Intraarterial and Intravenous Treatment of Transverse/Sigmoid Sinus Dural Arteriovenous Fistulas

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Summary

Transverse/sigmoid sinus (TS) is the most common location for cerebral dural arteriovenous fistulas (DAVFs). Most of them are cured by venous embolization or a combination of arterial embolization and surgery/radiosurgery. Our goal was to reconsider the endovascular treatment strategy of TSDAVFs according to the new possibilities of arterial embolization using Onyx-18.

Nineteen patients with TSDAVFs were included in a prospective study between 2004 and 2007. Three of them had type I, four had type IIa, six had type IIa+b, three had type III, and three had type IV fistulas. Three presented with subarachnoid hemorrhage. The approach routes, angiographic results, complications, and clinical outcome were assessed. The mean clinical follow-up period was 32.5 months.

In one patient, the DAVF had been obliterated spontaneously at ten month follow-up. Complete angiographic cure was obtained in nine cases with one case of progressive thrombosis. Of these ten cures were achieved after a single procedure in seven out of ten patients who had not been embolized previously. Three patients were cured with sinus packing with prior arterial embolization. Among these 19 patients, 15 underwent follow-up angiography which confirmed the complete cure. Partial occlusion was obtained in nine patients, one was cured after additional surgery, and one underwent radio-

surgery. Hallucination occurred in one completely cured patient on day one.

Based on this experience, we believe that intraarterial Onyx may be the primary treatment of choice for patients with TSDAVFs. The applicability of this new embolic agent indicates the need for reconsideration of the treatment strategy for such fistulas.

Introduction

TSDAVFs are mostly abnormal communications between the dural branches of the internal and/or external carotid artery, the vertebral arteries, and the sinus. The connections between dural arteries and dural veins empty the sinus involved. The essential lesion of the DAVFs is within the sinus wall¹. Transvenous or direct sinus packing offer a radical and safer alternative to surgical treatment, but still require long-term follow-up². Conditions associated with the development of DAVFs include pregnancy, sinusitis, trauma, and surgery^{3,4}. TSDAVFs have been classified according to the type of cerebral venous drainage (the UCSF grading system)⁵. Intravenous sinus packing is an option for Grade 2 TSDAVFs without cortical venous drainage. For Grade 2 TSDAVFs with cortical venous drainage and Grade 3 TSDAVFs, we typically recommend surgical isolation of the sinus after intravenous embolization. Grade 4 lesions are treated by surgery after intraarterial embolization.

The goals of treatment are the prevention of risks and the elimination of symptoms caused by the arteriovenous shunt. In general, treatment of such fistulas primarily involves an endovascular approach, and if this fails, surgical or radiosurgical approaches are used⁶⁻¹⁶. The venous approach was first consideration previously and arterial embolization is added if needed^{9,17}.

The transvenous embolization approach should be chosen only after careful analysis of the angiograms, with both the arterial supply and venous drainage being noted^{9,13,18}. Resection or occlusion of a functionally dependent sinus can be associated with venous infarction. The sinus segment chosen for obliteration must not be necessary for normal venous drainage. Patients at lower risk have traditionally been treated more conservatively, with attempts at carotid artery compressive therapy or palliative arterial embolization. However, transarterial embolization using a new nonadhesive liquid embolic agent (Onyx-18, ev3, Irvine, CA, USA) seemed to change this modality⁷. We evaluated intraarterial and intravenous embolization techniques for the treatment of TSDAVFs.

Patients and Methods

The charts of 19 patients with TSDAVFs treated between 2004 and 2007 via different intraarterial and intravenous routes were retrospectively analyzed. Nineteen patients (six women and 13 men; age range 29-60 yrs; mean age, 43.4 yrs) demonstrated DAVFs located at the transverse/sigmoid sinus. Symptoms includ-

ed pulsatile tinnitus (n=9), headaches (n=4), visual disturbances (n=4) and chemosis (n=1). According to the classification (Table 1) described by Cognard et al¹⁸, the TSDAVFs were of Type I (n=3), Type IIa (n=4), Type IIa+b (n=6), Type III (n=3) and Type IV (n=3). Fifteen patients were monitored with intraarterial angiography.

The following parameters were recorded for each procedure: the type of every embolized pedicle, any clinical complications, and the immediate angiographic result.

Bilateral selective ICA and ECA angiography and vertebral artery angiography were performed for all patients, for assessment of the feeding arteries, the fistula sites and the venous drainage. All patients underwent endovascular treatment under general anesthesia. The anticoagulation protocol was 20 IU/kg of bolus heparin at the commencement of the procedure, then continuous infusion to keep the activated clotting time (ACT) at approximately twice the normal value. Intraarterial Onyx embolization is performed primarily. Intravenous sinus packing is an option for the affected sinus is isolated or exhibits prominent retrograde drainage to the cortical veins and is not a functional part of the venous circulation.

Intraarterial embolization technique A 6F guiding catheter placed in the parent artery (Envoy; Cordis, Miami Lakes, FL, USA); super-selective catheterization of ONE arterial feeder using a microcatheter compatible with Onyx

Table 1 The Cognard grading system.

Type I	located in the main sinus, with anterograde flow
Type II	located in the main sinus
Type IIa	with reflux into the sinus
Type IIb	with reflux into cortical veins
Type IIa+b	both
Type III	with direct cortical venous drainage without venous ectasia
Type IV	with direct cortical venous drainage with venous ectasia
Type V	with spinal venous drainage

Figure 1 Case 13. A 30-year-old man with SAH. A) The Cognard type IIa+b TSDAVF fed by the right MMA with cortical vein reflux. Note the fistula point (arrow). B) The right MMA is catheterized (arrowheads). C) Injection of 1.8 mL of Onyx over 17 minutes resulted in occlusion of the draining vein origin (arrow). D) Complete occlusion. E) Postoperative 7-month assessment shows complete fistula cure.

(Marathon, ev3, Irvine, CA, USA) on a guidewire (Mirage, ev3, Irvine, CA, USA); positioning of the microcatheter as close as possible to the origin of the draining vein; flushing of the microcatheter with saline (5 mL), filling of the dead space with 0.25 mL of dimethyl-sulfoxide (DMSO) and then slow injection of 0.25 mL of Onyx (over 40 seconds) to wash out the DMSO;

very slow injection of Onyx under subtraction fluoroscopy; and then removal of the microcatheter by rapid withdrawal¹⁹⁻²¹.

Intravenous embolization technique

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 positioned in the jugular vein. A microcatheter (Echelon, MTI-EV3, Irvine, CA, USA) was navigated coaxially via internal jugular approach. The microguidewire was then carefully introduced and advanced to the fistula portion, followed by the microcatheter, as described previously²². All embolizations were performed with electrically detachable coils and/or fiber coils, using real-time digital subtraction fluoroscopic mapping.

Follow-up

Follow-up angiography was obtained in 15 cases from three to ten months and clinical follow-up periods for this group ranged from four to 36 months.

Results

The clinical data, the results of diagnostic imaging, and the angiographic results are summarized in Tables 2 and 3.

No reflux

In our series three fistulas were Type I without venous reflux. Two patients reported a history of pulsatile tinnitus and one presented with subarachnoid hemorrhage (SAH). Arterial supply to the fistulas included the middle meningeal artery (MMA) (n=3), the post meningeal artery (PMA) (n=1), and the occipital artery (OA) (n=2). Two patients underwent transarterial embolization of the MMA with Onyx-18. In one of the three patients, postinterventional angiography showed complete occlusion of the fistula; one patient had residual shunt. The other patient was observed.

Reflux through the sinus

Ten fistulas were Type IIa and IIa+b with sinus reflux. Six patients reported a history of pulsatile tinnitus, three presented with visual disturbance, three had intracranial hemorrhage and two had headaches. Arterial supply to the fistulas included MMA (n=9), PMA (n=9), OA (n=10), the meningohypophyseal trunk (MHT) (n=6), the posterior auricular artery (PAA) (n=6), the superficial temporal artery (STA) (n=4), the lateral tentorial artery (LTA) (n=3), the internal maxillary artery (IMA) (n=2) and the superior cerebellar artery (SCA) (n=2).

A

Seven patients underwent transarterial embolization of the supplying arteries alone (Onyx-18). In three of those patients, postinterventional angiography showed complete occlusion of the fistula; four patients had residual shunt. A combination of transarterial and transvenous intervention was performed in three patients, postinterventional angiography showed complete occlusion of the fistula in three patients.

Reflux straight into a cortical vein

Six fistulas were Type III and IV with cortical vein reflux. One patient reported a history of pulsatile tinnitus, one presented with chemosis, two had intracranial hemorrhage and two had headaches. Arterial supply to the fistulas included MMA (n=7), PMA (n=3), OA (n=4), MHT (n=2), PAA (n=3), STA (n=2), the posterior cerebral artery (PCA) (n=2), the middle cerebral artery (MCA) (n=1) and the inferoposterior cerebellar artery (PICA) (n=1). Six patients underwent transarterial embolization of the supplying arteries alone (Onyx-18). In three of those patients, postinterventional angiography showed complete occlusion of the fistula; three patients had residual shunt. Additional treatments of radiosurgery and neurosurgery were performed for two patients.

Angiographic results at follow-up

Follow-up angiography was obtained three

Figure 2 Case 14. A 55-year-old man presented with intracranial hemorrhage. A) CT scan shows a hematoma in the right temporo-occipital lobe. B) Right external carotid angiogram, lateral projection, showing a TSDAVF of Cognard Type III the right TS draining superiorly into the dilated Trolard vein (arrows) to the superior sagittal sinus and draining inferiorly into the tentorial sinus (arrowheads) to the right TS. C) Catheterization of the right MMA allowed injection of 2 ml of Onyx into the right MMA and 1ml in right OA, with retrograde occlusion of other feeders (D). E) Postoperative 3-month assessment shows complete fistula cure.

Table2. Clinical features of patients who underwent intraarterial embolization.

Patient No.	Age/Sex	Presentation	Cognard Type	Suppliers	Venous drainage	Treatment strategy	Angiographic results	Complications	Follow-up	Clinical outcome (mRS)
1.	50/F	Headaches	IV	MMA(R),PCA(R) PICA(R)	CV, varix	TAE	Complete	None	24-month	0
2.	47/F	Tinnitus	I	MMA(L), PMA(B)	TSS	TAE	Complete	None	19-month	0
3.	33/M	Intracerebral Hemorrhage	III	MMA(R),PCA(R)	TSS BVR	TAE	Incomplete	None	19-month	0
4.	28/M	Tinnitus	I	MMA(L),OA(L)	TSS	TAE	Incomplete	Cardiac Onyx migration	18-month	1
5.	48/M	Tinnitus	IIa+b	MMA(B),STA(B) OA(B),PMA(B) MHT(B),PAA(B)	TSS SSS	TAE	Incomplete	None	14-month	1
6.	42/M	Homonymous Hemianopsia	IIa+b	PAA(L),OA(L)	TSS CV	TAE	Complete	None	14-month	1
7.	29/F	Tinnitus Blurred vision	IV	MMA(L),OA(L) PMA(L),MCA(L)	SVV, varix TSS	TAE Radiosurgery	Incomplete	None	12-month	1
8.	59/M	Tinnitus (L)	IIa	MMA(B),STA(B) OA(B),PMA(B) MHT(B),PAA(B) IMA(B)	TSS	TAE	Incomplete	None	12-month	1
9.	48/F	Headaches	III	MMA(B),STA(B) OA(B),PMA(B) MHT(B),PAA(B) BVR	SSS TSS	TAE	Incomplete Neurosurgery	None	12-month	1
10.	38/M	SAH	IIa	PMA(B)	TSS	TAE	Incomplete	None	11-month	0
11.	39/M	Chemosia	III	MMA(L), PAA(L) OA(L)	Labbe (L)	TAE	Complete	None	8-month	0
12.	33/M	Visual disturbance Tinnitus	IIa+b	MMA(L),OA(L) MHT(L)	TSS SSS	TAE	Incomplete	None	7-month	1

Patient No.	Age/Sex	Presentation	Cognard Type	Suppliers	Venous drainage	Treatment strategy	Angiographic results	Complications	Follow-up	Clinical outcome (mRS)
13.	30/M	SAH	IIa+b	MMA(R)	Labbe (dilated)	TAE	Complete	None	7-month	0
14.	55/M	Intracranial hemorrhage	IV	MMA(R)	MCV (varix)	TAE	Complete	None	6-month	0
15.	60/F	Tinnitus Blurred vision Hemorrhage	IIa+b	MMA(R), OA(R) MHT(R)	TSS	TAE	Complete	Hallucination	5-month	0
16.	40/M	SAH	I	MMA(R), OA(R)	TSS	None	Spontaneous thrombosis	None	10-month	0

M, male; F, female; BVR, basal vein of Rosenthal; SAH, subarachnoid hemorrhage; IMA, internal maxillary artery branches; MMA, middle meningeal artery branches; MHT, meningohypophyseal trunk branches; OA, occipital artery; PMA, posterior meningeal artery; PAA, posterior auricular artery; STA, superficial temporal artery; TAE, transarterial embolization; CV, cortical veins; SVV, superior vermis vein; mRS, modified Rankin Scale.

Table 3 Clinical features of patients who underwent intravenous embolization.

Patient No.	Age/Sex	Presentation	Cognard Type	Suppliers	Venous drainage	Treatment and Angiographic results	Complications	Follow-up	Clinical outcome (mRS)
17.	50/M	Headaches	IIa	LTA(L), OA(L) PMA(L)	TSS	TAE, left OA; TVE: left TSS; coils; success; complete	None	36-month	0
18.	40/M	Headaches tinnitus	IIa+b	LTA(R), PAA(R) OA(R), MMA(R) PMA(R), SCA(R)	Left TSS, right Labbe vein,	TAE: right OA, MMA; coils; success; incomplete TVE: left TSS coils, success, complete	None None	26-month	0
19.	56/F	Tinnitus	IIa	LTA(L), MMA(L) OA(L), PMA(L) SCA(R)	Right TSS	TAE:left OA; coils; success; incomplete TVE: right TSS Coils; success; complete	None	4-month	0

LTA, lateral tentorial artery; MMA, middle meningeal artery branches; OA, occipital artery; TVE, transvenous embolization; CV, cortical veins; SVV, superior vermis vein.

to ten months after the last treatment (embolization or surgery/radiosurgery) in 15 patients showing a complete cure in 11 of them (including one patient after surgery). The patient who underwent radiosurgery will be followed by angiography for three years. Three patients refused follow-up angiography.

Clinical complications

Cardiac Onyx migration in one patient with Type I TSDAVF was treated with thoracic surgery. One patient complained of hallucination on the day after arterial Onyx embolization and recovered spontaneously.

Clinical outcome

All patients returned to independent clinical status during the follow-up period, which ranged from four to 36 months (mean, eight months). Clinical outcome was graded according to the Rankin Score (mRS), modified as follows: 0 [neurologically intact, $n=12$ (63.2%)]; 1 [mild symptoms without neurological deficits that does not interfere with daily functioning or work, $n=7$ (36.8%)]. There was no morbidity.

Discussion

DAVFs have diverse clinical symptoms such as benign pulsatile tinnitus to seizures, visual disturbances, tinnitus, dementia and catastrophic intracranial hemorrhage^{1,3,15,23-27}. The most common symptoms of TSDAVFs were pulsatile tinnitus (81% of cases), headaches (15% of cases), and intracranial hemorrhage (10% of cases)²⁸. This series validated the cortical venous drainage grading system for pretreatment morbidity. The indication to treat a TSDAVF in the presented series was related to relevant clinical symptoms (e.g., pulsatile tinnitus) and/or to angiographic findings such as cortical venous drainage.

The management of DAVFs in general may include conservative treatment, stereotactic irradiation, endovascular intervention, and microsurgery^{16,18,29,30}. In the early 1990s, since the experience with intracranial coil placement was limited, the predominant endovascular procedure to treat TSDAVFs was transarterial embolization¹⁷. Feeding artery embolization of external carotid artery branches with particles or liquid embolic agents is easily performed and may reduce the arteriovenous shunt. However, complete cures are sometimes difficult to

achieve with this method because of the existence of feeding arteries that cannot be catheterized and the recruitment of blood supply from collateral arteries^{8,9}. Therefore, this approach is mostly used to relieve symptoms or in combination with other procedures such as transvenous embolization, surgery, or irradiation. Halbach et al⁹ reported on 17 patients who had transarterial embolization using a variety of occlusive agents, primarily NBCA, and ten (59%) of these patients were cured. In our series, we treated 16 patients with transarterial embolization alone with Onyx-18, which is now used as an alternative to cyanoacrylates in many brain arteriovenous malformations (AVMs).

The main advantage of Onyx is the ability to make a good penetration of the fistula via a long-duration injection through one pedicle^{31,32}. This results in progressive filling of the arteriovenous network and veins with arterio-arterial retrograde migration of the agent, which avoids the need for multiple catheterizations and embolizations. Indeed, we found that it was far more efficient to gain access through the middle meningeal artery, 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 Onyx progression^{7,31}. Literature series of transvenous (with or without transarterial) procedures reported complication rates between 10% and 42%^{17,33}. Our overall complication rate was 5.3% ($n=1$).

No reflux

In our series, we encountered three patients with pulsatile tinnitus or headache and a benign venous drainage (Cognard type I). Two were treated via transarterial approach and one was observed. This results in one postinterventional complete occlusion, one follow-up occlusion, and one residual shunt. Two of these three patients were clinically cured and another showed symptom relief.

The risk associated with the use of Onyx in treatment of TSDAVFs is excessive venous passage³⁴. The risk in these sinus-type DAVFs was migration of Onyx from the sinus to the arterialized draining veins, which may cause distal venous occlusion and consequent venous infarction or hemorrhage. In the present cases, Onyx migrated into the right cardiac ventricle via the internal jugular vein. Arterial emboliza-

tion can also be safe and effective to reduce the shunted blood flow and to facilitate subsequent transvenous embolization or surgery. Spontaneous regression of TSDAVFs is relatively rare (maximum 5% of patients) and usually occurs following a hemorrhage as in our patient³⁵.

Reflux through the sinus

In our series, we treated ten patients with sinus reflux (Cognard type II). Transarterial embolization alone was indicated in seven patients and in three patients as adjunctive therapy for transvenous coil embolization. The occlusion rate was 60%; 40% of these patients were clinically cured and another 60% showed symptom relief.

Reflux straight into a cortical vein

We treated six patients with dangerous venous drainage (Cognard type III and IV), which were not accessible by a transvenous approach. The occlusion rate was 50% (3/6).

Conclusions

Arterial Onyx embolization is now frequently used as the first treatment for TSDAVFs, and complete cure is possible. Onyx arterial embolization may be performed as an alternative to retrograde venous catheterization. A combination of arterial, venous and surgery as well as radiosurgery, if necessary, is then indicated to prevent intracranial hemorrhage.

References

- 1 Nishijima M, Kuwayama N et Al: Clinico-pathological study in patients with transverse-sigmoid sinus dural arteriovenous malformations. *J Clin Neurosci* 5(Sup1): 42-44, 1998.
- 2 Cognard C, Houdart E et Al: Long-term changes in intracranial dural arteriovenous fistulae leading to worsening in the type of venous drainage. *Neuroradiology* 39: 59-66, 1997.
- 3 Shah SB, Lalwani AK, Dowd CF: Transverse/sigmoid sinus dural arteriovenous fistulas presenting as pulsatile tinnitus. *Laryngoscope* 109(1): 54-58, 1999.
- 4 Tomio S, Katsumi H et Al: Postsurgical development of dural arteriovenous malformations after transpetrosal and transtentorial operations: case report. *Neurosurgery* 37(4): 820-825, 1995.
- 5 Lalwani AK, Kowd CF, Halbach VV: Grading venous restrictive disease in patients with dural arteriovenous fistulas of the transverse/sigmoid sinus. *J Neurosurg* 79: 11-15, 1993.
- 6 Caragine LP, Halbach VV et Al: Parallel venous channel as the recipient pouch in transverse/sigmoid sinus dural fistulae. *Neurosurgery* 53(6): 1261-1266, 2003.
- 7 Cognard C, Januel AC et Al: Endovascular treatment of intracranial dural arteriovenous fistulas with cortical venous drainage: New management using Onyx. *Am J Neuroradiol* 29: 235-241, 2008.
- 8 Friedman JA, Pollock BE et Al: Results of combined stereotactic radiosurgery and transarterial embolization for dural arteriovenous fistulas of the transverse and sigmoid sinuses. *J Neurosurg* 94: 886-891, 2001.
- 9 Halbach VV, Higashida RT et Al: Transvenous embolization of dural fistulas involving the transverse and sigmoid sinuses. *Am J Neuroradiol* 10: 385-392, 1989.
- 10 Hanaoka M, Satoh K et Al: Microcatheter pull-up technique in the transvenous embolization of an isolated sinus dural arteriovenous fistula. Technical note. *J Neurosurg* 104(6): 974-977, 2006.
- 11 Kakarla UK, Keshmukh VR et Al: Surgical treatment of high-risk intracranial dural arteriovenous fistulae: clinical outcomes and avoidance of complications. *Neurosurgery* 61: 447-459, 2007.
- 12 Luo CB, Chang FC et Al: Transcranial embolization of a transverse-sigmoid sinus dural arteriovenous fistula carried out through a decompressive craniectomy. *Acta Neurochir (Wien)* 149(2): 197-200, 2007.
- 13 Noguchi K, Kamisaki Y et Al: Dural arteriovenous fistula involving the transverse sigmoid sinus after treatment: assessment with magnetic resonance digital subtraction angiography. *Neuroradiology* 49: 639-643, 2007.
- 14 Terada T, Kinoshita Y et Al: Clinical use of mechanical detachable coils for dural arteriovenous fistula. *Am J Neuroradiol* 17: 1343-1348, 1996.
- 15 Toulgoat E, Mounayer C et Al: Transarterial embolization of intracranial dural arteriovenous malformations with ethylene vinyl alcohol copolymer (Onyx18). *J Neuroradiol* 33: 105-114, 2006.
- 16 van Dijk JMC, TerBrugge K et Al: Clinical course of cranial dural arteriovenous fistulas with long-term persistent cortical venous reflux. *Stroke* 33: 1233-1236, 2002.
- 17 Roy D, Raymond J: The role of transvenous embolization in the treatment of intracranial dural arteriovenous fistulas. *Neurosurgery* 40(6): 1133-1144, 1997.
- 18 Urtasun F, Biondi A et Al: Cerebral dural arteriovenous fistulas: percutaneous transvenous embolization. *Radiology* 199(1): 209-217, 1996.
- 19 Lv XL, Li YX et Al: A complex cavernous sinus dural arteriovenous fistula secondary to covered stent placement for a traumatic carotid artery-cavernous sinus fistula. *J Neurosurg* 108(3): 588-90, 2008.
- 20 Lv X, Li Y et Al: Transarterial embolization of dural arteriovenous fistulas of the anterior cranial fossa Onyx-18: Case report. *Neuroradiol J* 20(3): 53-59, 2007.
- 21 Lv X, Jiang C et Al: Transarterial embolization of tentorial dural arteriovenous fistulas with Onyx-18. *Neuroradiol J* 21: 406-414, 2008.
- 22 Lv X, Li Y, Wu Z: Endovascular treatment of the anterior cranial fossa dural arteriovenous fistulas. *Neuroradiology* 50: 433-437, 2008.
- 23 Irie F, Fujimoto S et Al: Primary intraventricular hemorrhage from dural arteriovenous fistula. *J Neurol Sci* 215: 115-118, 2003.

- 24 Men S, Idiman F et Al: Reversible cytotoxic edema associated with dural arteriovenous fistula: a case report. *Euro J Radiol* 52: 1-5, 2004.
- 25 Satoh K, Satomi J et Al: Cerebellar hemorrhage caused by dural arteriovenous fistula: a review of five cases. *J Neurosurg* 94(3): 422-426, 2001.
- 26 Satoh M, Kuriyama M et Al: Brain stem ischemia from intracranial dural arteriovenous fistula: case report. *Surg Neurol* 64: 341-345, 2005.
- 27 van Rooij WJ, Sluzewski M, Beute GN: Dural arteriovenous fistulas with cortical venous drainage: incidence, clinical presentation, and treatment. *Am J Neuroradiol* 28: 651-55, 2007.
- 28 Kirsch M, Liebig T et Al: Endovascular management of dural arteriovenous fistulas of the transverse and sigmoid sinus in 150 patients. *Neuroradiology* (2009), DOI 10.1007/s00234-009-0524-9.
- 29 Lv X, Zhong J et Al: Dural arteriovenous fistula involving the transverse sigmoid sinus presenting as chemosis: a case report. *Neuroradiol J* 21: 428-432, 2008.
- 30 Patrick RT, Harry JC et Al: Evolution of the management of the tentorial dural arteriovenous malformations. *Neurosurgery* 52: 750-762, 2003.
- 31 Anil A, Servet I: Treatment of a superior sagittal sinus dural arteriovenous fistula with Onyx: Technical case report. *Neurosurgery*, 59(1) ONS1: E169-E170, 2006.
- 32 Rezende MTS, Poitin M et Al: Dural arteriovenous fistula of the lesser sphenoid wing region treated with Onyx: technical note. *Neuroradiology* 48: 130-134, 2006.
- 33 Rivet DJ, Goddard JK et Al: Percutaneous transvenous embolization of a dural arteriovenous fistula through a mastoid emissary vein. Technical note. *J Neurosurg* 105(4): 636-639, 2006.
- 34 Lv X, Jiang C et Al: Complications related to percutaneous transarterial embolization of intracranial dural arteriovenous fistulas in 40 patients. *Am J Neuroradiol* 30: 462-468, 2009.
- 35 Luciani A, Houdart E et Al: Spontaneous closure of dural arteriovenous fistulas: report of three cases and review of the literature. *Am J Neuroradiol* 22: 992-996, 2001.

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