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CT and MR imaging of non-cavernous cranial dural arteriovenous fistulas: Findings associated with cortical venous reflux

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ABSTRACT

Purpose: To compare the conventional CT and MR findings of DAVFs in relation to the venous drainage pattern on digital subtraction angiography (DSA).
Materials and Methods: Cross-sectional imaging findings (CT and/or MR) in 92 patients were compared to the presence of cortical venous reflux (CVR) on DSA.
Results: Imaging features significantly more prevalent in patients with CVR included: abnormally dilated and tortuous leptomeningeal vessels (92% vs. 4%, $p < 0.001$) or medullary vessels (69% vs. 0%, $p < 0.001$), venous ectasias (45% vs. 0%, $p < 0.001$) and focal vasogenic edema (38% vs. 0%, $p < 0.001$). The following findings trended towards association but did not reach the p value established following Bonferroni correction: dilated external carotid artery branches (71% vs. 38%, $p = 0.005$), cluster of vessels surrounding dural venous sinus (50% vs. 19%, $p = 0.009$), presence of hemorrhage (33 vs. 12%, $p = 0.040$), and parenchymal enhancement (21% vs. 0%, $p = 0.030$).
Conclusion: In the appropriate clinical setting, recognition of ancillary signs presumably related to venous arterialization and congestion as well as arterial feeder hypertrophy should prompt DSA confirmation to identify DAVFs associated with CVR.

1. Introduction

Dural arteriovenous fistulas (DAVFs) associated with cortical venous reflux (CVR), in particular those that present with clinical symptoms are associated with poor outcome if left untreated [1] thus generally requiring treatment [1–3]. Their early detection can therefore potentially avoid further progression or occurrence of complications. Although digital subtraction angiogram (DSA) is the gold standard for the diagnosis, clinical or radiological suspicion must be present prior to the performance of such invasive study. Similarly, newer non-invasive techniques such as dynamic CTA or MRA have been developed to better assess such pathology but are generally not routinely performed unless suspicion of a vascular pathology is present prior to the performance of such study. Computed tomography (CT) and/or magnetic resonance (MR) imaging is often performed as part of the initial work-up but, in our experience as well as prior reports [4], the diagnosis is often delayed secondary to the combination of non-specific clinical and neuroimaging features. With the exception of cavernous dural arteriovenous fistulas [5], conventional neuroimaging features of non-cavernous cranial DAVFs have, so far, only been reported in small series and case reports, the latter usually focused on unusual and rare presentations. To date the largest conventional imaging studies included respectively 12 and 25 patients [5,6], the latter including only 16 patients with non-cavernous DAVFs. Reported imaging features range from normality to hemorrhagic and non-hemorrhagic complications, dilated leptomeningeal or medullary vessels without a nidus, as well as a spectrum of non-specific and sometimes subtle findings [5–8]. Given the small number of patients per publications, we decided to reassess the prevalence of previously published conventional imaging findings of non-cavernous cranial DAVFs in relation to the drainage pattern on DSA in an attempt to confirm and identify new imaging clues that could help suggest the diagnosis of a DAVF associated with CVR.

2. Methods

2.1. Study population

Our institution ethic board approved this retrospective study. Patients were retrieved from our tertiary center interventional

Abbreviations: CECT, Contrast-enhanced CT; CERM, Contrast-enhanced MR; CVR, Cortical venous reflux.; DAVF, Dural arteriovenous fistula; DSA, Digital subtraction angiography; ECA, External carotid artery; IVH, Intraventricular hemorrhage; PPP, Pseudophlebitic pattern.

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neuroradiology patient database. Consecutive patients having undergone CT and/or MRI prior to DAVF treatment with available DSA confirmation of DAVF were included. Patients harboring cavernous fistulas or previously treated DAVF were excluded. From our database, 159 patients were identified. From these, 16 cavernous DAVF were excluded and 51 patients with poor imaging quality due to incompletely or poorly digitalized hardcopies were excluded. A total of 92 patients with imaging performed between September 1997 and May 2012 met the inclusion criteria.

2.2. Imaging methods

Digital subtraction cerebral angiograms were obtained on dedicated biplane neuroangiographic units. DSA generally consisted of injections of bilateral internal and external carotid artery as well as at least one of the vertebral arteries, supplemented with selective injections of the occipital, ascending pharyngeal, or internal maxillary arteries, if judged indicated.

Non-contrast CT (NCCT), contrast-enhanced CT (CECT) and computed tomography angiography (CTA) imaging were performed on different CT units at our institution and were sometimes available from referral hospital centers. Similarly, MR imaging was performed on various imaging platforms. Our standard protocol includes sagittal T1WI, axial FLAIR, axial TSE T2WI, axial T2*WI (or SWI, if available) and axial DWI but were often supplemented by post-gadolinium axial and coronal T1WI, 3D gradient echo post-gadolinium T1WI (e.g. SPGR) and/or contrast-enhanced magnetic resonance venography (MRV). Twenty-eight (30%) patients were assessed on 3.0 Tesla units whereas the remaining studies were performed on 1.5 Tesla units.

2.3. Data collection

Medical records were reviewed using our institution electronic patient record. Data included: age, sex and symptoms at presentation as well as history of previous cranial surgery, head trauma or cerebral venous thrombosis. Similar to a previous description [5], aggressive clinical presentation was defined as complications attributable to a DAVF including: acute intracranial hemorrhage, seizure, focal neurological deficit, cognitive change/dementia and/or altered level of consciousness.

Medical imaging records were reviewed for DSA, CT and MRI findings. DSA features included: DAVF anatomical location using the classification suggested by Geibprasert et al., [9], presence of pseudophlebitic pattern (PPP) [10], presence of cortical venous reflux [1,3,11] and Borden grade [3]. DAVFs without and with CVR were considered as “benign” and “malignant” respectively. The shortest time interval between CT/MR and DSA was noted. Recorded CT or MR findings included: acute or chronic hemorrhage (chronic ICH and pial siderosis were only assessed using MR), hydrocephalus, vasogenic edema and parenchymal enhancement as well as any other finding which was deemed not appropriate for the patient’s age. These additional features were assessed if CT was available: parenchymal calcifications [12] and abnormally prominent transcalvarial channels [13]. The following findings were assessed if CECT, CTA or MR were available: cluster of vessels surrounding dural venous sinus, dilated leptomeningeal vessels, dilated medullary vessels, venous ectasia and dilated extracranial ECA branches [5]. These abnormal vessels were inferred by the presence of enhancing vascular structures on CECT or CTA and/or flow voids or enhancing vessels on MR. Dilated extracranial external carotid artery (ECA) branches were arbitrarily defined as dilatation of the occipital, internal maxillary, middle meningeal or ascending pharyngeal at least two times the caliber of the contralateral side. If bilateral, the dilatation was considered present if the artery was judged unequivocally larger than the usual caliber for a given location. Venous ectasias were defined as larger than 5 mm and at least 3 times the diameter of the draining vein, as previously defined by Cognard et al. [11]. Veno-occlusive disease was defined as narrowed or occluded venous sinuses on the venous phase of DSAs, CTAs if adequate venous enhancement was present and/or MRVs if available. Parenchymal enhancement was assessed only on CECT or CEMR. Diffusion restriction on MRI was assessed qualitatively and noted as present or absent using the ADC maps. Of note, no attempt to diagnose early venous filling on CTA was performed given the small number of CTAs available and frequent venous contamination on these studies.

The aforementioned CT and MR imaging findings were assessed by one of the author (name blinded, second year neuroradiology fellow) who evaluated the original radiological reports and subsequently assessed directly the images searching for additional features. This observer was blinded to the DSA features but not to the DAVF diagnosis. In case of doubts on the presence or absence of a finding, second opinion was sought from the senior author (name blinded). The clinical and DSA features were subsequently assessed at least four weeks apart from the CT/MR readings by the same observer, again with reference to the original reports.

Table 1
Demographic and clinical findings in patients with benign and malignant DAVFs.

	Benign	Aggressive	*p*-value	
Demographics	26	66		
Age	52	58	0.089	
Sex (male)	9 (35%)	44 (76%)	0.007	*
Clinical findings				
Headache	9 (35%)	21 (32%)	0.809	
Tinnitus	20 (77%)	12 (18%)	<0.001	*
Aggressive clinical presentation	4 (15%)	47 (71%)	<0.001	*
Acute hemorrhage	4 (15%)	14 (21%)	0.771	
Seizure	0 (0%)	16 (24%)	0.004	*
Focal neurological deficit	2 (8%)	22 (33%)	0.016	*
Cognitive change/dementia	0 (0%)	10 (15%)	0.005	*
Altered level of consciousness	1 (4%)	6 (9%)	0.669	
Incidental imaging discovery	1 (4%)	6 (9%)	0.669	
Prior surgery	1 (4%)	3 (5%)	1.000	
Prior venous thrombosis	0 (0%)	2 (3%)	1.000	
Prior Head trauma	1 (4%)	4 (6%)	1.000	

* Indicates statistically significant result ($p < .05$).

2.4. Statistical analysis

The clinical and neuroimaging features were assessed in relation to the presence or absence of cortical venous reflux. Continuous variables were assessed using either the Student t test or Mann-Whitney U test, as appropriate following normality distribution assessment (Shapiro-Wilk test). Categorical variables were assessed by using the Fisher exact test. $p < 05$ was considered statistically significant. Given multiple comparisons, a Bonferroni correction was applied to the 13 CT and MR imaging findings listed in Table 2, therefore lowering the significance threshold to $p < 0.004$ ($\alpha = 0.05/13$). Statistical tests were performed using R, version 2.13.2 (http://cran.r-project.org/bin/windows/base/old/2.13.2/).

3. Results

Clinical features are summarized in Table 1 and imaging features in Table 2. Online Table 1 lists the different subtypes of hemorrhages encountered. The median time interval between CT/MR imaging and DSA for DAVFs without CVR was 55 days (interquartile range 15 to 82 days) and 12 days (interquartile range 2 to 76 days) for DAVFs with CVR, showing a non-significant trend for shorter interval in fistulas with CVR ($p = 0.075$). Online Table 2