Selective Transvenous Embolization for Dural Arteriovenous Fistulas with the Aid of Superselective Venograms of Fistulous Drainages and Involved Sinuses

M. NAKAMURA, Y. NAKAMURA, A. FUJITA, E. KOHMURA

Department of Neurosurgery, Kobe University Graduate School of Medicine, Kobe; Japan

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Summary

For the treatment of transvenous embolization (TVE) of dural arteriovenous fistulas (DAVFs) the sites of arteriovenous shunts, fistulous drainage, and the pathological changes inside the affected sinuses were explored in detail by means of preoperative arteriograms, superselective arteriograms, and superselective venograms.

Out of 42 adult patients with DAVFs involving a total of 63 sinuses, three distinctive findings were identified as essential for indication of selective TVE for DAVFs. The first is extra-sinus fistulous drainage, which is embolizable fistulous drainage, remote from the major dural sinus, that flows into the sinus lumen. The second is intramural fistulous drainage, which is embolizable fistulous drainage located within the dural leafs of the involved sinus and separate from the major sinus lumen. The third consists of several lumens inside the affected sinuses, which suggests a variety of histological changes in the developmental process of sinus thrombosis and DAVFs. The extra-sinus drainage was occluded in three torcular herophili fistulas and three transverse sinus fistulas.

The intramural fistulous drainage was eliminated in three superior sagittal sinus fistulas. Several lumens inside the affected sinuses were encountered in 17 posterior fossa fistulas (68%)

and 10 cavernous sinus fistulas (34%). These distinctive findings were recognized in 52% of the DAVFs.

Out of various modalities for treatment of DAVFs, TVE has been the method of choice for the treatment of diffuse DAVFs. The TVE of DAVFs do not correspond to simple sinus occlusion, but imply selective occlusion of fistulous drainages and sinus lumens.

The recognition of these three distinctive types of fistulous drainages have clinical impact in that it helps to completely occlude all the fistulous components of fistulas as well as preserve or restore the normal venous outflow through the involved sinus.

Introduction

The symptoms of dural arteriovenous fistulas (DAVFs) have been related to the venous drainage of the fistulas¹⁻³. The classification and grading of DAVFs, also based upon the fistulous drainage and associated sinus occlusion, correspond to the clinical severity and indications for treatment^{4,5}. Various treatment options have been reported, including surgical resection of affected sinuses⁶, surgical disconnection of the cortical venous reflux⁷, surgical packing of the involved sinuses⁸, irradiation or stereotactic ra-

Figure 1 Typical dural arteriovenous fistula (A) and three distinct patterns of fistulous drainage (B,C,D).

A) Typical dural arteriovenous fistula (DAVF) consists of feeding arteries, arteriovenous shunts located within the dural leaflets of the major sinus, and fistulous draining veins initially running within the dural leaflets of the sinus and then draining into the involved sinus.

B) Extra-sinus fistulous drainage. Portions of the arteriovenous shunts are located in the dura matter or the tentorium, and the embolizable fistulous drainage, separate from the major dural sinus, drains into the sinus lumen.

C) Intramural fistulous drainage. Portions of the arteriovenous shunts are located within the dural leaflets of the major sinus, and the embolizable fistulous drainage located within the dural leaflets and separate from the major dural sinus lumen, connects the major sinus lumen. The lumen of the major sinus is not strongly associated with stenotic or pathological changes.

D) There are several lumens inside the major sinus, implying differences in the parts of arteriovenous shunts, in the number of separate lumens, in the haemodynamic relationship between the fistulas and the normal venous outflow.

diosurgery⁹, transarterial endovascular embolization¹⁰, transvenous embolization (TVE)¹¹, and combined options.

DAVFs with cortical venous reflux can be treated with surgical disconnection of the cortical venous reflux or transarterial glue injection, and once the cortical reflux has entered the isolated sinus, surgical packing or surgical resection of the affected sinus can cure the lesions. These types of fistulas generally comprise localized fistulas involving one sinus. Treatment of another type of DAVFs with diffusely in-

involved sinuses has been difficult, because surgical treatment involves significant blood loss and transarterial embolizations requires numerous sessions and has a low cure rate. TVE has been indicated for this diffuse type of DAVF, but this method is well known to result in occlusion of the affected sinuses. We have found that TVE does not always involve only sinus occlusion but results in profound technical difficulties, because findings have varied and formed complex combination when TVE is used for the treatment of the diffuse type of

Figure 2 52-year-old male presenting with visual disturbance. Pre-embolization left vertebral angiogram, antero-posterior projection (A), demonstrates the presence of several arteriovenous fistulas draining the left transverse sinus, one of which is targeted with transvenous embolization. Superselective venograms, antero-posterior projection (B) and lateral projection (C), show the separate fistulous drainage from the lumen of the transverse sinus, which may be the fistulous tentorial sinus or newly developed pathological sinus. Post-embolization left vertebral angiogram, antero-posterior projection (D), demonstrates disappearance of the fistula involving the distal part of the left transverse sinus.

DAVFs^{12,13}. We report here our specific findings regarding the sites of arteriovenous shunts and of fistulous drainages, as well as the pathological changes inside the involved sinuses, which are essential parameters in TVE treatment.

Subjects and Methods

Seventy two patients with a total of 96 dural arteriovenous fistulas (DAVFs) were treated between 1993 and 2001. The subjects include 42 adult patients who underwent the transfemoral

transvenous embolization approach. Thirteen patients had multiple lesions, with the number of affected sinuses in our patient group totaling 63, including 29 in the cavernous sinus, 13 in the transverse sinus, 12 in the sigmoid sinus, three in the sinus herophili, and six in the superior sagittal sinus. The patients comprised 17 men and 25 women, ranging in age from 40 to 82 years (mean, 62).

For the transfemoral transvenous approach, systemic heparinization was followed by the placement of 5 Fr introducers in the femoral

Figure 3 70-year-old male presenting with cerebellar infarction. Pre-embolization left vertebral angiogram, antero-posterior projection (A) and right common carotid angiogram, antero-posterior projection (B), demonstrating the presence of two lumens in the left transverse sinus; one located caudally (arrow), and the other rostrally (arrow head). Superselective venogram, antero-posterior projection (C), shows the caudal lumen inside the left transverse sinus (arrow) after occlusion of the rostral one (arrow head). Post-embolization right common carotid angiogram, antero-posterior projection (D), shows the two lumens occluded with the coils (arrow and arrow head).

artery and vein, and the introduction of 5 Fr guiding catheters, one into the common carotid or vertebral artery and one into the affected internal jugular vein. Selective arteriograms using biplane digital subtraction angiogram (DSA) equipment, superselective arteriograms, superselective venograms, and pressure monitoring were routinely performed during the TVE procedures.

An 18-microcatheter (Rapid Transit, Cordis Neurovascular, Miami Lakes, FL) with a 14-micro guidewire (Transend-14, Boston Scientific/Target, Boston, MA) were then introduced into the affected sinuses and superselectively into the fistulous drainages as close as possible to the arteriovenous shunts. Before starting the embolization procedures, superselective explo-

ration with the microcatheter and micro guidewire was performed to identify superselective structures and haemodynamic correlations among fistulous portions, fistulous drainage, both fistulous and non-fistulous lumens inside the involved sinuses, and the contribution of normal venous outflow. The initial target of embolization with coils (interlocking detachable coils, Boston Scientific/Target) was to occlude the fistulous drainages by separating them from the major sinus lumens. The major sinus lumens, which already received the normal venous outflow, were always preserved. When all the sinuses should be occluded, the fistulous lumens were first obliterated, followed by a diagnosis of whether the normal venous outflow from the brain could be restored.

When the normal venous outflow could drain off through any of the lumens inside the involved sinus during TVE, TVE was suspended, and subsequent transarterial embolization procedures or follow-up angiograms performed 1 month later were selected.

Distinctive superselective venographic findings were obtained and the frequencies depending upon the sites of the affected sinuses were calculated from the number of involved sinuses for which TVE was used. These sinuses included both successfully embolized cases and unsuccessful cases of transvenous introduction of the microcatheter into the isolated sinuses. The number of distinctive fistulous drainages and intra-sinus pathological changes could be determined only when the microcatheter could be placed into these drainages and inside the sinuses.

Results

Identification of the three distinctive findings (figure 1) is important for TVE procedures. DAVFs typically consist of numerous feeding arteries, arteriovenous shunts, and fistulous drainage (figure 1A). Although histological findings for posterior fossa DAVFs have proven that arteriovenous shunts are located within the dural leafs of the affected sinuses^{14,15}, DAVFs can originate in any intracranial or extracranial dural structures.

The three distinctive findings are: 1) extra-sinus fistulous drainage (figures 1B,2); portions of the arteriovenous shunts are located in the dura matter or the tentorium, and the embolizable fistulous drainage, remote from the major dural sinus, flows into the major sinus lumen. 2) Intramural fistulous drainage (figure 1C); portions of the arteriovenous shunts are located within the dural leafs of the major sinus, and the embolizable fistulous drainage, located within the dural leafs but separate from the major dural sinus lumen, is connected to the

Figure 4 50-year-old male presenting with unbearable tinnitus. Left common carotid angiogram, lateral projection (A), and superselective middle meningeal angiogram, lateral projection (B), transvenous embolization procedure demonstrate the presence of a residual fistula localized in the left transverse-sigmoid junction, where the coils have already placed. Superselective venogram, lateral projection (C), obtained through the microcatheter placed in the fistulous drainage located in a different lumen from the one occluded with the coils (arrow head).

Table 1 Frequency of occurrence of distinctive types of fistulous drainage in cases of transfemoral transvenous approach

Involved Sinus	No. of TVE Cases	Extra-sinus Drainage	Intramural Drainage	Several sinus Lumens	Extra-sinus Drainage + Several Sinus Lumens	Total
Cavernous Sinus	29	0	0	10 (34%)	0	10 (34%)
Sinus Heroplili	3	3 (100%)	0	0	0	3 (100%)
Transverse Sinus	13	—	0	6 (46%)	3 (23%)	9 (69%)
Sigmoid Sinus	12	0	0	8 (67%)	0	8 (67%)
Superior Sagittal Sinus	6	0	3 (50%)	0	0	3 (50%)
Total	63	3 (5%)	3 (5%)	24 (38%)	3 (5%)	33 (52%)

*TVE = transvenous embolization

major sinus lumen, which is not strongly associated with pathological changes. 3) Several lumens inside the sinus (figure 1D,3,4); There are several lumens inside the major sinus, implying differences in arteriovenous shunts, the number of separate lumens, haemodynamic patterns of the fistulas and the normal venous outflow.

Frequencies of distinctive fistulous drainages in cases with transfemoral transvenous approaches are shown in table 1. The extra-sinus fistulous drainage was occluded in three sinus heroplili fistulas (100%) and three transverse sinus fistulas (23%), while the intramural fistulous drainage was occluded in three superior sagittal sinus fistulas (50%). Several lumens inside the affected sinuses were encountered in nine transverse sinus fistulas (69%), eight sigmoid sinus fistulas (67%), and 10 cavernous sinus fistulas (34%). Out of a total of 63 lesions, distinctive patterns were diagnosed in 33 fistulas (52%).

Discussion

The venous drainage of DAVFs has been well documented, as have its relationships to clinical symptoms, pathophysiologic mechanisms, and angiographic grading. Awad¹ have reported that the presence of leptomeningeal venous drainage, variceal or aneurysmal venous dilatations, or galenic drainage correlate

significantly with aggressive neurological presentation. Brown² found that angiographic predictors of intracerebral haemorrhage include lesions of the petrosal sinus and straight sinus, a varix on a draining vein, or lesions draining into the leptomeningeal veins. Lasjaunias³ have reviewed the mechanisms responsible for the neurological deficits associated with DAVFs and postulated that the central nervous system symptoms of DAVFs are most likely due to passive venous hypertension and/or congestion rather than to arterial steal. Venous dysfunction can occur secondary to venous high flow, venous thrombosis, venous ischemia, venous mass effect, or venous rupture. Lalwani⁴ and Cognard⁵, have proposed a grading system based on fistulous drainage as well as the severity of the venous restrictive disease associated with DAVFs.

TVE is generally thought to simply occlude the affected sinuses, thus resulting in limited treatment indications for affected sinuses containing both fistulas and normal venous outflow. The authors have used TVE mainly for diffuse types of DAVFs, with the target of TVE being the fistulous drainages closest to the arteriovenous shunts. This procedure led to the recognition of three distinctive fistulous drainage. We previously reported two unusual cases with intramural fistulous drainage, which was successfully occluded with TVE in 1997¹².

These two patients represented our third and fourth clinical experience with TVE. Both patients featured all three types of fistulous drainage in their multiple DAVFs. As a result, we already recognized these types when we first introduced the TVE procedures. As a result, we have always used pre-embolization arteriograms as well as selective and superselective arteriograms, and superselective venograms to explore the fistulous portions, fistulous drainages, and relationships of fistulas and normal venous outflow during the TVE procedures. Our clinical experience shows that it is not a foregone conclusion that TVE only means simple sinus occlusion with coils and some other embolic materials.

When the DAVFs include extra-sinus or intramural fistulous drainage, the fistulas can be obliterated with a few coils while the major sinus lumen is preserved, resulting in immediate recovery of the impaired sinus function^{12,13}. Such drainage was occluded in the case of sinus herophili fistulas and superior sagittal sinus fistulas treated by us, in all of which the neighboring sinus lumen was patent and received the normal venous outflow.

In other words, we occluded the fistulas, only when they featured types of embolizable fistulous drainages. Three unsuccessfully treated superior sagittal sinus fistulas were managed with subsequent transarterial embolization and surgical isolation of the affected superior sagittal sinuses.

Several lumens inside the involved sinuses were the most frequently encountered findings in both cavernous and transverse/sigmoid sinus fistulas, and have been the key indication for complete occlusion of the fistulas. Several lumens may be the result of the process of sinus thrombosis and recanalization, which is now believed to be the major pathogenic mechanism of DAVFs^{16,17}. When the transvenous embolization procedures fail to completely occlude all the components of the involved sinus-

es, the residual components may contribute to dangerous cortical reflux and affect newly developing fistulas in the neighboring sinuses. Preembolization angiograms can not show all lumens inside the affected sinuses, making it quite difficult to preoperatively identify in detail the structure inside the involved sinuses. Because detailed evaluation of superselective venograms during TVE procedures can contribute to a precise identification of sinus structures, exploration of the involved sinuses is essential before starting the coil embolization. After occluding one lumen, the next target site should be carefully selected to prevent the occurrence of residual lumens.

In cases when the normal venous outflow through the residual lumen is restored during TVE, careful examination is essential to determine whether to occlude all the lumens or to selectively leave the restored or preserved lumen patent. In such situations, we never occluded the preserved and restored sinus lumens but suspended TVE and replaced it with subsequent transarterial embolization procedures or follow-up angiograms after 1 month¹⁸.

Conclusions

Effective treatment of DAVFs mainly depends upon the fistulous sites and drainage patterns. Localized DAVFs with the cortical venous reflux and an isolated sinus should be treated with transarterial glue injection, surgical disconnection of the cortical venous reflux, surgical packing of the involved sinus, and surgical resection of the involved sinus.

For diffuse DAVFs, TVE is initially indicated, followed by identification of one of the three distinctive types of fistulous drainage, which is of clinical importance for determining to completely occlude the fistulas as well as preserve or restore the normal venous outflow through the involved sinuses and leads to selective TVE procedures.

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Mitsugu Nakamura, M.D.
 Department of Neurosurgery,
 Kobe University Graduate School of Medicine
 7-5-1 Kusunoki-cho, Chuo-ku,
 Kobe 650-0017, Japan
 E-mail: nakam@med.kobe-u.ac.jp