Original Article

Cranial Dural Arteriovenous Shunts: An Evaluation of the Outcome

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Objective: To evaluate the effectiveness of the treatment of patients with cranial dural arteriovenous fistulas [dAVFs] on long-term follow-up and determine factors that affect the post-treatment clinical outcome.

Materials and Methods: After being certified by the Siriraj Institutional Review Board, Faculty of Medicine Siriraj Hospital, Mahidol University, 180 patients with cranial dAVFs were retrospectively reviewed at the Interventional Neuroradiology Unit, Siriraj Hospital, Bangkok, Thailand. There were 118 females and 62 males, age ranged from 15 to 85 years with mean age of 52.64 years. The dAVFs were classified angiographically according to Davies' criteria and Cognard classification into benign and aggressive shunts. Endovascular procedure was the first treatment option. Therapeutic outcomes were measured by angiographic appearances to complete (no residual shunt or retrograde leptomeningeal venous drainage [RLVD]), partial treatment (residual RLVD), and procedural complications. The clinical outcomes were defined into favorable (cure or improved without new symptoms or disability) and unfavorable (unchanged or worsening symptoms). Thirty-one patients (17.22%) lost to follow-up were excluded. The possible factors that may associate with patient's outcome were compared between favorable and unfavorable groups. Relationship between therapeutic results and clinical outcome were analyzed.

Results: Of the 180 patients, there were 231 shunts. Multiple shunts were found at 26.11%. Thirty-nine patients (21.67%) had aggressive symptoms (e.g., neurological deficit, cognitive impairment, or seizure). The most common location of dAVF was the cavernous (55.84%), followed by transverse sigmoid sinus (27.27%) and superior sagittal sinus (7.79%) respectively. Aggressive shunts were found at 48.33%. The abnormal image findings were white matter changes at 16.81%, hemorrhage at 12.39%, hydrocephalus at 6.19%, and parenchymal calcification in one patient. One hundred forty-nine patients (82.78%) who had follow-up (ranging from 1 month to 12 years with average at 9.61 months), 136 (91.26%) had favorable outcome. For unfavorable outcome, significant related factors were hydrocephalus ($p = 0.002$) and calcification ($p = 0.002$). For favorable outcome, significant related factors were benign symptoms ($p<0.01$) and no associated sinus thrombosis ($p<0.01$). For therapeutic results, complete treatment achieved high favorable outcome (93.15%). Endovascular complication rate was 4.7%.

Conclusion: High favorable clinical outcome of cranial dAVF was achieved with low complication rate. Aggressive clinical and angiographic presentations as well as intracranial venous congestion were reversible following an effective treatment. The favorable clinical outcome is predictable in benign symptoms ($p<0.01$) and no associated sinus thrombosis ($p<0.01$). Excluding complication, unfavorable outcome is related with ventricular dilatation ($p = 0.002$) and subcortical calcification ($p = 0.002$) caused by prolong increased intracranial pressure or chronic venous congestion. When treatment result is unresponsive, offering treatment in patients with these factors should be reconsidered.

Keywords: Dural arteriovenous fistula, Dural arteriovenous shunt, Symptom, Clinical outcome

J Med Assoc Thai 2018; 101 (4): 471-9
Website: http://www.jmatonline.com

Cranial dural arteriovenous fistulas [dAVFs] are acquired abnormal arteriovenous connections within the dura or adjacent cortical veins. They account for 10% to 15% of all intracranial arteriovenous lesions[1-5]. Their locations essentially determine the type of symptoms, whereas the drainage characteristics are responsible for focal neurological complications. The clinical presentation is related to venous congestion that are exacerbated by venoocclusive disease[6,7], which may lead to aggressive features including intracranial hemorrhage, neurological deficit, cognitive impairment, and death. The natural history of dAVFs with normal antegrade venous drainage is usually

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How to cite this article: Churojana A, Songsaeng D, Khumtong R, Aurboonyawat T, Chankaew E, Chewvit P, et al. Cranial dural arteriovenous shunts: an evaluation of the outcome. J Med Assoc Thai 2018;101:471-9.

benign and the chances of stability or spontaneous regression can be expected. Conversely, those with retrograded venous drainage or cortical reflux require definite treatment with aim to complete obliteration of the shunts or at least eradicate the retrograded venous reflux. Endovascular approach is the initial modality treatment of choice, either from a venous or arterial route or a combination. Surgery is needed when endovascular techniques fail to be curative or is not feasible[8]. By observation, aggressive presentations as well as intracranial venous congestion are reversible after adequate treatment. However, some patients have not been recovered from functional impairment even when they achieved anatomical cure.

The purpose of the present study is to determine factors that may predict an unresponsive clinical outcome of treatment in patients with cranial dAVF.

Materials and Methods

The authors retrospectively reviewed 180 patients with cranial dAVFs presenting to the Interventional Neuroradiology Unit, Siriraj Hospital, Bangkok, Thailand during a 12-year period, between 1997 and December 2009. Information was also obtained from medical records (hospital files) and imaging databases (PAC system). There were 118 females and 62 males, age range from 15 to 85 years with mean age of 52.64 years (Table 1). Thirty-one patients (17.22%) lost to follow up were excluded.

All patients were informed of risks and benefits of the procedure. After informed consent, they underwent diagnostic angiography prior to any treatment options. The dAVFs were classified by angiographic appearance into two groups according to Davies' criteria and Cognard classification (Table 2), benign and aggressive shunts. The patients who had dAVFs with antegrade drainage only or with retrograde sinus reflux without retrograde leptomeningeal venous drainage [RLVD] (Cognard I-IIa) were classified as benign group. The others dAVFs with RLVD or cortical reflux (Cognard IIb-V) were defined as aggressive shunts[9,10].

In the benign group of dAVFs, of which the chances of stability or spontaneous symptom regression were high, the patients had clinical follow-up every one to three months. Elective endovascular treatment was indicated in Cognard IIa with sign of increased intracranial pressure, and occasionally required in some patients who could not tolerate the symptoms (tinnitus or diplopia) with aim for symptom reduction.

In aggressive group of dAVFs, which had poor natural history, treatment was indicated with aim for eradication of the shunts or at least to get rid of cortical venous refluxes. Endovascular procedure was the first treatment option for all these patients by either transarterial or transvenous embolization or combination. If the gold standard procedure could not be accomplished or failed by endovascular procedure, surgery was then performed. Retreatment, if it was indicated, was scheduled within next one to three months. After completed treatment, the patients had clinically followed-up every one to three months until complete resolution or stable of symptoms.

Therapeutic outcomes were graded by appearances of angiographic findings as the followings, 1) complete, if there were no residual shunts or remaining shunts but obliteration of RLVD, 2) partial, if there were residual RLVD, or 3) complications, if there were new lesion related to treatment procedure, no matter what dAVFs was cured or not.

The clinical outcomes were defined into two groups, 1) favorable outcome means patients had cure or improved without new symptoms or disability after

Table 1. Demographics and clinical presentation

Details	Number (%)
Total number	180 (100)
Sex	
Male	62 (34.44)
Female	118 (65.56)
Classification of shunt	
Benign (Cognard type I-IIa)	93 (51.67)
Aggressive (Cognard type IIb-V)	87 (48.33)
Treatment	
Conservative	48 (26.66)
Endovascular treatment	122 (67.78)
Combined surgery	10 (5.56)

Table 2. Cognard classification

Cognard classification	Details
I	Venous drainage into dural venous sinus with antegrade flow
IIa	Venous drainage into dural venous sinus with retrograde flow
IIb	Venous drainage into dural venous sinus with antegrade flow and CVR
IIa+b	Venous drainage into dural venous sinus with retrograde flow and CVR
III	Venous drainage directly into subarachnoid veins (CVR only)
IV	Type III with venous ectasias of the draining subarachnoid veins
V	Direct drainage into spinal perimedullary veins

CVR = cortical venous reflux

complete treatment, or 2) unfavorable outcome means patients had unchanged or worse symptoms and/or progressive disability.

Demographic data, type of dAVFs, shunt location, and treatment modalities of all patients were analyzed. The possible factors that may associate with patient's outcome, included demographics, clinical presentation, location of shunts, number of shunt, shunt classification, time to presentation, sinus thrombosis, and imaging finding of brain insults such as white matter changes, intracranial hemorrhage, hydrocephalus, and calcifications were compared between favorable and unfavorable groups of clinical outcomes using independent t-test and bi-variated correlation.

Relationship between therapeutic results and clinical outcome were analyzed by independent t-test and bi-variated correlation.

Analyses were performed using the SPSS statistical software [version 15.0, SPSS Inc., Chicago, IL]. A *p*-value of less than 0.05 was considered significant.

The literature reviews were obtained to compare our outcome to others. Literatures were searched from Pubmed libraries on electronic databases.

Results

Of the 180 patients, there were 231 shunts. Multiple shunts were found in 47 patients (26.11%). Thirty-nine patients (21.67%) had aggressive symptoms (e.g., neurological deficit, cognitive impairment, or seizure). The most common location of dAVF was the cavernous (55.84%), followed by transverse sigmoid sinus (27.27%) and superior sagittal sinus (7.79%) respectively, as shown in Figure 1.

According to shunt classification, the authors found benign shunt about 51.67% and aggressive about 48.33%, which were corresponding to the clinical presentations. One hundred forty-one patients (78.33%) had no neurological symptoms at initial presentation, included chemosis, proptosis, eye injection, tinnitus, and non-specific headache. The aggressive symptoms of our dAVF patients (21.67%) included progressive neurological deficit, increased intracranial pressure, cognitive impairment, and seizure. Most patients (75.22%) had no parenchymal abnormality on computed tomography [CT] or magnetic resonance imaging [MRI]. The abnormal imaging findings were white matter changes in 16.81%, hemorrhage in 12.39%, hydrocephalus in 6.19%, and parenchymal calcification in one patient.

One hundred twenty-two patients (67.78%) had undergone endovascular embolization and 10 patients (5.56%) had combined surgery (Figure 2).

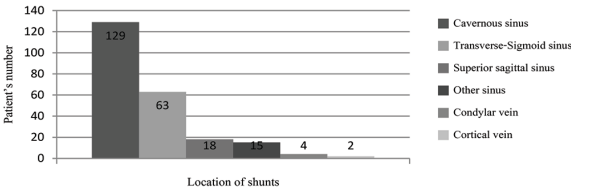

Figure 1. Location of 231 shunts in 180 patients.

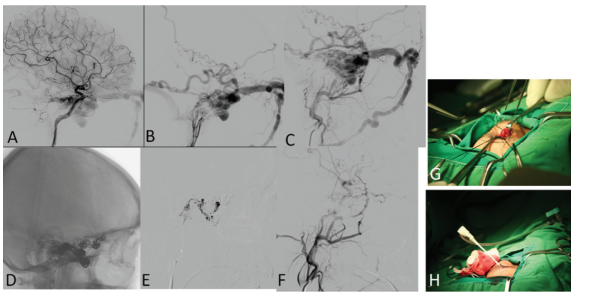

Figure 2. A 20 year old pregnant woman presented with spontaneous left exophthalmos and bruit on the left orbit for a year which was aggravated during pregnancy. (A-C) The angiogram showed large dural CCF receiving supplies from C5 branches of internal carotid artery, ascending pharyngeal artery and middle meningeal artery with drainage solely through the huge superior ophthalmic vein [SOV] without demonstrated inferior petrosal sinus. (D-F) The patient had complete shunt occlusion by combination of trans-SOV coiling and transarterial glue embolization via ascending pharyngeal artery. (G-H) Surgical exposure of the SOV for transvenous assessment had done before retrograde catheterization of the cavernous sinus.

One hundred forty patients (82.78%) had follow-up (follow-up periods ranging between 1 month and 12 years with averaged at 9.61 months), 136 (91.26%) had favorable outcome (Table 3).

Patients that came with benign symptoms had favorable outcome (94.74%) higher that patients came with aggressive symptoms (80%). Patients with single shunts had more favorable outcome (92.92%) than with multiple shunts (86.11%). Unfavorable outcome was found 7.79% in benign shunts and 9.72% in aggressive shunts, which was not statistically different.

Table 3. Comparison of therapeutic results and clinical outcome (149 patients)

Therapeutic results	Clinical outcome	
	Favorable (n = 136)	Unfavorable (n = 13)
Complete	94	4
Partial	42	2
Complication	0	7

Thirty patients (20.13%) had associated sinus thrombosis, 21 (70%) were found in aggressive shunts, and nine (30%) were found in benign shunts. The patients with no associated sinus thrombosis had favorable outcome (94.96%), with statistical significance (p-value <0.01). In contrast, patients with associated sinus thrombosis (23.33%) showed no statistically significant relation to unfavorable outcome.

Hydrocephalus and parenchymal calcification were demonstrated to be significantly associated with unfavorable outcome (p-value 0.002), whereas hemorrhage and white matter changes were not. Comparison of characteristic features of dAVFs and clinical outcomes is summarized on Table 4.

Complete treatment without complication had favorable outcome 95.92%. However, four in 98 patients with angiographically cure had unfavorable outcomes (patients number 1 to 4 in Table 5). Three patients with initial aggressive neurological deficits (patients number 1 to 3) and aggressive shunts were stable after complete treatment. Calcification was present in one of these patients. Another patient died from myocardial infarction.

Two unfavorable patients who had partial treatment (patients number 5 to 6) died from progressive diseases during interval of treatments. Seven patients had

Table 4. Comparison of characteristic features of dAVFs and clinical outcomes (149 patients)

Characteristic features	Clinical outcome		Total (%)
	Favorable (improve) (n = 136)	Unfavorable (stable and worse) (n = 13)	
Sex			
Male	44	1	45 (30.20)
Female	92	12	104 (69.80)
Average age			
<40 years	28	6	34 (22.82)
40 to 60 years	54	4	58 (38.93)
>60 years	54	3	57 (38.26)
Clinical presentation			
Benign	108*	6	114 (76.51)
Aggressive	28	7	35 (23.49)
Location of shunt			
Cavernous sinus	103	6	109 (57.98)
Transverse-sigmoid sinus	42	6	48 (25.53)
Superior sagittal sinus	11	3	14 (7.45)
Other sinus	9	2	11 (5.85)
Condylar vein	3	1	4 (2.13)
Cortical vein	2	0	2 (1.06)
Total	170	18	188 (100)
Number of shunts			
Single	105	8	113 (75.84)
Multiple	31	5	36 (24.16)
Shunts classification			
Benign (Davies, Cognard type I-IIa)	71	6	77 (51.68)
Aggressive (Davies, Cognard type IIb-V)	65	7	72 (48.32)
Presentation (findings)			
Time to treat (average months)	9.4	8.7	9.05 (average)
Associate sinus thrombosis			
• Yes	23	7	30 (20.13)
• No	113*	6	119 (79.87)
Image findings (98/149 patients)			
No parenchymal changes	67	6	73 (66.97)
White matter changes	13	4	17 (15.60)
Hemorrhage	10	1	11 (10.09)
Hydrocephalus	4	3**	7 (6.42)
Calcification	0	1**	1 (0.92)
Total	94	15	109 (100)

dAVFs = dural arteriovenous fistulas

* p-value <0.01, ** p-value 0.002

procedural complications as described in Table 5 (patients number 7 to 13).

Discussion

The dAVFs can present with varied clinical findings from benign e.g., non-specific headache, tinnitus, exophthalmoses to aggressive presentation e.g., intracranial hemorrhage with neurological deficit or death according to shunt location and pattern of venous drainage. The annual morbidity and mortality rates of dAVFs with an aggressive presentation differ widely, ranging from 10.4% to 20% per year[5,10,11] and the annual risk of intracranial hemorrhage without treatment is about 1.8% to 8.1% per year[5,11]. In contrast, any treatment including endovascular embolization, surgery, radiosurgery, or combined treatment results in good consequence with low complication rate[1,12]. In our study, favorable clinical outcome of treatment was achieved in 91.27%. Unfavorable outcome (included complications) occurred in 13 patients (8.73%). Seven of them had procedural complication resulting in 4.7% endovascular complication rate. Factors associated with outcome that had been analyzed in our study were grouped into three major influencing factors including initial clinical presentation, adequacy of treatment, and procedural complication.

For initial clinical presentation, only two significant related factors were hydrocephalus (p = 0.002)

Table 5. Summary of patients with unfavorable outcome

No.	Age/ sex	Presentation	Location	Davies/ Cognard classification	Treatment	Complication/ results	Clinical follow-up
1	18/F	Traumatic SAH with hydrocephalus S/P craniectomy status bed ridden had developed epilepsy	Left sigmoid sinus	Aggressive/ Cognard IIb	Transarterial glu embolization and combined surgery	No residual shunt	Stable to slightly improve
2	66/F	Unconsciousness with left hemiparesis	Multiple dAVFs	Aggressive/ Cognard IIb	Transvenous coil and transarterial glu embolization	No residual shunt	Stable
3	37/F	Left hemiparesis	Left transverse sinus	Aggressive/ Cognard V	Transarterial glu embolization	No residual shunt	Stable
4	58/F	Erythematous conjunctiva of left eye	Left cavernous sinus	Benign/ Cognard I	No treatment	- Benign shunt - No treatment	Dead from MI
5	F	Gliotic changes of both frontal lobes and hematoma at both occipital lobes with WM changes	Superior sagittal sinus	Aggressive/ Cognard IIb	No treatment	Death before treatment	Death
6	F	Detoriation of concious	Right transverse sinus	Aggressive/ Cogard IIb	Transverse coil embolization	Residual CVR	Death
7	41/M	Right tinnitus	Condylar vein	Benign/ Corgnard I	Transarterial glu embolization	- No residual shunt - Right CN 10 palsy	- No tinnitus - Mild disability of swallowing
8	43/F	Right exophthalmos with erythematous conjunctiva	Right cavernous sinus	Benign/ Cognard I	Conservative treatment	- No residual shunt - Transient left hemisensation loss immediately after diagnostic angiogram - Asymptomatic fontal branch of left MCA emboli during 2 months follow-up angiogram	- No neurodeficit - No opthalmic symptom
9	73/M	Bilateral exophthalmos	Bilateral dural CCFs	Benign/ Cognard I	Transvenous coil embolization	- Residual benign shunt - Unknown cause diffuse SAH immediately after embolization	Full recovery during follow-up period
10	77/F	Erythematous conjunctiva with intracranial hematoma	Bilateral cavernous sinuses	Aggressive/ Cognard IIb	Transarterial glu embolization	- Residual CVR - Left facial palsy from glu reflux	- Left facial palsy - Recovery eye symptom
11	38/F	Progressive visual loss with papilledema of both eyes	Left transverse sinus	Benign/ Cognard IIa	Coil embolization and combined surgery	- Residual CVR - Air emboli with small right thalamic infarct	Right hemianopia, left blindness, facial palsy, and impaired VA of both eyes
12	32/F	Progressive headache and tinnitus 5 months	Left sigmoid sinus and torcular herophili	Aggressive/ Cognard IIb	Transvenous coil and transarterial glue embolization	- Residual CVR - Glue reflux to anastomosis (right MHT)	Left hemiparesis
13	54/F	Headache tinnitus with right sway gait	Right transverse sinus	Aggressive/ Cognard Iia	Transvenous coil embolization	- Residual CVR - Hematoma at right temporal lobe from right Labbe vein occlusion	Full recovery with minimal tinitus

F = female; M = male; SAH = subarachnoid hemorrhage; WM = white matter; dAVFs = dural arteriovenous fistulas; CCFs = caroticocavernous fistulas; CVR = cortical venous reflux; CN = cranial nerve; MCA = middle cerebral artery; MHT = meningohypophyseal trunk; MI = myocardial infarction; VA = visual acuity

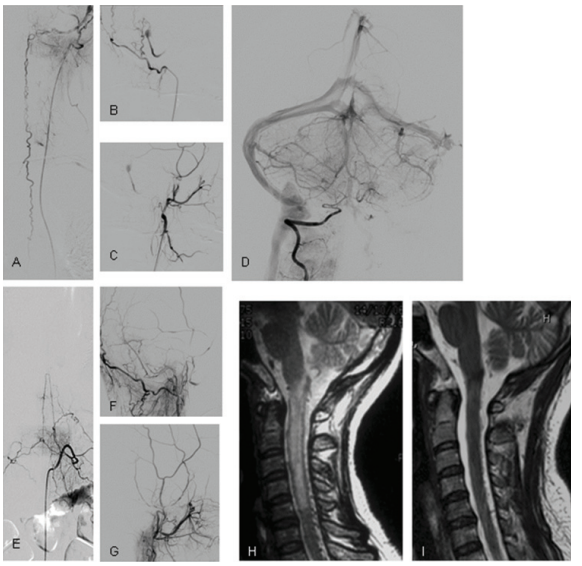

Figure 3. A 37-year-old female had progressive right-sided paresthesia and left-sided weakness for 6 months. (A) Frontal view of occipital artery injection, (B, C) lateral views of left occipital and left internal maxillary arteries injection, revealed dAVF at left transverse-sigmoid junction with draining into posterior spinal veins. (D) Frontal view of right vertebral artery injection revealed thrombosis of left sigmoid sinus. (E) Frontal view of normal radiculomedullary artery was arising from intercostal artery of left T12 level. (F, G) Lateral views of occipital and internal maxillary arteries injection revealed completed obliteration of shunt after glue embolization. However, patient had not recovered from those symptoms. (H) Preoperative MRI showed abnormal signal changes on T2W at cervicomedullary junction to C5 level with multiple flow voids posteriorly. (I) Post treatment MRI showed reversible high signal intensity of spinal cord and diminished flow voids. However, the image was not corresponding to the clinical outcome.

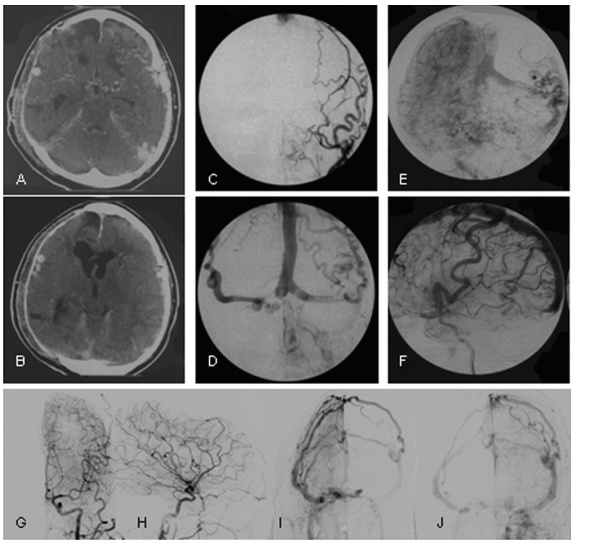

Figure 4. A 18 year old woman had traumatic subdural hematoma at right frontal lobe 6 years ago S/P craniectomy and VP shunt, status bed ridden, had developed recurrent epilepsy and neurological decline for a year. (A, B) CT revealed abnormal dilated leptomeningeal vessels, bilaterally. (C-F) The angiogram revealed dAVF at left sigmoid sinus with bilateral sigmoid sinus thrombosis and severe cortical refluxes (C and D, frontal views of left internal maxillary artery [IMA] on arterial and venous phases; E, frontal view of right internal carotid artery [ICA]; F, lateral view of left ICA). (G-J) Angiogram of post successful eradication of the shunt by combination of transarterial glue embolization and surgery showing regression of the venous congestion with reopening of both sigmoid sinuses (G and H, frontal and lateral views of left common carotid artery; I and J, frontal views on venous phase of right and left ICAs). However, patient had slightly clinical improvement.

and calcification ($p = 0.002$). Presence of calcification and hydrocephalus had higher incidence of unfavorable outcome than others [100% versus 42% versus others e.g., white matter change (23.53%), hemorrhage (9.09%), and no white matter changes (8.22%)]. There were explanations from prior literatures that venous sinus hypertension cause cerebrospinal fluid [CSF] hydrodynamic disorders and ventricular enlargement by chronic impairment of CSF absorption[13]. Calcification in dAVF is resulted from chronic hypoperfused state (arterial steal phenomenon) or with dystrophic changes in the walls of congested veins[14]. These findings could represent severe increased intracranial pressure and chronicity of the disease before treatment. Even when completed treatment of shunt had achieved its objective, patients still had unchanged symptoms (patients in Figure 3, 4). Even when there is no cortical reflux, prolong increased intra-sinus pressure from the shunt that caused functional thrombosis of other sinuses may cause progressive thrombosis of sinus, increased aggressiveness disease, and permanent neurological deficit (patient in Figure 5).

In general, white matter change on MRI is predicted to recover after treatment because of resolving of brain congestion. However, the disability of our patient did not recover, even after complete closure of the shunt was obtained (Figure 3). In addition, one patient who completely recovered from symptoms still had white matter change on MRI (Figure 6). The authors thought that recovery of white matter change is not assured. Another presentation that probably predicted the bad outcome was chronic neurological deficit or status of bed-ridden before admission. Three bed-ridden patients in this group did not recovered after treatment because of probable irreversible damage of

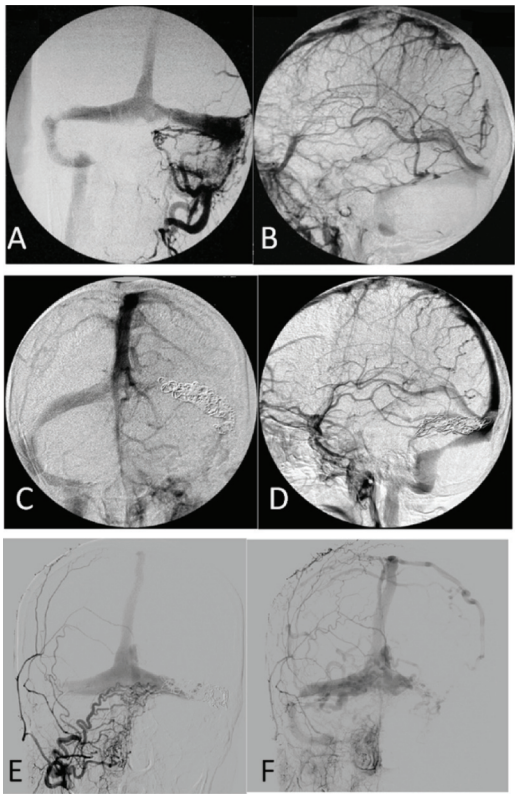

Figure 5. A 42 year old woman presented with chronic headache for 1 year and progressive blur vision of both eyes about 10 months. The MRV revealed left transverse-sigmoid thrombosis (not shown). (A, B) The angiogram showed dAVF at left transverse sigmoid sinus with retrograde sinus drainage (Cognard 2a) causing functional thrombosis of the superior sagittal sinus [SSS]. Partial treatment by transvenous coil embolization of the nonfunctioning left transverse sinus was performed with successful obliteration of the retrograde reflux resulting in re-visualization of the SSS (C, D). The patient had recovered from all symptoms except permanent impaired vision from chronic increased intracranial pressure. Three years later, the patient had progressive cognitive impairment and left hemiparesis. Progression of the shunts at left transverse sinus which was aggravated by progressive right transverse sinus occlusion (E, F). The patient finally had successful combined embolization with surgery. However, the clinical outcome was stable.

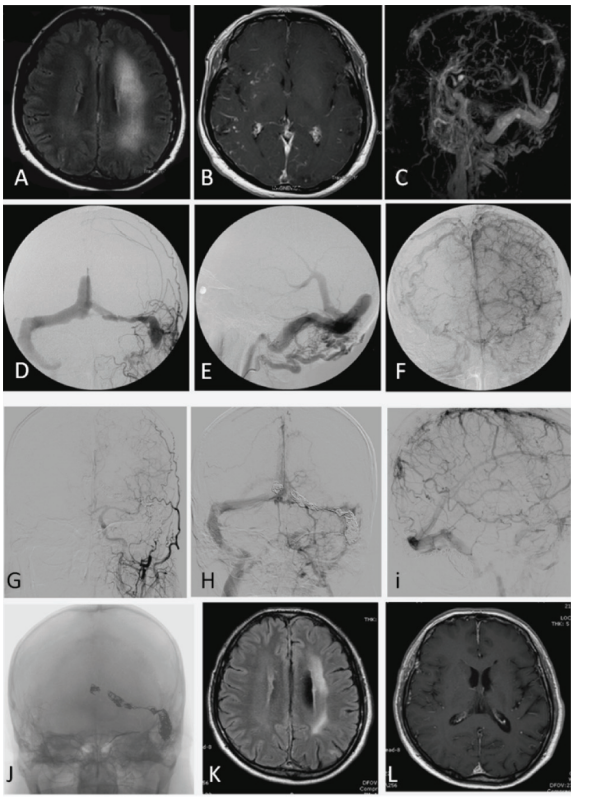

Figure 6. A 49 year old man had progressive right sided weakness with deteriorated cognitive function, ataxia and blur vision. (A-C) MRI and MRA before treatment showed white matter change with malignant cortical reflux. (D-F) The angiogram revealed left sigmoid sinus thrombosis and dural AV shunts with retrograded drainage into superior sagittal sinus, right transverse sigmoid sinus with cortical reflux (Cognard IIa+b) resulting in venous congestion and severe white mater change, particularly on the left side. The patient had successful complete closure of the dural AV shunt by both transvenous coiling and transarterial glue embolization. The angiogram showed re-functional of posterior 1/3 of superior sagittal sinus without venous congestion (G-I). Although the clinical outcome was favorable, and the patient had complete recovery, the MRI still showed white matter changes at 4 years follow-up (J-L).

neurological function.

For adequacy of treatment, complete treatment achieved high favorable outcome about 95.92%, whereas partial treatment and procedural complication gained about 82.35%. In addition, partial treatment, and procedural complication had higher incidence of unfavorable outcome as compared to complete treatment (17.65% versus 4.08%). From our experiences, cortical refluxes should be eradicated as much as possible to decrease the possibility of prolonging the increased intracranial pressure, venous thrombosis, or hemorrhage.

The favorable outcome also depended on procedural complication. Endovascular complication in our study were found in seven patients (Table 4, 5), resulting in 4.7% endovascular complication rate. In benign shunt, unfavorable rate without treatment occurred in about 6.45% but treatment caused complication rate accounted for 10.87%. However, this result vary by operator's experiences. Some resolvable causes of complication such as hemorrhage could have

full recovery, but dangerous glue refluxes or emboli had more tendency of fail.

The other unpredictable factors may cause unfavorable outcome on admission e.g., comorbid diseases such as myocardial infarction, chronic pulmonary disease, or infection. One patient grouped in unfavorable outcome died from myocardial infarction after having diagnostic benign dAVF.

The favorable outcome significantly related factors were benign symptoms ($p<0.01$) and no associated sinus thrombosis ($p<0.01$). Patients who presented with benign symptoms almost had favorable outcome (only 5.26% had unfavorable outcome). Patient who had no sinus thrombosis had incidence of favorable outcome up to 94.96%, and decreased to 76.67% if had associate sinus thrombosis. From our experiences, associated sinus thrombosis was an important factor effecting to venous outlet of shunt, partway drainage of brain, and accessible route of endovascular treatment, which plays major role to achieve favorable outcome.

A limitation of the present study is the interpretation of image findings to determine white matter changes as they had lower sensitivity in CT as compared to MRI in small number of patients who had only CT. However, the authors had tried to improve validity by inter-observer concordance. The authors did not study in details of treatment process, which was a factor influencing clinical outcome, due to operator dependent.

Conclusion

High favorable clinical outcome of cranial dAVF was achieved with low complication rate. Aggressive clinical and angiographic presentations as well as intracranial venous congestion are reversible following an effective treatment. The favorable clinical outcome is predictable in benign symptoms ($p<0.01$) with no associated sinus thrombosis ($p<0.01$). Excluding complication, unfavorable outcome is related with ventricular dilatation ($p = 0.002$) and subcortical calcification ($p = 0.002$) caused by prolong increased intracranial pressure or chronic venous congestion. As treatment result may be unresponsive, offering treatment in patients with these factors should be reconsidered.

What is already known on this topic?

Craninal dAVF was one major of intracranial arteriovenous lesion that leads to aggressive features including intracranial hemorrhage, neurological deficit, cognitive impairment, and death. The role of endovascular treatment of dAVF is the first option treatment with the aim to complete obliteration of the shunts or at least eradicate the retrograded venous reflux.

Even with the outcome as anatomical cure, some patients have not recovered from functional impairment. Many factors were described of concern for the clinical success. Even when the dAVF endovascular procedure shows low complication, the recovery of the patient is still not guarantee.

However, the procedure determination and outcome prediction were based on anatomical aspect described by Lasjaunias et al (1996)[6]. Therefore, the factors associated with outcome needed more research to predict accurately the favorable and unfavorable outcome.

What this study adds?

The favorable clinical outcomes were not only procedure success and low complication, but the recovery of the patient, which is more important. Offering treatment to the predicable unresponsive patient is much more involved.

When reading the MRI of the brain, it is recommended to interpret the initial clinical presentation, such as ventricular dilatation and subcortical calcification. It will help predict the outcome of treatment.

Treatment consideration should be based on the effectiveness. A cranial dAVF patient with no symptoms and no sinus thrombosis could be promoted to favorable outcome of treatment.

Potential conflicts of interest

The authors declare no conflict of interest.

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