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Clinical Study

Risk factors for dural arteriovenous fistula intracranial hemorrhage

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ABSTRACT

To our knowledge, the risk factors for intracranial hemorrhage from dural arteriovenous fistula (DAVF) have not been systematically described, due to the complexity of their anatomy and low incidence. We performed this retrospective study to investigate the DAVF factors predicting intracranial hemorrhage. A 10 year database of 144 consecutive patients with DAVF was reviewed. Data collected and analyzed were demographics, morphologic features of DAVF, sex, age, fistula flow rate, arterial supply, lesion location, and venous drainage pattern. Linear univariate and multivariate logistic regression analyses were used to evaluate the association between influencing factors and hemorrhage. A first linear univariate analysis was performed for all influencing factors, and showed that sex, lesion location, and venous drainage pattern were statistically significant in predicting intracranial hemorrhage ($p < 0.05$). Secondary multivariate logistic regression analysis with sex, lesion location, and venous drainage pattern showed that only venous drainage pattern was statistically significant in predicting intracranial hemorrhage ($p < 0.05$). Therefore, venous drainage pattern, particularly the cortical venous drainage, significantly predicts intracranial hemorrhage from DAVF. Both sex and lesion location may be confounding factors in predicting intracranial hemorrhage from DAVF, while the other factors may not be associated with hemorrhage.

1. Introduction

Dural arteriovenous fistula (DAVF) is a rare neurovascular abnormality, which accounts for approximately 10–15% of all intracranial arteriovenous lesions. The DAVF shunts blood from the dural arteries to the dural venous sinuses, the meningeal veins, or the cortical veins [1–3]. The etiology of DAVF is incompletely understood, but they are considered to be acquired. The primary symptoms of DAVF are intracranial hemorrhage and non-hemorrhagic neurological dysfunction, which may be related to numerous factors including age, sex, fistula flow rate, arterial supply, lesion location, and venous drainage pattern. Among these, sex, lesion location, and venous drainage pattern have attracted increasing attention. The most significant influencing factor may be the venous drainage pattern, particularly cortical venous reflux (CVR), which is strongly associated with aggressive clinical manifestations, especially intracranial hemorrhage [4,5]. Previously published reports have shown that the annual mortality for DAVF with CVR may be as high as 10.4%, with an annual risk of intracranial hemorrhage of 10.9% [6]. The re-hemorrhage rate of patients with DAVF is estimated to be up to 35% in the first 2 weeks following an initial hemorrhage. In some studies, the re-hemorrhage rate is as high as 43% in the first few days [7]. We undertook a retrospective study to assess features of DAVF associated with intracranial hemorrhage, and consequently, to determine treatment for those DAVF high risk to reduce the incidence of aggressive clinical manifestations.

The clinical presentation of DAVF is closely related to the venous drainage pattern. The widely used Borden classification [27] of DAVF is based on the venous drainage pattern [8] as is the Cognard classification [28], but with greater detail [9,10], including CVR and the pattern of venous sinus drainage.

2. Materials and methods

2.1. Patient selection

A retrospective 10 year clinical database in Beijing Tiantan Hospital, Capital Medical University, of 144 consecutive patients was reviewed for all patients with DAVF. The clinical records and imaging studies, including CT scans, CT angiography, MRI, magnetic resonance angiography and digital subtraction angiography (DSA), were reviewed in detail. Patients with complete clinical and imaging information were entered into a database created for this study. All included patients had available imaging with CT scan and conventional DSA, including bilateral external carotid arteries, bilateral internal carotid arteries, and bilateral vertebral

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arteries to assess the arterial supply, lesion location, fistula flow rate and the venous drainage pattern. Patients without complete clinical and imaging information were excluded from the study.

2.2. Definition of fistula flow rate and classification of DAVF

The fistula flow rate was grouped into two types according to the initial contrast agent filling time of the fistula/venous drainage compared to the initial contrast agent filling time of the M1 internal carotid artery segment on DSA. A high fistula flow rate was defined as an initial contrast agent filling time of the fistula/venous drainage earlier than that of the M1 internal carotid artery segment. In contrast, low fistula flow rate was defined as an initial contrast agent filling time of the fistula/venous drainage later than that of M1 internal carotid artery segment.

The DAVF were classified into three types based on the Borden classification, with reference to Cognard type [8,9,11–13]:

Type I: Direct anterograde flow into the dural sinus/meningeal vein without CVR.

Type II: Drainage into the sinus with CVR and without significant ectasia of the leptomeningeal veins.

Type III: Direct CVR (drainage into the sinus with CVR, with veins/venous lakes >5 mm or three times larger than the diameter of the draining vein).

2.3. Statistical analysis

The Statistical Package for the Social Sciences (SPSS, Chicago, IL, USA) was used to analyze the association between DAVF features and hemorrhage risk. All factors were expressed in the form of mean ± standard deviation or number including sex, age, fistula flow rate, artery supply, lesion location and venous drainage pattern, and continuous variables were analyzed using the *t*-test, and categorical variables using Pearson's chi-squared test. To identify independent predictive factors and confounding factors for intracranial hemorrhage from DAVF, univariate analyses and multivariate logistic regression analysis (forward stepwise conditional) were performed for clinical and angiographic parameters. A p value <0.05 was regarded as statistically significant.

3. Results

3.1. Patient demographics and angiographic characteristics

Baseline characteristics and presentation of the 144 patients are shown in Table 1. The most common presentations were headache (55.6%) and intracranial murmur/bruit (53.4%).

The average age was 43.0 ± 13.4 years in the non-hemorrhage group *versus* 40.7 ± 13.3 years in the hemorrhage group, with no significant difference ($p = 0.745$), similar to many other previous studies. The arterial supply of DAVF was divided into two groups by unilateral or bilateral arterial supply. Hemorrhage occurred in 14 out of 80 patients (17.5%) with unilateral arterial supply, and in 18 out of 64 (28.1%) patients with bilateral arterial supply. However, arterial supply was not significantly different ($p = 0.128$). According to the fistula flow rate defined above, 89 patients had a high flow fistula with a 20.2% risk of hemorrhage, while 55 patients had a low flow fistula, with a 25.5% risk of hemorrhage. However, the risk of intracranial hemorrhage with respect to the fistula flow rate was not significantly different ($p = 0.463$).

There was a female dominance (∼1.5:1), with 87 females and 57 males. The incidence of hemorrhage was 18 out of 57 (31.6%) males, and only 14 out of 87 (16.1%) females ($p = .029$).

Lesions were located at the cavernous sinus (49.3%), transverse and sigmoid sinus (33.3%), superior sagittal sinus (4.9%), anterior cranial fossa (4.2%), and tentorium (8.2%). These results were dichotomized into a cavernous sinus territory group and a non-cavernous sinus territory group (including superior sagittal sinus, transverse and sigmoid sinus, anterior cranial fossa and tentorium) with a significantly different risk of hemorrhage seen between these groups ($p = 0.000$). Surprisingly, unlike other reports of Borden Type I DAVF, no patients with Type I in our study incurred bleeding, while 13 out of 30 (43.3%) Type II patients and 19 out of 25 (76%) Type III patients experienced hemorrhage (Tables 2 and 3).

Table 1
Presentation and clinical symptoms of patients with dural arteriovenous fistula

	n	%
Headache	80	55.6
Intracranial murmur/bruit	77	53.4
Cavernous sinus hyperemia (conjunctival congestion, chemosis)	75	52.1
Unilateral	60	41.7
Bilateral	15	10.4
Visual deterioration	16	11.1
Blindness	2	1.4
Seizure	8	5.6
Exophthalmos	35	24.3
Disorders of consciousness	5	3.8
Other neurological deficit	6	4.2

Table 2
Correlation of dural arteriovenous fistula classification with risk of intracranial hemorrhage

Current study		Borden [27]		Cognard [28]	
Type I	0%	Type I	2%	Type I	0%
Type II	43.3%	Type II	39%	Type IIa	7%
Type III	76%	Type III	79%	Type IIb	38%
				Type IIa + b	40%
				Type III	69%
				Type IV	83%
				Type V	100%

3.2. Significant factors related to intracranial hemorrhage

Patients were divided into a hemorrhage group and non-hemorrhage group according to their history (Table 3). To investigate the factors correlated with hemorrhage, all factors (sex, age, lesion location, arterial supply, fistula flow rate and venous drainage pattern) were enrolled into the univariate analysis for both the non-hemorrhage patients and hemorrhage patients. After excluding the non-significant factors (age, arterial supply and fistula flow rate), sex, lesion location and venous drainage pattern were significantly associated with hemorrhage in another univariate analysis ($p < 0.05$).

Secondly, the significant factors of sex, lesion location and venous drainage pattern were enrolled into a logistic regression model using a forward stepwise conditional method (Table 3). The adjusted odds ratios and p values for independently predicting hemorrhage are shown in Table 4. Multivariate analysis indicated that sex and lesion location did not have a significant impact on the risk of hemorrhage ($p > 0.05$), with non-significant odds ratio values. Only the venous drainage pattern was an independent and significant factor in predicting hemorrhage from DAVF. Consequently, patients with CVR had a higher risk of intracranial hemorrhage than those without CVR; and the risk of hemorrhage in Type II patients was lower than the risk in Type III patients. In addition, the odds ratio value was as high as 11.950 for venous drainage pattern in logistic regression analyses, indicating venous drainage pattern was a significant predictor of hemorrhage.