Cranial Dural Arteriovenous Fistulas: Can Non-invasive Imaging Predict Angiographic Findings?

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ABSTRACT

Objective: To access the practical of non-invasive diagnostic tools including computed tomography (CT) and magnetic resonance imaging (MRI) to determining the characteristics and aggressiveness of a cranial dural arteriovenous fistula (DAVF).

Methods: Retrospective review of patients with cranial DAVFs who had registered at the Interventional Neuroradiology Center, Siriraj Hospital between January 2007 and December 2016 was performed. The pre-treatment imaging findings were recorded for presence of diagnostic criteria of DAVF, number and location of shunts, and aggressiveness of the disease. Cerebral angiography was used as standard reference in each patient.

Results: There were 86 patients with 119 DAVFs, of which 70.6% were aggressive type. By non-invasive imaging criteria, the shunt detection rate was 95.3%. Inaccuracy of localization and aggressiveness pattern of the disease occurred in 10.4% and 5.9% of the cases respectively. Dural sinus thrombosis was shown in 38%. MRI was superior to CT in accuracy of multiplicity (76.7% VS 55.3%) and identification of aggressiveness (90.2% VS 80%).

Conclusion: Both CT scan and conventional MRI have capability in detection of DAVFs and identification of the disease aggressiveness. Diagnostic limitation and mistaken aggressiveness can occur in patients who have DAVFs with dural sinus drainage only. CT or MRI should be used in practice as the initial work up, with clinical correlation, to identify patients with DAVFs who require endovascular treatment at the appropriate time.

Keywords: Cranial dural arteriovenous fistulas; cerebral angiography; retrograded sinus drainage; cortical venous drainage (Siriraj Med J 2018;70: 289-297)

INTRODUCTION

Dural arteriovenous fistula (DAVF) is defined as an abnormal fistulous communication between the dural arteries and cerebral venous sinus and/or cortical veins.[1,2] A recent population-based study mentions its detection rate as 0.16 per 100,000 adults per year and is estimated to relate to approximately 10-15% of all intracranial arteriovenous malformations.[3-5]

Most DAVFs in adulthood are considered as an acquired lesion.[1,6] The exact etiology and pathogenesis of the DAVFs has remained controversial. Nevertheless, most of these lesions are thought to be secondary from dural venous sinus thrombosis.Venous occlusion results in venous congestion and increased venous pressure. Venous hypertension may increase angiogenic activity which lead to development of DAVFs.[6]

The symptoms of DAVFs depended on their locations and the venous drainage pattern, which ranges from asymptomatic, non-specific headache, focal cranial nerve deficit, exophthalmos, chemosis, pulsatile tinnitus, to

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Received 16 January 2018 Revised 31 March 2018 Accepted 20 April 2018
doi:10.14456/smj.2018.47

even more aggressive symptoms such as motor and/or sensory deficits, seizure, dementia or even intracranial hemorrhage.[7,8]

Nowadays, various classifications are proposed which have mostly focused on the pattern of venous drainage, which is crucial in the risk assessment of these lesions. DAVFs with the presence of cortical venous drainage (CVD) or retrograded sinus drainage (RSD) or both are considered to have a higher risk of neurological sequelae and intracranial hemorrhage. For clinical and therapeutic consideration, DAVFs are classified into 2 major groups: benign and aggressive, by the absence and presence of CVD or RSD on angiographic study, respectively.[7,9]

Identification of DAVFs is crucial because it is a curable disease. The suspicion of the disease is leadby clinical presentation and imaging finding. Although the catheter-based cerebral angiography is currently regarded as the gold standard for diagnosis, and classification of the aggressiveness[10], the procedure is invasive and should be reserved for patients who require endovascular treatment.

Practically, patients who have clinical symptoms are usually first referred for non-invasive diagnostic imaging such as computed tomography (CT) and/ or magnetic resonance imaging (MRI), which are feasible tools in general practice. Hence, if they have diagnostic capability and accurate depiction for severity of DAVFs, this would be useful to rule-in patients who need to perform cerebral angiography and subsequent endovascular treatment, particularly if aggressive features present which require urgent specific care.

This study aimed to assess the practical applicability of non-invasive diagnostic imaging include CT and/ or MRI of the brain to determine characteristics and aggressiveness of DAVFs.

MATERIALS AND METHODS

This study was approved by the Human Research Committee, Siriraj Hospital (Si 692/2016). The records of 96 patients with DAVFs who had referred to Interventional Neuroradiology Center, Siriraj Hospital between January 2007 and December 2016 were retrospectively reviewed. The patients who had no pre-treatment diagnostic imaging (cranial CT and/or MRI) available in Siriraj picture archiving and communication system (PACS) or who had diagnostic study prior to catheter angiogram more than 6 months were excluded.

The pre-treatment imaging including cranial CT which were both noncontrast CT (NCCT) and contrast enhanced CT (CECT) and conventional MRI (with or without MR angiography) were reviewed by two authors who were one interventional neuroradiologist and one 2nd year interventional neuroradiologist fellow. They were blinded to patient's history, clinical presentation and results of cerebral angiographic examination. The discrepancies were resolved by discussion. The data collection included presence of diagnostic criteria of DAVFs, number and location of shunts, and aggressiveness of diseases. The presence of associated venous sinus thrombosis was also recorded. Imaging of the patients who had both CT and MRI examinations were reviewed in random sequence with the other patients.

The criteria for presence of DAVFs on both CT scan and MRI were demonstrable enlarged and/or early filling of dural sinus or venous structure(s) with or without detectable asymmetrically dilatation of external carotid arterial branch(es) that were located near the presumed fistulous point(s). (Fig 1)

The locations of DAVFs were presumed at the segmental enlargement of the dural sinus(es), which were identified as: jugular bulb, transverses-sigmoid sinus, cavernous sinus, superior sagittal sinus, torcular Herophili and straight sinus/ vein of Galen. The sites at transverse-sigmoid and cavernous sinuses were also recorded as left, right or bilateral.

The criteria for presence of CVD and/ or RSD were (Figs 2 and 3)

1. Early filling of the cortical veins
2. Asymmetrically rapid filling of dural sinus(es) that was proximal to the suspected DAVF location
3. Increase in the size and/or number of cortical veins

The DAVFs would be defined as aggressive if CVD and/ or RSD were present, and benign if CVD and RSD were absent.

In the specific location of DAVF at cavernous sinus, if only drainage through the superior ophthalmic vein (SOV) was demonstrated, it was considered as benign type.

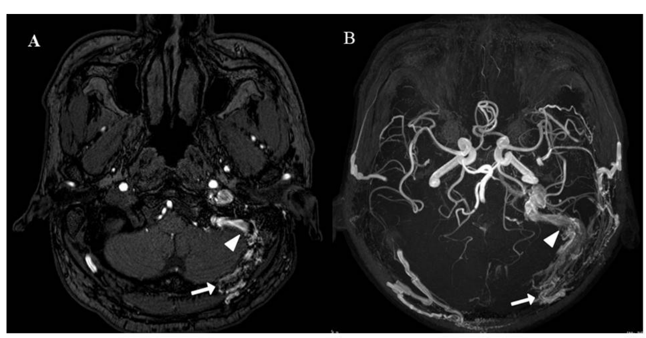

Fig 1. Criteria for presence of cranial dural arteriovenous fistula (DAVF). **(A)** MR angiography and **(B)** Maximum intensity projection (MIP) demonstrated dilated transosseous branches of left occipital artery (arrows) to supply the DAVF at left sigmoid sinus (arrowheads)

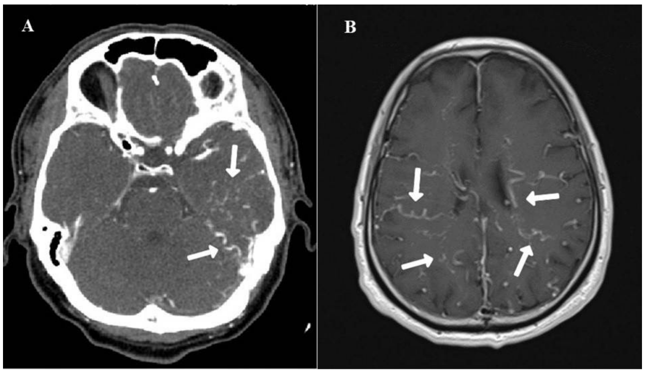

Fig 2. Criteria for presence of cortical venous drainage (CVD). **(A)** Contrast enhanced Computed Tomography (CECT) and **(B)** Post gadolinium T1W magnetic resonance imaging (MRI) in different patients showed dilatation and tortuosity of cortical veins (arrows).

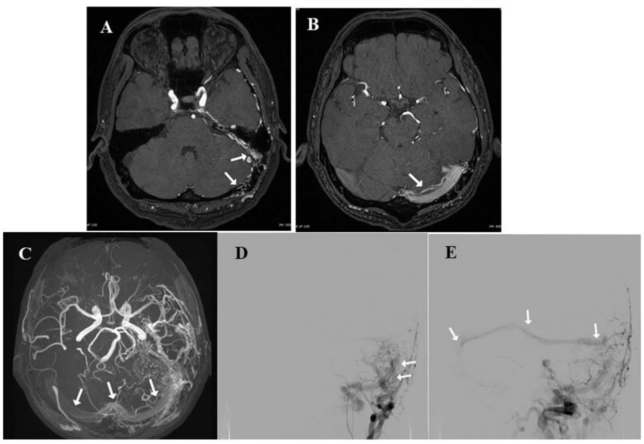

Fig 3. Left sigmoid cranial dural arteriovenous fistula (DAVF), aggressive type in a 49-year-old man who presented with pulsatile tinnitus.
(A)(B) MR angiography and **(C)** Maximum intensity projection (MIP) craniocaudal direction demonstrated cranial dural arteriovenous fistula (DAVF) at left sigmoid sinus (arrows in A) with visualized retrograded flow in bilateral transverse sinuses which were indicative of retrograded sinus drainage (RSD). No cortical venous drainage (CVD) was recognized.
(D) Early and **(E)** late arterial phases of left occipital angiography, frontal projection, revealed corresponding findings of cranial dural arteriovenous fistula (DAVF) at left sigmoid sinus with retrograded sinus reflux only. Also noted antegraded drainage of distal sigmoid sinus (arrows in D) without evidence of sinus thrombosis.

The CVD was recorded as "present" if there was early filling and/ or prominent size of the ipsilateral sphenoparietal sinus.

Catheter angiography was the gold standard for diagnosis of cranial DAVFs, shunt locations, characteristics of venous drainage pattern and type of fistula.

Data were prepared and analyzed using PASW statistics 18.0 (SPSS). Continuous data were described as mean and standard deviation (SD) or median and range, as appropriate. Numbers and percentages were expressed for categorical data and compared using Chi-square test or Fisher's exact test. All tests of significance were two tailed, and p-value of <0.05 was considered as statistical significant.

RESULTS

There were 86 patients with 119 DAVFs who were included in this study (50 women and 36 men with age range between 18-87 years and mean age at 56.17 ±14.25 years), 35 DAVFs (29.4%) were benign type and 84 (70.6%) were aggressive. Most patients (72.1%) had solitary DAVF, whereas 2 patients (2.3%) had maximal number of 4 fistulas.

The duration of clinical presentations varied from a few days to 24 months with mean duration at 2.4 months. The critical clinical presentations, including progressive neurological deficits, seizure, dementia and alteration of consciousness was correlated with aggressive type of DAVFS 96.2% (25/29 patients). Nevertheless, 54.4% (31/57) of patients who had non-serious clinical presentations, which were tinnitus, chemosis and headache, also had aggressive pattern. The angiographic characteristics of DAVFs were shown in the Table 1.

The common locations were cavernous sinuses (40.4%) and transverse-sigmoid sinuses (36.1%), respectively. Most benign DAVFs (54.3%) were found to be located at cavernous sinuses. The aggressive DAVFs were equally at transverse-sigmoid sinuses (35.7%) and cavernous sinuses (34.5%). All DAVFs demonstrated at superior sagittal sinus, torcular herophili and straight sinus had characteristics of aggressive pattern.

CT scans were performed in 43 cases (50%) with accompanying CT angiography in 37 (43%). MRI and MR angiography were available in 34 patients (40.5%), and only conventional MRI in 5 (5.8%). Both CT scan and MRI were carried out in 4 cases (4.7%).

The capability of diagnosis and characteristic identification of DAVFs from noninvasive imaging studies were demonstrated in Table 2.

The criteria of diagnosis of DAVFs were not recognised in 4 patients (4.7%), 3 from CT scan (1 CECT, 2 CT angiography) and the other one from the studies of MRI and MR angiography. Three of them were interpreted to be normal and one had reported to have dural sinus thrombosis only. Two patients had aggressive type showing RSD, without CVD. One patient with cavernous sinus location had antegraded drainage to inferior petrosal sinus only, without dilatation of superior ophthalmic vein.

TABLE 1. Angioarchitectures of cranial dural arteriovenous fistulas (DAVFs).

Characteristics	N (%)	Total N (%)
Aggressiveness		
Benign	35 (29.4%)	119 fistulas (100%)
Aggressive	84 (70.6%)	
Multiplicity		
One	62 (72.1%)	
Two	20 (23.3%)	86 patients (100%)
Three	2 (2.3%)	
Four	2 (2.3%)	
Location		
Cavernous sinus	48 (40.4%)	
Transverse-sigmoid sinus	43 (36.1%)	
Superior sagittal sinus	8 (6.7%)	119 fistulas (100%)
Jugular bulb	5 (4.2%)	
Torcular Herophili	13 (10.9%)	
Straight sinus/vein of Galen	2 (1.7%)	

TABLE 2. Diagnosis of cranial dural arteriovenous fistulas (DAVFs) from Computed Tomography (CT) and/or Magnetic Resonance Imaging (MRI).

Parameters	N (% Correction)	Total (N)
Identification of cranial dural arteriovenous fistulas (DAVFs)		
No	4 (4.7%)	86 patients
Yes	82 (95.3%)	
Location		
Undetermined location	9 (10.4%)	86 patients
Cavernous sinus	40 (83.3%)	48 fistulas
Right	19 (79.2%)	24 fistulas
Left	21 (87.5%)	24 fistulas
Transverse-sigmoid sinus	27 (62.8%)	43 fistulas
Right	8 (57.1%)	14 fistulas
Left	19 (65.5%)	29 fistulas
Superior sagittal sinus	2 (25.0%)	8 fistulas
Jugular bulb	4 (80.0%)	5 fistulas
Torcular Herophili	1 (7.7%)	13 fistulas
Straight sinus/ vein of Galen	1 (50.0%)	2 fistulas
Multiplicity		
One	47 (75.8%)	62 patients
Two	12 (60.0%)	20 patients
Venous sinus thrombosis		
Absent	56 (86.2%)	65 patients
Present	8 (38.1%)	21 patients
Aggressiveness		
Benign	27 (90.0%)	30 patients
Aggressive	46 (82.1%)	56 patients

DAVFs were able to diagnose, but failed to demonstrate their locations in 9 patients (10.4%). The cavernous sinus was the location of the highest percentage of correct detection (40 of 48 shunts, 83.3%), whereas the torcular herophilli was the lowest (1 of 13 shunts, 7.7%). Dural venous sinus thrombosis was recognized in only 38% (8/21 patients).

The multiplicity of DAVFs revealed by noninvasive studies were as many as two locations. MRI demonstrated more superior accuracy in detection of multiple DAVFs than CT studies, with the accuracy of 76.7% and 55.3%, respectively.

Concerning determination of DAVFs aggressiveness from CT studies, the percentage of correction was 80% (36/45), the sensitivity and specificity were 80.0% (95% CI: 61.4-92.3) and 80.0% (95%CI:51.9-95.7), respectively. Positive predictive value (PPV) was 88.9% (95%CI: 74.1-95.7) and negative predictive value (NPV) was 66.7% (95%CI: 48.3-81.0). From MRI studies, the correction was 90.2% (37/41), sensitivity and specificity were 78.9 % (95% CI: 54.4-94.0) and 95.6% (95%CI: 78.0-99.9), respectively. Positive predictive value (PPV) was 93.8% (95%CI: 68.5-99.0) and negative predictive value (NPV) was 84.6% (95%CI: 69.6-93.0). (Table 3)

There were 7 aggressive DAVFs (5.9%) which were interpreted as benign lesions, 4 by CT and 3 by MRI. Four cases had DAVFs at cavernous sinuses which demonstrated retrograded venous reflux into the sylvian veins on catheter angiography and the other three patients had lesions located at transverse-sigmoid sinuses with retrograded drainage to the other side of transverse sinuses, without evidence of CVD. The patient characteristics were shown in Table 4.

DISCUSSION

The common presenting symptoms of DAVFs in this study were pulsatile tinnitus and ocular symptoms, this was similar to previous reports in the literature.[4,11-12] Among these patients, about half of them were definitely aggressive type of DAVFs. Thus, the initial radiologic work-up would be crucial for assessment of brain parenchyma and for treatment planning. The usefulness of CT scan and MRI was proved for differentiation of vascular etiologies[13] Particularly in the suspicious case, for the negative imaging result it is impossible to exclude DAVF unless confirmed by cerebral angiography.

There were many reports of diagnostic clues of DAVFs on non-invasive imaging studies, such as the visualization of asymmetrical enlargement of arterial feeders, shaggy appearance of the dural sinus, asymmetrical dural sinus enhancement, trans-calvarial vascular channels, trans-osseous vessel enhancement, and asymmetrical attenuation of jugular veins on CT angiography.[14-16] The presence of flow void along the dural sinus margin in conventional MRI and flow-related enhancement around the dural sinus or cerebral vein were the suggestive evidences on MR angiography.[17-20]

The criteria for diagnosis of DAVFs which were used in this study could provide 95.3% of shunt detection rates.

TABLE 3. Comparison of cranial dural arteriovenous fistula (DAVF) classification for aggressiveness between noninvasive images and angiography.

Noninvasive classification		Angiographic classification		
		Benign	Aggressive	Total
CT	Unclassified	1	2	3
	Benign	12	4	16
	Aggressive	2	24	26
	Total	15	30	45
MR	Unclassified	1	0	1
	Benign	15	3	18
	Aggressive	0	22	22
	Total	16	25	41

TABLE 4. Patients who was missed aggressive cranial dural arteriovenous fistulas (DAVFs) from noninvasive imagings.

No	Age (y) /sex	Symptoms	Studies	Locations from DSA	Venous drainages		Dilate of cortical vein	
					CT/MRI	DSA	CT/MRI	DSA
1	45/F	Lt. eye chemosis	CECT	Lt. CS	Lt. SOV	Lt. SOV, Rt SMCV	None	Rt. SMCV
2	77/F	Rt. Lateral rectus palsy	CECT	Rt. CS	Rt. SOV	Rt. SOV, Rt. SPS, Rt. SMCV	None	Rt. SMCV
3	44/M	Rt. 3rd nerve palsy	CECT	Bilat. TS	Bilat. SOV	Bilat. SOV, StS, posterior 1/3 of SSS	None	None
4	75/M	Rt. eye chemosis	CECT	Rt. CS	Rt. SOV	Rt. SOV, Rt. SMCV	None	Rt. SMCV
5	54/M	Pulsatile tinnitus	MRA	Lt. TS	Lt. IJV	Lt.TS, Rt.TS	None	None
6	49/M	Pulsatile tinnitus	MRA	Lt. TS	Lt. IJV	Lt.TS, Rt.TS	None	None
7	42/M	Headache	MRA	Rt. CS	Rt. SOV	Rt.SOV, Rt.SMCV	None	Rt. SMCV

Abbreviations: DSA = digital subtraction angiography, CECT = contrast enhanced CT, MRA = Magnetic Resonance Angiography, bilat = bilateral, CS = cavernous sinus, TS = transvers sinus, SS = sigmoid sinus, StS = straight sinus, IJV = internal jugular vein, IPS = inferior petrosal sinus, SPS = superior petrosal vein, SOV = superior ophthalmic vein, SSS = superior sagittal sinus, SMCV = superficial middle cerebral vein

One patient who was misinterpreted of DAVF, but false positive of sinus thrombosis by CECT, the cerebral angiography revealed a shunt with location at right sigmoid sinus, supplied from trans-osseous branches of right occipital artery. No thrombus in the right sigmoid sinus was identified, although the affected sinus was not visualized as normal venous emptying channel from normal brain circulation, because it had been already occupied by higher blood pressure from the arteriovenous shunts. The filling defect at the sigmoid sinus seen on CT scan might result from artifact of flow competition. In addition, the transosseous arteries supplying the shunts which were overlapped with the cranial vault could not be recognized from CT scan. (Fig 4) The hybrid CT angiography has been reported to have a higher sensitivity and specificity in the diagnosis of DAVFs by using bone removal technique which may provide more advantage for demonstrations of vascular details near skull base and bony structure.[15]

In the other 3 cases with absent criteria of DAVFs, the cerebral angiogram revealed both antegraded and retrograded sinus drainage. All had no CVD, and particularly, no dilatation of the SOV in the case with cavernous DAVF. Furthermore, each affected sinus showed symmetrical appearance on the opposite side. No sinus thrombosis was identified. Thus, CT scan could not recognize DAVFs, because there was no morphologic change of those venous structures. In addition, the visualization of transosseous arterial feeders, which were not significantly dilated, through the cranial vault was also difficult, by spatial and temporal resolution of CT scan. Although there were reports that MRA could improve the identification rate of DAVFs by recognizing flow-related enhancement in the cavernous sinus, and also correctly interpreting posterior drainage in those without anterior drain to superior ophthalmic vein.[18,20-21]

For the characterization of DAVFs, the location at cavernous sinus which was the most common locations

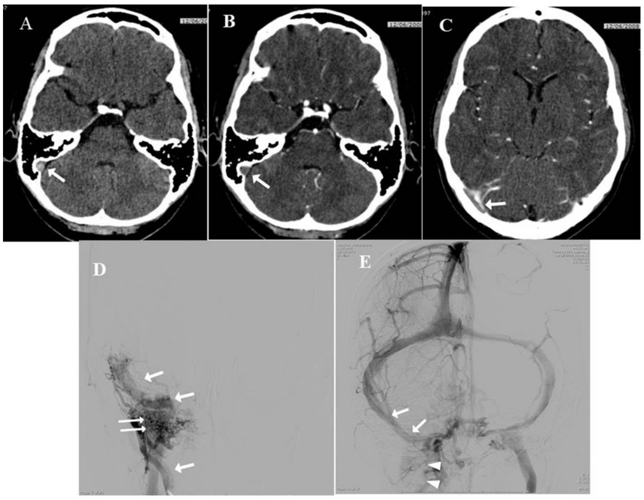

Fig 4. Aggressive cranial dural arteriovenous fistula (DAVF) in a 35-year-old female, presenting with headache was missed diagnosis from CT scan **(A)** Noncontrast enhanced Computed Tomography (NCCT) showed high density blood at the right sigmoid sinus (arrow) **(B) and (C)** contrast enhanced Computed Tomography (CECT) revealed corresponding filling defect at the sigmoid sinus(arrows) (D) Right external carotid angiography frontal view demonstrated DAVF at distal sigmoid sinus to internal jugular vein junction supplying by small trans-osseous branches of occipital artery (small long arrows) with both antegraded and retrograded drainage in the internal jugular vein and proximal sigmoid sinus respectively (arrows) **(E)** Venous phase of right internal carotid angiography frontal view exhibited no visualized distal sigmoid sinus (arrows) and internal jugular vein (arrowheads), which was "functional thrombosis" phenomenon.

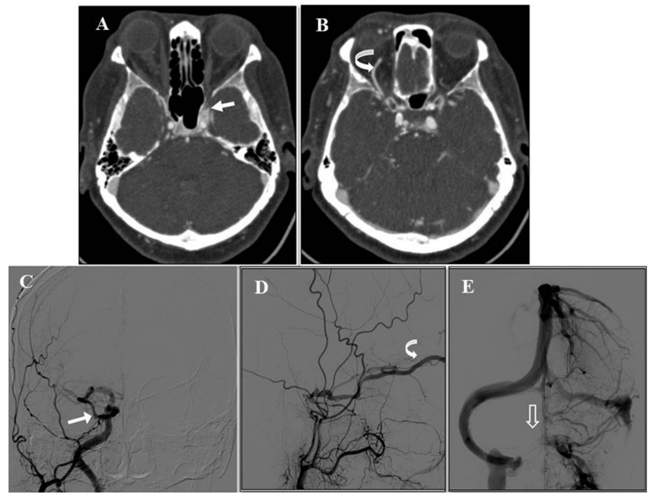

Fig 5. Right cavernous cranial dural arteriovenous fistula (DAVF), benign type, with right cavernous sinus thrombosis. **(A) and (B)** Contrast enhanced Computed Tomography (CECT) revealed prominent left cavernous sinus (arrow) as compared to the right and dilatation of the right superior ophthalmic vein (SOV) (curved arrow) On the basis of visualized sinus morphology, the cranial dural arteriovenous fistula (DAVF) was interpreted to be on the left side. **(C)** Frontal and **(D)** lateral views of right external carotid angiography demonstrated shunt location at the outlet of right superior ophthalmic vein (SOV) **(E)** Note no filling of right cavernous sinus on frontal projection of right internal carotid angiography (arrow) indicative of right cavernous thrombosis.

of our DAVFs, was the most accurate detected from these noninvasive imagings. The most helpful sign for localization was dilatation of the SOV.

Conversely, the lateralization of cavernous sinus location of DAVFs might have some difficulty, because the dilatation of SOV could present on the opposite side to the shunt or even bilaterally. It revealed an interesting pitfall in our study. The patient was demonstrated on cerebral angiography to have DAVF at right cavernous sinus where it had partially thrombosed, and the left cavernous sinus was slightly more prominent than the involved one. On CT images, although the right SOV was larger, the cavernous sinus morphology misled to place the lesion on the left side. (Fig 5) There were previous studies which reported that only a half of carotid-cavernous fistulas detected on contrast-enhanced CT, showed focal or diffuse bulging of the involved side. In contrast to superior ophthalmic vein, it was more frequently observed on the same side as the shunt, in 86%-100% and 75-100% on contrasted CT and conventional MR, respectively.[21-25]

Although shunt locations and multiplicity of the disease were not depicted by the noninvasive imaging tool, it did not change the decision making, once diagnosis of DAVFs were documented, cerebral angiogram with treatment consideration would be indicated. In general, patients who had multiple DAVFS would be recognized by the major one which caused the most serious symptom. The rate of correct detection of venous sinus thrombosis in this study was 38%. In previous studies, it was about 50% by CT and MRI with the usefulness of empty delta sign or filling defect on contrast-enhanced study. Nevertheless, other etiologies, such as arachnoid granulations, intrasinus septa, and venous sinus duplication could mimic the filling defect.[26-28]

Regarding the aggressive behavior of DAVFs, dilated and tortuous leptomeningeal or medullary vessels, venous ectasia as well as leptomeningeal or medullary vascular enhancement were used as evidence of cortical venous reflux.[11,20,29,30] Our result revealed diagnostic accuracy of CT scan and MRI to be good with high sensitivity and specificity. The correct interpretation of aggressive DAVFs by CT was 80% sensitivity and specificity, and MR was 78.9% sensitivity and 95.6% specificity, respectively. (Fig 6)

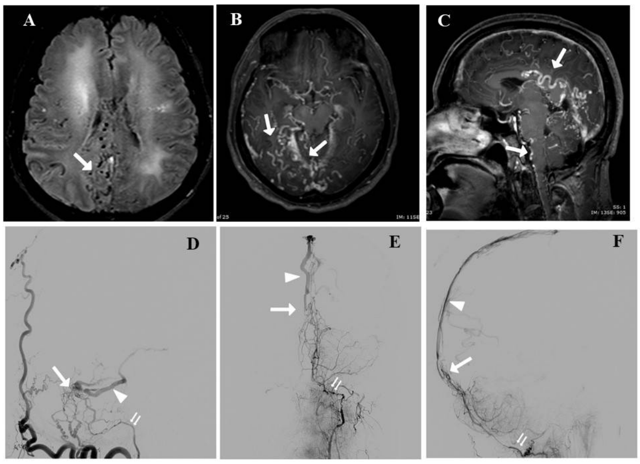

Fig 6. Multiple aggressive type of cranial dural arteriovenous fistula (DAVF) in a 52-year-old man who presented with seizure with incomplete consciousness. **(A)** Magnetic resonance imaging (MRI), axial FLAIR showed abnormal periventricular white matter hypersignal intensity bilaterally with multiple flow voids of cortical venous congestion at right parieto-occipital region (arrow) **(B) and (C)** post gadolinium T1W MRI axial and sagittal views revealed multiple abnormal dilated and tortuous cortical veins including perimesencephalic and spinal cord veins. (arrows). No arterial feeders and sinus thrombosis were identified. (not shown images) The impression was aggressive type of DAVF, however, the site of shunt could not be localized. **(D)** Lateral view of left occipital angiography demonstrated cranial dural arteriovenous fistula (DAVF) at straight sinus (arrow: fistulous point, arrowhead: straight sinus) supplying from tiny emissary branches (small arrows). **(E)** Frontal and **(F)** lateral views of left vertebral angiography demonstrated the 2nd cranial dural arteriovenous fistula (DAVF) at distal 1/3 level of superior sagittal sinus with retrograded drainage fashion. (double small arrows: vertebral artery, arrow: fistulous point, arrowhead: superior sagittal sinus)

Concerning our 7 aggressive DAVFs which were interpreted as benign lesion, 4 cases were cavernous DAVFs, with CVR only into the superficial middle cerebral vein, and they was not dilated enough to be observed from CT or MRI. The other 3 cases were transverse-sigmoid DAVFs with solely retrograded sinus drainage.

CT and MRI could depict the morphology of the dural sinuses and the size of cortical veins, but it was difficult to differentiate the dynamic physiology of venous drainage between DAVFs and normal circulation, particularly with subtle hemodynamic change of the superficial middle cerebral vein. The susceptibility-weighted imaging (SWI) and the time-resolved technique MRI with visible flow direction in different phases, were introduced to overcome the static MRI that benefits not only to determine venous drainage, but also detect small lesions.[31,32]

In our study, the aforementioned findings had emphasized the importance of radiological images in detection of DAVFs, in correlation with clinical presentations, for further planning of endovascular treatment in appropriate time. Those criteria for depiction of DAVFs and their aggressiveness were proved to be applicable on conventional CT and MRI, although there were some limitations for interpretation of the shunt location and multiplicity of the disease.

The limitation of our study was retrospective, single center study with small sample size. The imaging protocol was inhomogeneity and the interpreters were not blinded to the diagnosis of DAVF.

CONCLUSION

The conventional CT and MRI, as available non-invasive diagnostic tools, have shown their capability in detection of DAVFs and identification of the disease aggressiveness. CT or MRI should be used in practice as the initial work up for those symptomatic patients. Nevertheless, diagnostic limitation and misled aggressiveness might be unavoidable in patients who have DAVFs with only dural sinus drainage and no cortical venous reflux. Careful interpretation with clinical correlation are important and helpful for treatment determination in the appropriate time. Cranial angiography should be reserved for patients who require endovascular management and those who have negative imaging result, but present with serious symptoms.

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