Transarterial and Transvenous Embolization for Cavernous Sinus Dural Arteriovenous Fistulae

J. ZHANG, X. LV, C. JIANG, Y. LI, X. YANG, Z. WU

Beijing Neurosurgical Institute, Beijing Tiantan Hospital, Capital Medical University; Beijing, China

Key words: cavernous sinus, dural arteriovenous fistula, embolization

Summary

We report on the safety and efficacy of transarterial and transvenous Onyx embolization in the treatment of dural arteriovenous fistulae (DAVFs) of the cavernous sinus.

We reviewed the findings from a retrospectively database for 22 patients with cavernous sinus DAVFs who were treated with either transarterial Onyx embolization alone ($n = 8$) or transarterial and transvenous Onyx embolization ($n = 14$) over a four year period. The mean follow-up period after endovascular treatment was 21.6 months (range 3-42 mths).

Total number of embolizations was 27 for 22 patients. Two patients were treated transvenously after transarterial embolization. All 22 patients (100%) experienced improvement of their clinical symptoms. All 22 patients (100%) experienced total obliteration of their DAVFs, as documented by angiography performed at a mean follow-up of 5.8 months after the last treatment. No patient experienced a recurrence of symptoms after angiography showed DAVF obliteration. One patient exhibited temporary deterioration of ocular symptoms secondary to venous hypertension after near total obliteration; one had transient V cranial nerve deficit related to transarterial embolization, and two patients exhibited transient III and VI cranial nerve weakness related to transvenous embolization. Two patients experienced recurrent symptoms after incomplete transarterial embolization and underwent transvenous embolization at three and four months. Both patients achieved clinical and angiographic cures.

Transarterial and transvenous embolization with Onyx, whenever possible, proved to be a safe and effective management for patients with cavernous sinus DAVFs.

Introduction

Cavernous sinus dural arteriovenous fistulae (DAVFs) are abnormal arteriovenous communications between dural branches of the internal carotid artery (ICA) and external carotid artery (ECA) and the cavernous sinus¹³. These fistulae arise spontaneously and generally affect the middle-aged population⁶. Cavernous sinus DAVFs occur less frequently than transverse/sigmoid sinus DAVFs and have a low risk of hemorrhage¹⁰. Patients with cavernous sinus DAVFs may develop an alarming symptom complex consisting of proptosis, chemosis, extraocular muscle palsies, and, sometimes, threatened visual loss resulting from either increased intraocular pressure or reduced ocular perfusion pressure^{1,4,22}. For these patients, rapid curative treatment is necessary to prevent visual deterioration, in addition to diplopia and intracranial bruits⁴. Management of cavernous sinus DAVFs has included observation, intermittent manual compression of the ICA, stereotactic radiosurgery, transarterial or transvenous embolization and neurosurgery^{8,10,11, 12,14,21,27}. Endovascular techniques have become the most common treatment for patients with symptomatic cavernous sinus DAVFs that do not spontaneously resolve, because of the high rates of cure after emboliza-

tion^{2,6,10,14,24}. However, embolization of cavernous sinus DAVFs has been reported to cause at least temporary ophthalmoplegia in eight to 50% of patients^{1,20}, and recanalization of embolized DAVFs is well documented²⁶. Direct surgical treatment is difficult and is associated with high rates of postoperative cranial nerve deficits²⁷. In addition, major morbidity related to occlusion of the ICA has been reported after neurosurgical treatment of cavernous sinus DAVFs²⁷. We report our experience with 22 patients using transarterial and transvenous Onyx embolization which provides rapid symptom relief and elimination of the fistula.

Patients and Methods

Patient population

Between March 2005 and March 2009, 24 consecutive patients with cavernous sinus DAVFs were encountered at Beijing Tiantan Hospital. Twenty-two (91%) patients were treated with endovascular transarterial and transvenous Onyx (MTI-EV3, Irvine, CA, USA) embolization with one (4.5%) regression after observation, and one (4.5%) was treated with radiosurgery. Twenty-two patients treated endovascularly were included in this study, including six women and 16 men. The clinical and angio-

E

F

Figure 1 Patient 1. A) Right ECA injection, lateral view. B) Left carotid artery injection, anteroposterior view. C) Superselective injection of the right MMA through a Marathon catheter. D) Fluoroscopic image after embolization, lateral view. E) Right carotid artery injection after embolization, lateral view. F) Right carotid artery injection performed 7 months after embolization, showing complete obliteration of the DAVF.

graphic characteristics of the patients are presented in Table 1. The median patient age was 49 years (range, 32–71 years). All patients exhibited symptoms resulting from the fistulae and had experienced failure of conservative management of one to three months for Cognard Type I fistulae. Two patients had experienced subarachnoid hemorrhage before the procedure. For four patients, cortical venous drainage was noted during diagnostic angiography.

Patient evaluation

All patients underwent ophthalmological examination by an ophthalmologist before treat-

ment. Objective tests of visual acuity and visual fields were performed to provide baseline data for comparison during follow-up monitoring. Because of the complexity of the DAVF cases referred to our institution, the available imaging results were reviewed by an interventional neuroradiologist before management decisions were made. Bilateral selective ICA, ECA, and vertebral artery angiographic series were essential for diagnosis and identification of all arterial supplies to the fistulae. Some patients required superselective branch-vessel angiography to establish the exact site of a fistula. For several patients we thought it necessary to repeat angiog-

raphy at our institution before decisions could be made regarding management. Cases of Cognard type I were treated conservatively for one to three months. The final decision to proceed with transarterial and transvenous embolization was made only after analysis of the clinical and imaging findings in each case.

Transarterial Onyx embolization

If there was an accessible arterial supply, transarterial Onyx embolization would be preferred. Transarterial procedures were performed with the patients under standardized general endotracheal anesthesia. Catheterization was performed via transfemoral approach using standard coaxial techniques. Systemic heparinization was achieved during the procedures with heparin 4000U bolus followed by 1000U of heparin every hour. The Marathon or Echelon10 microcatheters (MTI-EV3, Irvine, CA, USA) used for the embolization procedure were DMSO (dimethylsulfoxide) compatible. The microcatheter tip was placed as close as possible to the fistula region to ensure that the liquid embolic agent could penetrate and occlude the lesion. Once the microcatheter tip had been advanced to reach the optimal position, the injection of Onyx-18 was carried out as follows:

- 1) the microcatheter was flushed with 5 ml of normal saline;
- 2) 0.25 ml of DMSO was injected into the microcatheter to fill the dead space of the microcatheter;
- 3) Onyx was aspirated into a 1ml syringe, and the first 0.25 ml of Onyx injected slowly for 40 s to fill the microcatheter and replace the DMSO in the catheter dead space;
- 4) slow injection of Onyx was then performed under fluoroscopy. The procedure was completed as soon as a control angiogram revealed complete occlusion of the fistula or ONYX could not be filled antegradely.

Transvenous Onyx embolization

All embolization procedures were performed with the patient under general anesthesia. The arteriovenous shunts were approached via the venous routes of the facial vein or the inferior petrosal sinus. We first placed 6 French sheaths in the femoral artery and vein. A 5 French diagnostic catheter with continuous heparinized flush was positioned in the internal carotid artery for selective control angiograms. A 5 F guiding catheter was placed in the jugular vein

and, using road mapping technique and fluoroscopic guidance, a microcatheter (Echelon14/Marathon) was advanced over a guidewire (Silverspeed14/Mirage, MTI-EV3, Irvine, CA, USA) into the inferior petrosal sinus (IPS) or facial vein (FV) up to the fistula point. Onyx injection was performed without or with detachable platinum coils (GDC/Orbit, Cordis, Miami, USA; Microcomplex, Microvention, Aliso Vajo, USA) packed first to reduce the venous outflow.

The detachable coils were selected according to the volume of the cavernous sinus. Then, under biplane roadmapping, the catheter was slowly flushed with 0.25 ml of DMSO over 40 s and this was followed by injection of Onyx. In the meantime caution was exerted to avoid inadvertent embolization of the right internal carotid artery during the slow injection of Onyx. Patency of the internal carotid artery on the same side was checked frequently during the intermittent injection of the embolic material. The procedure was completed as soon as a control angiogram revealed complete occlusion of the fistula.

Follow-up

Clinical and angiographic assessments were attempted for all patients. Additional transvenous treatment was considered if the patients remained symptomatic after the transarterial procedures. Clinical follow-up data were available for all patients for a mean of 21.6 months after endovascular treatment (range 3-42 mths).

Figure 2 Patient 2. A) Left ECA injection, lateral view. B) Left ICA injection, lateral view. C) Super-selective injection of the cavernous sinus via a Marathon catheter, lateral view. D) Fluoroscopic image after embolization, lateral view. E) Left carotid artery injection after embolization, showing complete obliteration of the DAVF.

Results

Patient symptoms

Ocular symptoms related to venous congestion (chemosis or proptosis) resolved completely in all affected patients. Two patients with decreased visual acuity regained normal vision. Nine patients with preprocedural diplopia (caused by cranial nerve palsies) experienced normalization during follow-up monitor-

ing. Intracranial bruits ($n = 10$) and headaches ($n = 3$) were resolved for all patients. No patient experienced intracranial hemorrhage during the follow-up period.

Angiographic outcomes

All 22 patients (100%) experienced complete obliteration of their DAVFs, as demonstrated in follow-up angiograms in 20 patients obtained a median of six months after the last

endovascular treatment (range 4-10 mths). The remaining two patients treated transvenously were waiting for sixmonth follow-up angiography but are clinically cured.

Complications and additional treatments

Complications related to transarterial embolization procedures (n=11) occurred in one patient (9%) with transient V cranial nerve damage. Complications related to transvenous embolization procedures (n=16) occurred in three patients (19%). Two patients developed new VI and III cranial nerve pareses after transvenous embolization and recovered completely within four months respectively. One patient experienced deterioration of chemosis and proptosis after near total obliteration after transvenous embolization, which completely recovered at 11 months follow-up. Reflexive bradyarrhythmia, which was extinguished by intravenous administration of atropine, was discovered in three patients during transvenous Onyx embolization. Two patients with a Cognard type IIa fistula experienced chemosis and proptosis after transarterial embolization. Angiography performed after three months showed that the ECA supply

was gone but the ICA supply to the fistula persisted. These two patients were cured by additional transvenous embolization.

Illustrative cases

Patient 1

A 51-year-old woman presented with chemosis, proptosis, diplopia and headaches resulting from a right cavernous sinus DAVF (Figure 1). The Type D fistula received arterial supply from both the right and left ICA and ECA. Venous outflow was retrograde through the cortical venous drainage (Type IIa+b). The patient underwent transarterial embolization alone because it was thought that significant reduction of the arteriovenous shunting could be accomplished by transfemoral embolization with acceptable risk. Seven months after embolization, the headaches, chemosis and diplopia of the patient had recovered and angiography showed that the DAVF had been completely obliterated spontaneously.

Patient 2

A 51-year-old man presented with chemosis, proptosis resulting from a left cavernous sinus DAVF (Figure 2). The arterial supply was from the left ECA and ICA (Type D). Venous outflow was through the left superior ophthalmic vein, without cortical venous drainage (Type IIa). The patient underwent transvenous embolization. A Marathon microcatheter was advanced through the guiding catheter via the left facial vein up to the left superior ophthalmic vein and into the left cavernous sinus. Occlusion of the fistula was accomplished by filling the left cavernous sinus with 4.5 ml Onyx-34. There were no complications during the procedure. He was discharged three days after the procedure with symptoms improved.

Table 1 Clinical and angiographic characteristics of 22 patients with cavernous sinus DAVFs

Characteristic	No. of patients (%)	
	Transarterial N=8	Transvenous and transarterial N=14
Chemosis/proptosis	6 (75)	6 (43)
Cranial nerve palsy	1 (12.5)	8 (57)
Decreased vision	2 (25)	0 (0)
Intracranial bruits	3 (37.5)	7 (50)
Headaches	2 (25)	1 (7)
SAH	0	2 (14)
Cognard Type		
I	0 (0)	3 (21)
IIa	5 (62.5)	9 (65)*
IIa+b	2 (25)	1 (7)
III	1 (12.5)	1 (7)*

* Two patients underwent transvenous Onyx embolization with incomplete obliteration after transarterial Onyx embolization.

Discussion

It is accepted that cavernous sinus DAVFs are clinically benign lesions as some patients experience complete remission of their symptoms without any intervention⁸. Because of the low prevalence of aggressive symptoms and the relatively high rates (10%-50%) of spontaneous regression, it is suggested that cases of Cognard type I be treated conservatively for one to three months¹⁰. However, patients with Cognard Type IIa-III fistulae often require treatment to preserve visual

function and reverse the orbital venous congestion⁴. In this series there was cortical venous drainage in four patients, and bleeding occurred in two, meaning that the rate of intracranial bleeding in this particular type of lesion is very high (50%) and similar to other locations. The presence of cortical venous drainage is an indication for aggressive treatment. Treatment of cavernous sinus DAVFs includes transarterial and transvenous embolization, conservative observation and radiosurgery¹⁰. Direct surgical treatment is difficult and is associated with high rates of postoperative cranial nerve deficits²⁷.

Transarterial embolization

Techniques for permanent occlusion include transarterial embolization with NBCA and ONYX-18^{14,15,19,29}. Transarterial embolization can result in angiographic elimination and cure of an arteriovenous shunt in some instances of limited fistulae with the safety of an accessible blood supply of dural branches. We highlight several important caveats in the management of lesions of cavernous sinus¹⁵. Cavernous DAVF involve the anterior meningeal branch of the middle meningeal artery and the branches form the internal carotid artery. The anterior meningeal branch should be spared while using liquid embolic agent due to anastomoses between it and the ophthalmic artery to prevent filling of Onyx. The internal carotid artery can be protected by placing a Hyperglide balloon at the cavernous carotid artery or a diagnostic catheter to check the patency frequently. Temporary dilation of Hyperglide balloon can also be adopted in the pedicle of the middle meningeal artery so that Onyx reflux can be prevented and Onyx can be pushed into some small feeding vessels. But this may cause transient V and VI cranial nerve deficit after the procedure¹⁵. In our series, this occurred in one patient who recovered completely within a month. DAVFs treated by palliative transarterial embolization should be monitored closely because the low-risk drainage patterns of DAVFs developed into high-risk patterns with progressive thrombosis or restriction of the cavernous sinus outlet. When transarterial embolization was deemed not possible or of little benefit, transvenous embolization is the treatment of choice.

Transvenous embolization

Although there are different transvenous routes to the cavernous sinus, i.e., by way of

the inferior petrosal sinus, contralateral inferior petrosal sinus, basilar plexus or circular sinus, through the facial vein, angular vein, superior ophthalmic vein, superior petrosal sinus, or through the pterygoid plexus, the facial vein and the inferior petrosal sinus are frequently used^{3,5,9,10,21,23,25,28}. Transvenous embolization is currently our treatment of choice for symptomatic DAVF of the cavernous sinus that require prompt therapy. For sequential occlusion and for planning the venous approach, the drainage system of symptomatic and progressive DAVFs must be carefully analyzed with respect to the drainage of the brain and anatomic variants. When catheterization is possible, transvenous embolization is associated with a high rate of permanent long-term occlusion^{6,25}. To achieve complete occlusion, the cavernous sinus was tightly packed with GDC or a combination with NBCA¹⁰. The complex nature of the fistula, the unexpected difficulty in the placement of detachable coils, and our previous experience with transarterial Onyx embolization in the treatment of DAVFs promoted us to use Onyx transvenously in the treatment of our patient⁷. We have described a liquid embolic system (Onyx) for transvenous embolization of DAVFs of the cavernous sinus. Onyx-34 is usually used intravenously because it is more viscous than Onyx-18^{6,7}. This higher viscosity makes it more stable in the cavernous sinus. Its nonadhesive and cohesive properties make this agent suitable for transvenous casting of the cavernous sinus.

The nonadhesive property makes Onyx a more controllable agent than NBCA¹⁵. The slow injection of Onyx might have been the key factor that keeps gradual casting of the cavernous sinus, with filling of its interstices and blocking of the minute fistulous communications without occlusion of the draining vein. Before the cavernous sinus is filled, we think that the Onyx will not permeate into the carotid artery due to low pressure. There are several DMSO compatible microcatheters: Marathon, Echelon14 and Ultraflow. In our cases, we generally used Marathon and Echelon14 and they are used for different venous approaches.

Inferior petrosal sinus approach

If the dural fistula is posterior and drainage is mainly posterior, through the inferior petrosal sinus (IPS), this route may be used to access the cavernous sinus. When the IPS is visualized on the angiogram, an approach through it is a

relatively safe procedure that can be performed with a high degree of success. From this point of view, we prefer to use Onyx-34 in combination with platinum coils. We usually use 5mm or 6mm coils in diameter and the coils are Onyx placed at the origin of ophthalmic vein. In this situation, distal migration of Onyx to the ophthalmic vein can be avoided.

Facial vein approach

If the dural fistula is drained anteriorly, through the superior ophthalmic vein (SOV) and facial vein (FV), this route may be used to access the cavernous sinus if the IPS is not visible on the angiogram. For this long and tortuous route, we prefer to use a Marathon catheter. This caliber of the Marathon is so small that it cannot be used to deliver coils. Onyx-34 was the only embolic agent under this circumstance. The tip of the microcatheter should reach the posterior part of the fistula, Onyx injection should be slow and should be kept in the cavernous sinus.

Radiosurgery

Patients without any accessible arterial and venous approaches can be treated using gamma knife radiosurgery, complete obliteration can be achieved in 80%-90% cases of cavernous sinus DAVFs, obtained six to 15 months after radiosurgery (23).

Complications

The rates of temporary and permanent neurological deficits related to transarterial and transvenous Onyx embolization were 18.2% and 0%, which seems better than that (10% and 5%, respectively) related to radiosurgery management²³. We think that our results compare quite favorably with recent studies of endovascular treatment of patients with cavernous sinus DAVFs.

Miller et al reported the results of ten patients with Types B to D cavernous sinus DAVFs treated transvenously, several patients (number not specified) experienced transient ocular motor dysfunction; one patient developed new VI cranial nerve weakness, which did not resolve and necessitated later strabismus surgery²⁰. Roy and Raymond treated 12 patients with cavernous sinus DAVFs treated with either a transarterial, transvenous or combined endovascular approach, transient VI cranial nerve weakness was observed for five patients (42%); one patient experienced permanent abducens palsy²⁵.

Reflexive bradycardia during the procedure

Another problem of transvenous use of Onyx to treated cavernous sinus DAVFs is reflexive bradycardia, which occurred in three patients (21%). Injection of Onyx is likely to provide a chemical stimulation or ongoing mass effect causing reflexive bradyarrhythmia; this reflex was blocked with atropine and did not recur even after the atropine dissipated^{16,17}. However, in some author's experience, atropine may not always work³⁰.

Conclusions

Transarterial and transvenous Onyx embolization provided high cure rates for patients with cavernous sinus DAVFs. Transarterial embolization alone was effective for patients with DAVFs whose arterial supply was accessible via a transarterial approach. Transvenous Onyx embolization was effective for patients with DAVFs whose arterial supply was not accessible via a transarterial approach or not cured after transarterial embolization.

References

- 1 Aihara N, Mase M, Yamada K, et al. Deterioration of ocular motor dysfunction after transvenous embolization of dural arteriovenous fistula involving the cavernous sinus. *Acta Neurochir.* 1999; 141: 707-710.
- 2 Benndorf G, Bender A, Campi A, et al. Treatment of a cavernous sinus dural arteriovenous fistula by deep orbital puncture of the superior ophthalmic vein. *Neuroradiology.* 2001; 43: 499-502.
- 3 Benndorf G, Bender A, Lehmann R, et al. Transvenous occlusion of dural cavernous sinus fistulas through the thrombosed inferior petrosal sinus: report of four cases and review of the literature. *Surg Neurol.* 2000; 54: 42-54.
- 4 Goldberg RA, Goldey SH, Duckwiler G, et al. Management of cavernous sinus-dural fistulas. Indications and techniques for primary embolization via the superior ophthalmic vein. *Arch Ophthalmol.* 1997; 115 (6): 823-824.
- 5 Jahan R, Gobin YP, Glenn B, et al. Transvenous embolization of a dural arteriovenous fistula of the cavernous sinus through the contralateral pterygoid plexus. *Neuroradiology.* 1998; 40: 189-193.
- 6 Jiang C, Lv X, Li Y, et al. Transvenous treatment of cavernous sinus dural arteriovenous fistulae with Onyx and coils. *Neuroradiol J.* 2008; 21: 415-422.
- 7 Jiang C, Lv X, Li Y, et al. Transvenous embolization of cavernous sinus dural arteriovenous fistula with Onyx-18 and platinum coils: Technical Note. *Neuroradiol J.* 2007; 20 (3): 47-52.
- 8 Kai Y, Hamada J, Morioka M, et al. Treatment of cavernous sinus dural arteriovenous fistulae by external manual carotid compression. *Neurosurgery.* 2007; 60: 253-258.
- 9 Kazekawa K, Iko M, Sakamoto S, et al. Dural AVFs of the cavernous sinus: transvenous embolization using a direct superficial temporal vein approach. *Radiation Medicine.* 2003; 21 (3): 138-141.
- 10 Kiyosue H, Hori Y, Okahara M, et al. Treatment of intracranial dural arteriovenous fistulas: current strategies based on location and hemodynamics, and alternative techniques of transcatheter embolization. *Radiographics.* 2001; 21 (6): 1637-1653.
- 11 Krisht AF, Burson T. Combined pretemporal and endovascular approach to the cavernous sinus for the treatment of carotid-cavernous dural fistulae: technical case report. *Neurosurgery.* 1999; 44 (2): 415-418.
- 12 Kuwayama N, Endo S, Kitabayashi M, et al. Surgical transvenous embolization of a cortically draining carotid cavernous fistula via a vein of the sylvian fissure. *Am J Neuroradiol.* 1998; 19 (7): 1329-1332.
- 13 Leonard F, Jeffrey B, Nicholas JV. Cavernous sinus fistulas: carotid cavernous fistulas and dural arteriovenous malformations. *Curr Neurol Neurosci Rep.* 2003; 3 (5): 415-420.
- 14 Liu HM, Huang YC, Wang YH, et al. Transarterial embolization of complex cavernous sinus dural arteriovenous fistulae with low-concentration cyanoacrylate. *Neuroradiology.* 2000; 42: 766-770.
- 15 Lv X, Jiang C, Li Y, et al. Embolization of intracranial dural arteriovenous fistulas with Onyx-18. *Eur J Radiol.* 2009 Jan 12. [Epub ahead of print].
- 16 Lv X, Jiang C, Zhang J, et al. Complications related to percutaneous transarterial embolization of intracranial dural arteriovenous fistulas in 40 patients. *Am J Neuroradiol.* 2009; 30: 462-468.
- 17 Lv X, Jiang C, Li Y, et al. Percutaneous transvenous embolization of intracranial dural arteriovenous fistulae with detachable coils and/or in combination with Onyx. *Interventional Neuroradiology* 2008; 14: 415-427.
- 18 Lv X, Li Y, Lv M, et al. Trigemino-cardiac reflex in embolization of intracranial dural arteriovenous fistula. *Am J Neuroradiol.* 2007; 28: 1769-1770.
- 19 Lv XL, Li YX, Liu AH, et al. A complex cavernous sinus dural arteriovenous fistula secondary to covered stent placement for a traumatic carotid artery-cavernous sinus fistula. *J Neurosurg.* 2008; 108 (3): 588-90.
- 20 Miller NR, Monsein LH, Debrun GM, et al. Treatment of carotid-cavernous sinus fistulas using a superior ophthalmic vein approach. *J Neurosurg.* 1998; 83: 838-842.
- 21 Nakamura M, Tamaki N, Kawaguchi T, et al. Selective transvenous embolization of dural carotid-cavernous sinus fistulas with preservation of sylvian venous outflow. Report of three cases. *J Neurosurgery.* 1998; 89 (5): 825-829.
- 22 Oishi H, Arai H, Sato K, et al. Complications associated with transvenous embolization of cavernous dural arteriovenous fistula. *Acta Neurochir.* 1999; 141: 1265-1271.
- 23 Pollock BE, Nichols DA, Garrity JA, et al. Stereotactic radiosurgery and particulate embolization for cavernous sinus dural arteriovenous fistulae. *Neurosurgery.* 1999; 45: 459.
- 24 Quinones D, Duckwiler G, Gobin PY, et al. Embolization of dural cavernous fistulas via superior ophthalmic vein approach. *Am J Neuroradiol.* 1997; 18 (5): 921-928.
- 25 Roy D, Raymond J. The role of transvenous embolization in the treatment of intracranial dural arteriovenous fistulas. *Neurosurgery.* 1997; 40 (6): 1133-1144.
- 26 Satomci J, Satoh K, Matsubara S, et al. Angiographic changes in venous drainage of cavernous sinus dural arteriovenous fistulae after palliative transarterial embolization or observational management: a proposed stage classification. *Neurosurgery.* 2005; 56: 494-502.
- 27 Tu YK, Liu HM, Hu SC. Direct surgery of carotid cavernous fistulae and dural arteriovenous malformations of the cavernous sinus. *Neurosurgery.* 1997; 41 (4): 798-806.
- 28 Urtasun F, Biondi A, Casaco A, et al. Cerebral dural arteriovenous fistulas: percutaneous transvenous embolization. *Radiology.* 1996; 199 (1): 209-217.
- 29 Watanabe T, Matsumaru Y, Sonobe M, et al. Multiple dural arteriovenous fistulae involving the cavernous and sphenoparietal sinuses. *Neuroradiology.* 2000; 42: 771-774.
- 30 Amiridze N, Darwish R. Hemodynamic instability during treatment of intracranial dural arteriovenous fistula and carotid cavernous fistula with Onyx: preliminary results and anesthesia considerations. *J NeuroInterventional Surgery.* 2009; 1: 146-150.

Zhongxue Wu, MD
Beijing Neurosurgical Institute
No. 6, Tiantan Xili, Chongwen
Beijing, 100050
P.R.China
E-mail: ttyzjb@sina.com
lvxianli000@163.com