	34
Type III ($n = 4$)	2.2	21
Type IV ($n = 3$)	2	22
Mean	3.4	28

malformation. Our series included a wide spectrum of clinical presentations, and most of the DAVFs were located in the lateral dural sinuses. We attempted to occlude the fistula with the goal of preserving sinus patency and function.

Regarding the Onyx injection technique, the microcatheter tip should be navigated into a dural feeder as close to the fistula as possible. Usually, reflux is slowly built up with a 1−3-minute pause between injection attempts until the feeding artery is plugged. Then Onyx starts to advance into the fistula and draining veins. Sometimes from five to 15 attempts are needed prior to Onyx advancing. When a microcatheter is inserted into a branch of the external carotid artery, reflux of Onyx of 3−4 cm to the feeder can be accepted, although Onyx does not react with or stick to the vessel wall. After injections of longer than 30−40 minutes with a long segment of reflux, the microcatheter may be difficult to retrieve completely. In our series, there were two occasions of breaking and retention of a distal microcatheter into a feeder of the occipital arteries during retrieval, which were associated with greater than 35 minute injections and more than 3 cm reflux. Fortunately, there was no significant arterial injury such as dissection, rupture, or brain ischemia.

There are several advantages of TAOE in DAVFs. The main advantage is the ability to deliver a large volume of Onyx during a prolonged injection through a single pedicle.[6−10] The diffusion properties of the agent allow progressive filling of the arteriovenous network and veins with artery-to-artery retrograde migration of the agent. In many of our cases, a substantial portion of the lesion could be embolized from a single arterial injection because the agent successfully penetrated the depths of the fistula and then flowed into other arterial feeders. Onyx also offers the possibility of venous sinus packing/occlusion from an arterial side approach, which may be very helpful in cases with isolated dural sinus. The potential to backfill multiple feeding arteries from a single arterial injection is critical to the hypothesis that DAVFs may be cured by arterial embolization alone with the use of Onyx. However, Onyx embolization is associated with several disadvantages.[14] In very high-flow lesions or large-diameter vessels, Onyx, similar to any embolic agent, can migrate into the veins and embolize to the lungs resulting in a pulmonary embolism. Therefore, high-concentrated N-butyl cyanoacrylate (NBCA) or detachable coils may be more appropriate in those high-flow fistulas. Another consideration is the excess radiation exposure due to prolonged fluoroscopic duration.

Previous studies have shown that MMA is the most common route for Onyx injection and it can be readily catheterized to a distal position.[6−8] Long segments of arterial reflux can be accepted because microcatheter removal proved to be easy in such cases. However, ischemic injury to the trigeminal and facial nerve may occur with excessive proximal arterial reflux of Onyx beyond the foramen spinosum.[9] Inadvertent embolization of the ophthalmic artery leading to loss of visual acuity may occur via dangerous anastomosis. Therefore, the common complications of TAOE are related to MMA injection and include cardiac Onyx migration, reflexive bradyarrhythmia, transient visual hallucination, and transient or permanent cranial nerve palsy. Such complications may occur in up to 24−31% of patients undergoing TAOE.[9,11] Permanent neurological complications such as intracranial hemorrhage or ischemia are rare and occur in approximately 4−5% of patients.[6,13] In our series, we selected the occipital artery for Onyx embolization in 65% of feeding pedicle for injection, largely because most DAVFs were located in the posterior fossa and primarily fed by occipital artery. Another advantage of trans-occipital artery embolization is the comparative safety of the procedure when compared with trans-MMA, owing to the reduced risk of cranial palsy or through dangerous anastomosis to embolize pial vessels. The disadvantage of trans-occipital artery embolization is that most occipital arteries are tortuous and more difficult to catheterize; however, meticulous manipulation of the microcatheter with successful navigation of the microcatheter to the ideal site can usually be achieved in the majority of cases. In our initial experiences, there were no significant periprocedural complications.

In conclusion, although there was a lack of DSA follow-up, our initial experience shows that treatment of DAVFs by TAOE is effective and safe. This technique allows for the complete occlusion of the DAVFs in a single session in most cases. This technique is particularly useful in those DAVFs with Cognard type III and type IV owing to the lower volume of Onyx, short injection time, and high cure rate.

Acknowledgments

This work was supported in part by grants from Taipei Veterans General Hospital (V98C1-153, V99C1-012) and the National Science Council (NSC97-2314-B-075-062-my2, NSC99-2314-B-075-045-my2)

References

1. Newton TH, Cronqvist S. Involvement of dural arteries in intracranial arteriovenous malformations. *Radiology* 1969;**93**:1071−8.
2. Borden JA, Wu JK, Shucart WA. A proposed classification for spinal and cranial dural arteriovenous fistulous malformations and implications for treatment. *J Neurosurg* 1995;**82**:166−79.
3. Cognard C, Gobin YP, Pierot L, Bailly AL, Houdart E, Casasco A, et al. Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. *Radiology* 1995;**194**:671−80.
4. Carlson AP, Taylor CL, Yonas H. Treatment of dural arteriovenous fistula using ethylene vinyl alcohol (Onyx) arterial embolization as the primary modality: short-term results. *J Neurosurg* 2007;**107**:1120−5.
5. Maimon S, Nossek E, Strauss I, Blumenthal D, Frolov V, Ram Z. Transarterial treatment with Onyx of intracranial dural arteriovenous

fistula with cortical drainage in 17 patients. *Am J Neuroradiol* 2011;**32**:2180–4.

6. Lv X, Jiang C, Li Y, Wu Z. Embolization of intracranial dural arteriovenous fistulas with Onyx-18. *Eur J Radiol* 2010;**73**:664–71.
7. MacDonald JHM, Millar JS, Barker CS. Endovascular treatment of cranial dural arteriovenous fistulae: a single-centre, 14-year experience and the impact of Onyx on local practice. *Neuroradiology* 2010;**52**:387–95.
8. van Rooij WJ, Sluzewski M. Curative embolization with Onyx of dural arteriovenous fistulas with cortical venous drainage. *Am J Neuroradiol* 2010;**31**:1516–20.
9. Luo CB, Teng MMH, Chang FC, Guo WY, Chang CY. Transorbital direct puncture of posterior cavernous sinus through the ICA for embolization of isolated cavernous sinus dural arteriovenous fistula. *J Neurointerv Surg* 2013;**5**:e1.
10. Luo CB, Teng MMH, Chang FC, Lin CJ, Chang CY. Direct puncture of a prematurely detached balloon in the supraclinoid ICA via optic canal during embolisation of traumatic carotid-cavernous fistulae. *Acta Neurochir (Wien)* 2010;**152**:321–4.
11. Liu CA, Chen HC, Luo CB, Guo WY, Teng MMH, Chen SH, et al. Dural sinus malformation with arteriovenous fistulae in a newborn: positive outcome following endovascular management. *J Chin Med Assoc* 2012;**75**:43–6.
12. Rezende MT, Piotin M, Mouayer C, Spelle L, Abud DG, Moret J. Dural arteriovenous fistula of the lesser sphenoid wing region treated with Onyx: technical note. *Neuroradiology* 2006;**48**:130–4.
13. Lv X, Jiang C, Li Y, Wu Z. Results and complications of transarterial embolization of intracranial dural arteriovenous fistulas using Onyx-18. *J Neurosurg* 2008;**109**:1083–90.
14. Adamczyk P, Amar AP, Mack WJ, Larsen DW. Recurrence of "cured" dural arteriovenous fistulas after Onyx embolization. *Neurosurg Focus* 2012;**32**:1–7.