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Original Article

Surgical treatment for ruptured dural arteriovenous fistula with large intracranial hematoma

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Abstract: The rupture of dural arteriovenous fistula (DAVF) is a serious complication endangering the lives of patients. It is difficult to treat such ruptured DAVF with large intracranial hematoma since lacking of early diagnostic methods. Meanwhile, there was no consensus of how to surgically treat these patients in early stage. In this study, we tried to use 4D-CTA to diagnose DAVF and guide surgical treatment. Based on the result of 4D-CTA, we attempted to eliminate DAVF at the same time we removed hematoma. The result was encouraging. 7 patients with ruptured DAVF presented as large spontaneous intracranial hemorrhage were included in this research between May, 2010 and August, 2012 in our hospital. 4D-CTA was performed in all cases. All results of 4D-CTA inspections were studied by both neurosurgeon and neuroradiologist. The therapeutic options were evaluated based on the clinical and angiographic results. All fistulas of seven patients were eliminated at the same time the hematoma being evacuated. 4D-CTA was sufficient for detecting and recognizing basic vessel angioarchitecture of DAVF to guide surgical treatment. Main arterial supplies, fistula location and CVDs found during surgery are consistent with the results 4D-CTA. All seven cases achieved completely fistula occlusion in operation without new neurological complication. We favor one stage surgical treatment for ruptured DAVF with large intracranial hemorrhage. 4D-CTA plays an important role in preoperative emergent inspection for its safety, rapidity and accuracy. However, it still needs further and larger investigations to optimize such treatment methods and to find out other potential risks.

Keywords: DAVF, 4D-CTA, intracranial hemorrhage, surgical treatment

Introduction

Dural arteriovenous fistula (DAVF) is an obstinate cerebral vascular disease [1]. Intracranial hemorrhage, the most dangerous complication of DAVF caused by its rupture in venous ends, would seriously endanger patients' lives [2]. So far, there is no consensus of how to deal such patients with huge intracranial hematoma [3]. In this study, 4D-CTA was used as a dynamic image method to diagnose DAVF [4]. One stage resection of DAVF was performed at the same time we made emergent evacuation of intracranial hematoma. Satisfactory outcome was achieved.

Methods

Patients

7 patients with ruptured DAVF presented as large spontaneous intracranial hemorrhage were included in this research between May, 2010 and August, 2012 in our hospital. Detail information such as hemorrhage location, preoperative condition, fistula location, arterial supply, venous drainage, etc, were summarized in **Table 1**. The pre-operative conditions of these patients were all in emergent status.

After intracranial hemorrhage detected by computed tomography, patients with irregular shape of hematoma, non-basal ganglia hemorrhage, young patients (age below 40), no underlying diseases such as hypertension and/or diabetes were advised to run further inspection due to suspicion of DAVF or other cerebral vascular malformations. Because of their unconscious or restless pre-operative condition, DSA examination was not performed. 4D-CTA as an only screening method was used in such emergent situation. After inspections completed, all results of 4D-CTA were discussed by neurosur-

Table 1. Detail information of 7 patients with dural arteriovenous fistula presented as intracranial hemorrhage

Patient no.	Age/Sex	Hemorrhage location and volume (ml)	Pre-operative condition (GCS)	Fistula location	Arterial supply (4D-CTA)	Borden	Treatment	Angiographic results of review (DSA/4D-CTA)	Outcome; follow up (mouth)/KPS
1	70/M	(R) F; (40)	GCS 8	(R) frontal cranial base	(L) OA	III	HE + FR	(-)/cure	asymptomatic; 12/70
2	67/F	(L) F; (40)	GCS 10	(L) frontal cranial base	(L + R) OA	III	HE + FR	(-)/cure	asymptomatic; 9/70
3	61/M	(R) T + O; (40)	GCS 8	(R) occipital dural	(R) ECA	III	HE + FR	(-)/cure	asymptomatic; 8/70
4	61/M	(R) F; (35)	GCS 10	(R) frontal cranial base	(R) MMA	III	HE + FR	(-)/cure	asymptomatic; 9/80
5	55/M	(R) P + O; (40)	GCS 10 (left paralysis)	(R) superior sagittal sinus	(L + R) MMA + (L + R) PMA + (L + R) OCA	III	HE + FR	cure/cure	left paralysis; 8/80
6	61/M	(R) F; (40)	GCS 8	(R) frontal cranial base	(R) OA	III	HE + FR	(-)/cure	asymptomatic; 10/90
7	55/M	(L) T + P; (40)	GCS 5 (right paralysis)	(L) middle cranial base	(L) MMA	II	HE + FR	(-)/cure	right paralysis; 31/60

(-) = no result of this inspection.

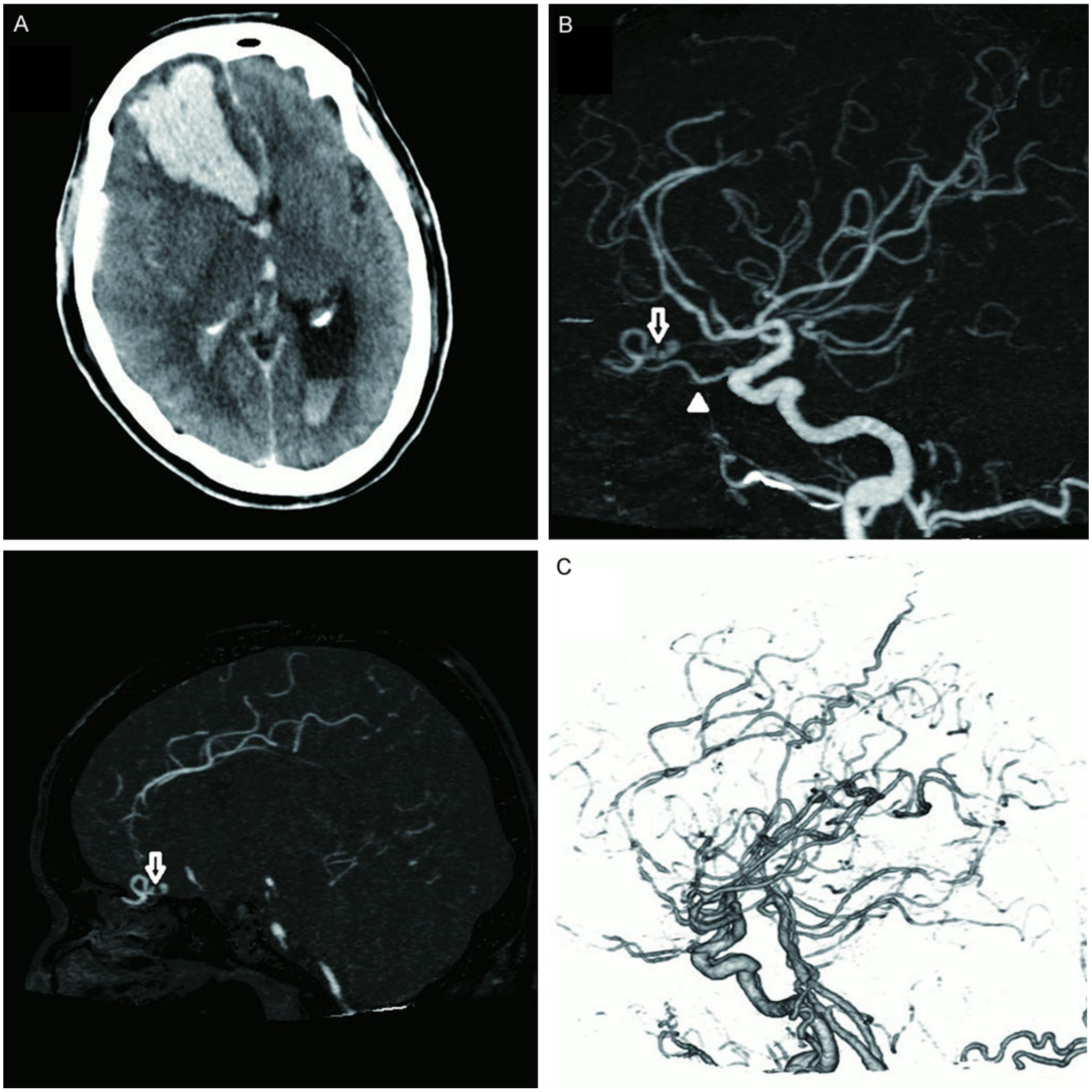

Figure 1. Case 1 had intracranial hemorrhage in right frontal lobe (A). Before surgical treatment, lateral projection of 4D-CTA showed frontal fistula (hollow arrow) on the base of anterior fossa base with arterial feeder supplied by OA (white triangle) (B). Review of 4D-CTA after surgical treatment in the same projection, abnormal blood flow was disappeared (C).

geons and neuroradiologists. The therapeutic options were evaluated based on the clinical and angiographic results.

4D-CTA examination

It was performed by Aquilion ONE multi-detector CT scanner of Toshiba Medical Systems, which equips 320 × 0.5 mm detector rows covering 16 cm of volume per rotation sufficient to cover whole brains. The manner of performing imaging was followed by the procedures below. First, injection of 60 ml intravenous infusion of nonionic contrast medium, with 20 ml of saline, was followed by a dynamic acquisition sequence (22 dynamic volumes each protocol, 80 kVp, 120 mAs) with a gantry rotation (one mask volume, 80 kVp, 300 mAs) speed of 1 rotation per second. After subtracting the mask volume from the dynamic volumes, a total of 7,040 (22 dynamic volume ×320 slice) images (temporal resolution 3 frames per second, spatial resolution 1024 × 1024) were stored as 22 DICOM file. Finally, by using these files, the standard scanner software generated time-resolved (arterial to venous) MIPs at different viewing angles. These general manners and steps have been previously described and accepted [5, 6].

Surgical treatment

All the patients underwent surgical treatment. After dural disclosed, partial hematoma was removed to lower the intracranial pressure. The area around the hematoma was explored carefully. In non-sinus-type fistula, the operative strategy consisted of sole interruption of arterialized leptomeningeal vein either by coagulation or clipping, shortly after the dural entry/exit point. No attempt was made to coagulate meningeal feeding arteries or to excise the arterialized dural. In sinus-type fistula, both the meningeal feeding arteries and the arterialized leptomeningeal vein were cut.

Results

All patients had 4D-CTA examinations, there were 4 fistulas in frontal cranial base, 1 in middle cranial base, 1 in superior sagittal sinus and 1 in occipital. The hematoma evacuation and fistula elimination were performed at the same time. The fistulas were all confirmed by the intra-operative finding. For case 5 with superior sagittal sinus DAVF, the supplying arteries from occipital and middle meningeal cerebral artery branches were cut, and the cortical venous reflux from the fistula was disconnected. For the other cases, only arterialized leptomeningeal veins were cut. There was no mortality or new neurological deficit.

Follow-ups

All seven cases had post-operative follow-up, mean 12.43 months. The follow-up examinations included DSA and/or 4D-CTA. There was no presence of initial fistula re-opening. There was no new neurological complication.

Case 1

This 70-year-old man had a sudden headache and quickly lost his consciousness, he was in coma with GCS 8 when he was sent to our hospital. An emergent CT scan showed a right frontal hematoma (**Figure 1**). An additional 4D-CTA revealed right frontal base DAVF. During operation, the fistula was found in the anterior frontal fossa base. It was cut. Post-operative review of 4D-CTA in the same projection identified the complete occlusion of the fistula following coagulation of the leptomeningeal vein.

Case 2

A 55-year-old male felt headache and had paralysis in his left limbs. He was in a restless condition with GCS 10 at admission to hospital. First CT scan proved a hematoma nearly 40 ml in his parietal and occipital lobe (**Figure 2**). Preoperative 4D-CTA displayed a DAVF with arterial feeders from left anterior, middle meningeal and occipital arteries, which had reflux into superior sagittal sinus though several CVDs. During operation, these arterial supplies and CVDs were cut. Follow-up review by 4D-CTA demonstrated that DAVF had disappeared.

Case 3

A 50-year-old male was transported to our hospital due to a mild headache and vomit. Unfortunately, he suddenly got into coma with left pupil dilating and GCS 5. The initial CT scan found a giant hematoma in temporal lobe. Since highly suspicious of cerebral vascular malformation, an emergent 4D-CTA was performed. It demonstrated a left temporal fossa base vascular ectasia and was diagnosed of a DAVF. In operation, a large cortical arterialized vein was found in middle fossa base, and it was cut. During his follow-up by 4D-CTA, no abnormal blood flow was detected (**Figure 3**).

Discussion

Dural arteriovenous fistula is abnormal arteriovenous anastomosis occurred between dural arteries and dural veins, cerebral venous sinus and cortical veins, responsible for nearly 10%-15% [7] of intracranial vascular malformations. The symptoms of DAVF were related to the location of lesion and pattern of venous drainage [8]. Pulsatile tinnitus [9] is a common and benign symptom of non-cavernous sinus DAVF. Regretfully, it has been usually neglected until severe presentations including intracranial hemorrhage and/or non-hemorrhagic neurological deficits have been found [10].

It is difficult to diagnose ruptured DAVF with huge intracranial hematoma. CT and MR imaging are usually predominant in initial radiological evaluation which can only reflect indirect signs of DAVF such as edema and/or dilated

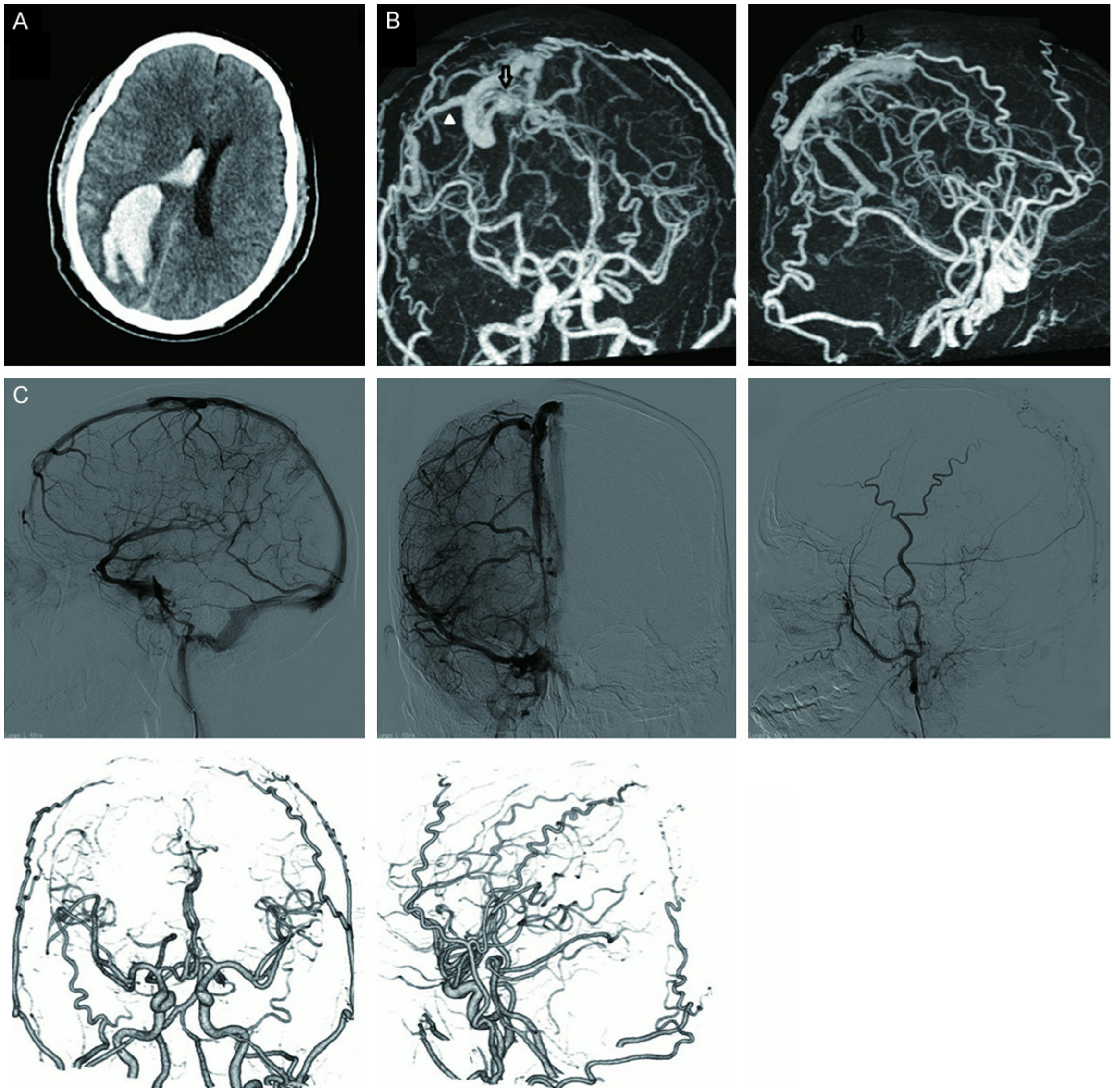

Figure 2. Case 5 with parietal and occipital hemorrhage (A). Before surgical treatment, 4D-CTA displayed superior sagittal sinus DAVF with the enlarging leptomeningeal vein and fistula (hollow arrow) supplied by middle meningeal and occipital arteries (B). During operation, both arterial supplies and fistula were cut. Follow-up by 4D-CTA and DSA found no abnormal blood flow (C).

vessels. Non-contrast CT is used to rule out intracranial hemorrhage or space occupying lesions but unable to make differential diagnosis of vascular pathogenesis. MR imaging is superior to CT in diagnosing vascular malformation. For instance, dilated venous structures, vascular enhancement, and venous hypertension can be demonstrated in high-grade lesions [11]. However, it is hard for CT and MR to make definite diagnosis of DAVF with large hemorrhage. In order to make up precise vascular angioarchitecture and to differentiate DAVF with other vascular malformation, dynamic CTA, MRA or DSA must be considered [12]. For now, the criterion standard for DAVF diagnosis remains DSA [13] despite of its invasion and risks of both silent and symptomatic embolic events [14]. Time-resolved MRA techniques are promising and may be reliable for DAVF screening and surveillance [15]. Reinacher et al [16] had pointed out that DAVF can be correctly graded by time-resolved MRA, which is essential for therapeutic decision-making though small feeders may be overlooked. And it seems especially suitable to ascertain whether fistula has been occluded completely during follow-up.

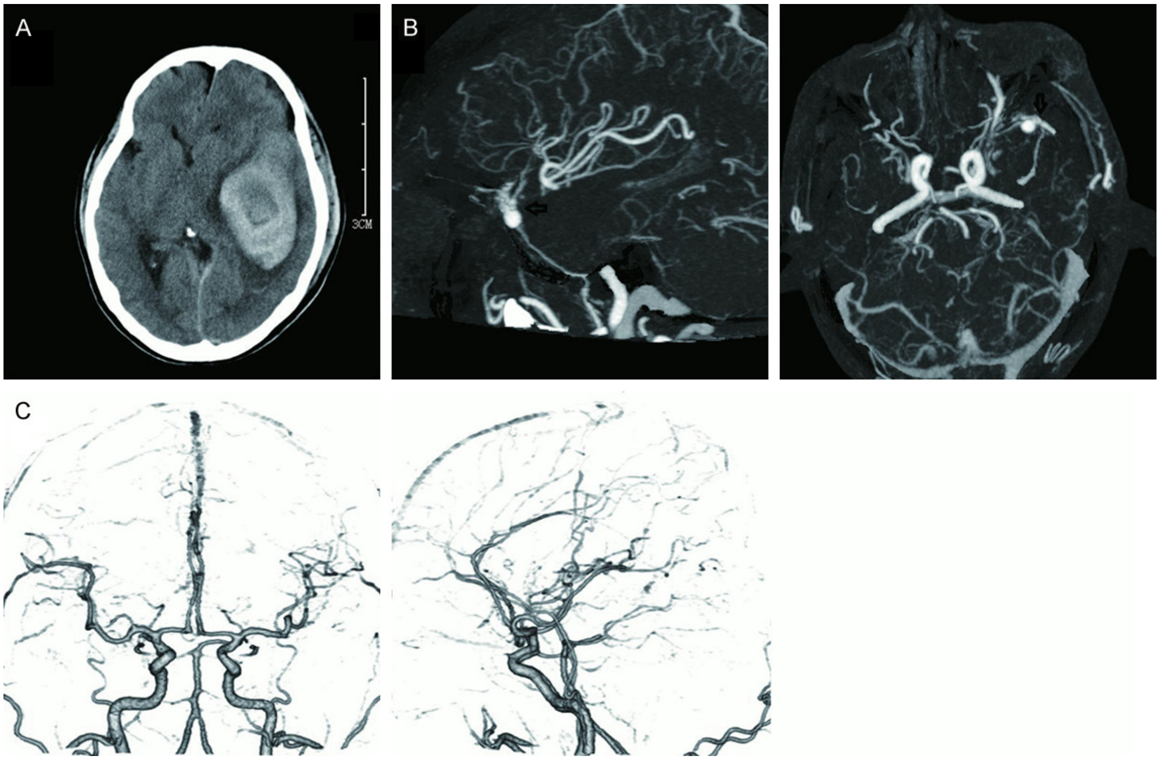

Figure 3. Case 7 with temporal and parietal hemorrhage was highly suspicious of DAVF rupture (A). 4D-CTA reflected left temporal base fistula (hollow arrow) fed by MMA (B). Diagnosis of DAVF was confirmed by intra-operative findings. During his follow-up by 4D-CTA, no abnormal blood flow was detected (C).

But for coma and restless patients with severe intracranial hemorrhage, it is difficult to run time-consumed examinations, such as DSA or MRA carefully.

Recently, as the representative of dynamic CTA, 4D-CTA has highlighted its potential value to correctly diagnose AVM [4] and DAVF [5, 17] with full head coverage, less invasiveness and more rapidity. In the previous study of DAVF by Willems et al [18] whose images were independently read by two blinded observers, 10 of 11 cases were full agreement between DSA and 4D-CTA and only one small slow-flow DAVF was missed by 4D-CTA. In Beijer et al [19] cases, the result indicated that 4D-CTA correctly differentiated distinct patterns of venous drainage and made precise classification of Borden type I, II and III, as confirmed by DSA. In our cases, 4D-CTA successfully detected fistulas and CVDs in all patients, which was confirmed by intra-operative findings. It is worth noting that all our cases were in high grade which was more sensitive to CTA. However, CVDs were not shown in every case, which might be caused by the compression of large hematoma. Despite the nonselective nature of 4D-CTA and its lower spatial and temporal resolution compared with DSA, it is able to provide the correct information in high-grade case. We believe 4D-CTA is a very useful method in DAVF examination, especially in emergent situation.

Treatment methods of DAVF include interventional treatment, surgery and radiation therapy. There is still no consensus of how to deal patients with huge intracranial hematoma due to DAVF rupture. Interventional treatment by intravenous or arterial route is the main choice to cure DAVF and has satisfactory occlusion rate. But it is less reported to be used in acute patients with huge intracranial hematoma. Houdart et al [20] had indicated that surgical treatment should be applied when space occupying effect of intracranial hematoma exists due to DAVF rupture. There were two different options: only making evacuation of intracranial hematoma, or resecting vascular malformation while cleaning intracranial hematoma. Leaving DAVF intact would put patients in danger of its re-rupture during the rest time. Duffau et al [21] reported that CVDs draining to the transverse sinus present a high risk of rupture and re-rupture. Meanwhile, the second operation to eliminate the fistula would be difficult since the adherence of cerebral tissue inheriting from the first operation and containing more complications. One stage treatment of hematoma and DAVF has the advantage of avoiding those potential disasters. Our experience suggested that the early surgical treatment of DAVF was safe and suitable for patients with huge hematoma needing emergent evacuation. For patients with mild hematoma and condition, we prefer elaborate and adequate inspections, for deciding therapeutic strategy, including embolization and/or surgery, even radiation therapy. According to the available reports, surgical treatment for DAVF was mainly applied in lesions in anterior, middle cranial fossa or involving superior sagittal sinus. Our cases are all in these regions. For ruptured-DAVF involving the transverse sinus, sigmoid sinus and cavernous area which was difficult for microsurgery, staged treatment should be considered.

Conclusions

Acute rupture is the most serious presentation of cerebral DAVF and carries high morbidity and mortality. 4D-CTA could play an important role in preoperative inspection for emergent cases due to its safety, rapidity and accuracy. Following initial diagnosis with 4D-CTA, we favor one stage surgical treatment for patients with severe intracranial hemorrhage from DAVF rupture. Not only did it make evacuation of hematoma, but also prevented the high risk of re-rupture. It still needs further and larger investigations to optimize such treatment methods and to find out other potential risks.

Disclosure of conflict of interest

None.

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References

[1] Hacein-Bey L, Konstas AA and Pile-Spellman J. Natural history, current concepts, classification, factors impacting endovascular therapy, and pathophysiology of cerebral and spinal dural arteriovenous fistulas. Clin Neurol Neurosurg 2014; 121: 64-75.
[2] Peng T, Liu A, Jia J, Jiang C, Li Y, Wu Z and Yang X. Risk factors for dural arteriovenous fistula intracranial hemorrhage. J Clin Neurosci 2014; 21: 769-772.
[3] Novakovic RL, Lazzaro MA, Castonguay AC and Zaidat OO. The diagnosis and management of brain arteriovenous malformations. Neurol Clin 2013; 31: 749-763.
[4] Willems PW, Taeshineetanakul P, Schenk B, Brouwer PA, Terbrugge KG and Krings T. The use of 4D-CTA in the diagnostic work-up of brain arteriovenous malformations. Neuroradiology 2012; 54: 123-131.
[5] Brouwer PA, Bosman T, van Walderveen MA, Krings T, Leroux AA and Willems PW. Dynamic 320-section CT angiography in cranial arteriovenous shunting lesions. AJNR Am J Neuroradiol 2010; 31: 767-770.
[6] Salomon EJ, Barfett J, Willems PW, Geibprasert S, Bacigaluppi S and Krings T. Dynamic CT angiography and CT perfusion employing a 320-detector row CT: protocol and current clinical applications. Klin Neuroradiol 2009; 19: 187-196.
[7] Daniels DJ, Vellimana AK, Zipfel GJ and Lanzino G. Intracranial hemorrhage from dural arteriovenous fistulas: clinical features and outcome. Neurosurg Focus 2013; 34: E15.
[8] Koyanagi M, Sakai N, Adachi H, Ueno Y, Kunieda T, Imamura H and Kikuchi H. "Loop-like formation" in the cortical venous reflux of dural arteriovenous fistula with intracranial hemorrhage. J Neuroradiol 2013; [Epub ahead of print].
[9] Bink A, Berkefeld J, Kraus L, Senft C, Ziemann U and du Mesnil de Rochemont R. Long-term outcome in patients treated for benign dural arteriovenous fistulas of the posterior fossa. Neuroradiology 2011; 53: 493-500.
[10] Yeh SJ, Tsai LK and Jeng JS. Clinical and carotid ultrasonographic features of intracranial dural arteriovenous fistulas in patients with and without Pulsatile Tinnitus. J Neuroimaging 2010; 20: 354-358.
[11] Cohen SD, Goins JL, Butler SG, Morris PP and Browne JD. Dural arteriovenous fistula: diagnosis, treatment, and outcomes. Laryngoscope 2009; 119: 293-297.
[12] Kwon BJ, Han MH, Kang HS and Chang KH. MR imaging findings of intracranial dural arteriovenous fistulas: relations with venous drainage patterns. AJNR Am J Neuroradiol 2005; 26: 2500-2507.
[13] Fujiwara H, Momoshima S, Akiyama T and Kuribayashi S. Whole-brain CT digital subtraction angiography of cerebral dural arteriove-

nous fistula using 320-detector row CT. Neuroradiology 2013; 55: 837-843.
[14] Farb RI, Agid R, Willinsky RA, Johnstone DM and Terbrugge KG. Cranial dural arteriovenous fistula: diagnosis and classification with time-resolved MR angiography at 3T. AJNR Am J Neuroradiol 2009; 30: 1546-1551.
[15] Sakamoto S, Shibukawa M, Kiura Y, Matsushige T, Abe N and Kurisu K. Evaluation of dural arteriovenous fistulas of cavernous sinus before and after endovascular treatment using time-resolved MR angiography. Neurosurg Rev 2010; 33: 217-222; discussion 222-213.
[16] Reinacher PC, Stracke P, Reinges MH, Hans FJ and Krings T. Contrast-enhanced time-resolved 3-D MRA: applications in neurosurgery and interventional neuroradiology. Neuroradiology 2007; 49 Suppl 1: S3-13.
[17] Siebert E, Bohner G, Dewey M, Masuhr F, Hoffmann KT, Mews J, Engelken F, Bauknecht HC, Diekmann S and Klingebiel R. 320-slice CT neuroimaging: initial clinical experience and image quality evaluation. Br J Radiol 2009; 82: 561-570.
[18] Willems PW, Brouwer PA, Barfett JJ, terBrugge KG and Krings T. Detection and classification of cranial dural arteriovenous fistulas using 4D-CT angiography: initial experience. AJNR Am J Neuroradiol 2011; 32: 49-53.
[19] Beijer TR, van Dijk EJ, de Vries J, Vermeer SE, Prokop M and Meijer FJ. 4D-CT angiography differentiating arteriovenous fistula subtypes. Clin Neurol Neurosurg 2013; 115: 1313-1316.
[20] Houdart E, Saint-Maurice JP, Chapot R, Ditchfield A, Blanquet A, Lot G and Merland JJ. Transcranial approach for venous embolization of dural arteriovenous fistulas. J Neurosurg 2002; 97: 280-286.
[21] Duffau H, Lopes M, Janosevic V, Sichez JP, Faillot T, Capelle L, Ismail M, Bitar A, Arthuis F and Fohanno D. Early rebleeding from intracranial dural arteriovenous fistulas: report of 20 cases and review of the literature. J Neurosurg 1999; 90: 78-84.