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Angioarchitectural Characteristics of Brain Arteriovenous Malformations with and without Hemorrhage

Xianli Lv, Zhongxue Wu, Chuhan Jiang, Xinjian Yang, Youxiang Li, Yong Sun, Nai Zhang

Key words
- Arteriovenous malformation
- Hemorrhage

Abbreviations and Acronyms
AVM: Arteriovenous malformation
CI: Confidence interval
OR: Odds ratio


Beijing Neurosurgical Institute and Beijing Tiantan Hospital, Capital Medical University, Beijing, China

To whom correspondence should be addressed: Zhongxue Wu, M.D. [E-mail: ttyyzjb@sina.com]

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OBJECTIVE: **To explore angioarchitectural features of brain arteriovenous malformations (AVMs) manifesting with hemorrhage and without hemorrhage.**

METHODS: **During the period 1999–2008, 302 consecutive patients with AVMs were retrospectively reviewed. Univariate and multivariate logistic analysis was used to assess AVM characteristics in patients who presented with hemorrhage and patients who presented without hemorrhage. Annual and cumulative incidence rates of AVM rupture were analyzed using Kaplan-Meier life-table analyses.**

RESULTS: **The annual risk of hemorrhage from AVMs in this study was 1.9%. In the comparison of 159 patients with AVM with hemorrhage at initial presentation with 143 patients who did not experience hemorrhage initially (total 302 patients), deep and infratentorial AVM location, AVM size <3 cm, single arterial feeder, single draining vein, combined deep and superficial drainage, presence of varices in the venous drainage, and coexisting aneurysms were statistically associated with hemorrhage presentation ($P = 0.000$, $P = 0.000$, $P = 0.007$, $P = 0.000$, $P = 0.000$, $P = 0.000$, and $P = 0.003$) in univariate analysis. Deep and infratentorial AVM location, single draining vein, presence of varices in the venous drainage, and coexisting aneurysms were statistically associated with hemorrhage occurrence ($P = 0.007$, $P = 0.008$, $P = 0.018$, and $P = 0.002$) in multivariate logistic analysis.**

CONCLUSIONS: **The angioarchitectural characteristics of AVM associated with hemorrhage include deep and infratentorial AVM location, AVM size <3 cm, single arterial feeder, single draining vein, combined deep and superficial drainage, presence of varices in the venous drainage, and coexisting aneurysms.**

INTRODUCTION

Data from multiple diagnostic techniques for brain arteriovenous malformation (AVM) suggest an overall brain AVM detection rate of 1.3 (95% confidence interval [CI] 1.29–1.57) per 100,000 person-years (4). AVMs are congenital lesions that occur most frequently in the supratentorial region (18). Diagnosis of AVM increases with patient age, but an AVM is often detected in patients younger than 50 years old. About half of patients with AVMs present with hemorrhage followed by focal or generalized seizures (25%), headache (15%), and focal neurologic deficits and other symptoms (3). The variable angioarchitectural characteristics of AVMs may be associated with occurrence of hemorrhage (5, 10, 12, 20). Detailed understanding of AVM angioarchitecture would help us identify characteristics that correlate with hemorrhage. Knowledge of these specific factors may also help provide a morphologic basis for AVM treatment (20). We performed this study to obtain a better understanding of the factors associated with hemorrhage in AVM patients.

METHODS

During the period 1999–2008, 302 consecutive patients with cerebral AVMs were referred to our institution for endovascular embolization. Demographic, clinical, morphologic, and treatment data related to these patients were retrospectively reviewed (**Table 1**). Patients ranged in age from 5–65 years (mean ± SD, 28.3 ± 12.8). There were 188 male patients and 113 female patients.

Arteriovenous Malformation Characteristics

Initial AVM manifestation was defined as hemorrhage and nonhemorrhage. The following angioarchitectural characteristics were evaluated on digital subtraction angiography: size of AVM, location of AVM, type of feeders, characteristics of venous drainage, and location and number of aneurysms. The lesions were classified according to size as small (<3 cm), medium (3–6 cm), and large (>6 cm). AVM location included three categories: cortical, deep, and infratentorial. A deep AVM was defined as one involving ventricular nuclei, thalami, ventricles, and diencephalon. A cortical AVM was defined as one on the surface of the cerebrum. An infratentorial AVM was defined as one on the brainstem and cerebellum. Feeders were classified into two categories: cortical branches and perforators. Five parameters of venous drainage were considered (deep or superficial, number of draining veins, presence of varices, and presence of venous stenosis). A varix was defined as a markedly ectatic vein, and venous stenosis was defined as a reduction of ≥50% of the vein diameter. Aneurysms were classified into three groups: intranidal, flow-related (on feeding arteries), and unrelated (remote to AVM).

Statistical Analysis

Univariate tests (χ^2 test) and multivariate logistic analyses (with $P < 0.05$ being considered significant) including age, sex, AVM location, AVM size, type of feeders, venous drainage pattern, and associated aneurysms were done to assess the angioarchitectural characteristics of AVMs for patients presenting with hemorrhage and without hemorrhage. Rupture rate in each parameter by Kaplan-Meier analysis was calculated.

Table 1. Demographic and Morphologic Characteristics of 302 Patients with Arteriovenous Malformation (AVM) Presenting with Intracranial Hemorrhage (ICH) (n = 159) and without ICH (n = 143)

	ICH (n = 159)	Non-ICH (n = 143)
Sex		
Male, no. (%)	95 (59.7)	94 (65.7)
Female, no. (%)	64 (40.3)	49 (34.3)
Age at presentation (mean ± SD), years	28.4 (± 13.1)	28.3 (± 12.5)
AVM location		
Cortical, no. (%)	103 (64.8)	123 (86)
Deep, no. (%)	36 (22.6)	14 (9.8)
Infratentorial, no. (%)	20 (12.6)	6 (4.2)
AVM size		
Small (<3 cm), no. (%)	83 (52.2)	37 (25.9)
Medium (3–6 cm), no. (%)	59 (37.1)	74 (51.7)
Large (>6 cm), no. (%)	17 (10.7)	32 (22.4)
No. arterial feeders		
1, no. (%)	72 (45.3)	43 (30.1)
2, no. (%)	57 (35.8)	53 (37.1)
≥3, no. (%)	30 (18.9)	47 (32.9)
Arterial feeders		
Cortical, no. (%)	118 (74.2)	111 (77.6)
Cortical and perforating, no. (%)	20 (12.6)	9 (6.3)
Perforating, no. (%)	21 (13.2)	23 (16.1)
No. draining veins		
1, no. (%)	81 (50.9)	32 (22.4)
2, no. (%)	29 (18.2)	27 (18.9)
≥3, no. (%)	49 (30.8)	84 (58.7)
Venous drainage		
Superficial venous drainage, no. (%)	78 (49.1)	88 (61.5)
Deep and superficial venous drainage, no. (%)	47 (29.6)	16 (11.2)
Deep venous drainage, no. (%)	34 (21.4)	39 (27.3)
Venous dilation, no. (%)	46 (28.9)	71 (49.7)
Venous stenoses, no. (%)	6 (3.8)	5 (3.5)
Coexisting aneurysms		
Intranidal, no. (%)	25 (15.7)	19 (13.3)
Flow-related, no. (%)	21 (13.2)	3 (2.1)
Unrelated, no. (%)	5 (3.1)	2 (1.4)

AVM, arteriovenous malformation; ICH, intracranial hemorrhage; SD, standard deviation.

RESULTS

Of the 302 patients, 159 (52.6%) were diagnosed because of intracranial hemorrhage. The remaining 143 patients (47.4%) had a nonhemorrhagic diagnostic event, such as seizure (n = 74 [24.5%]), headache (n = 38 [12.6%]), focal neurologic deficit (n = 19 [6.3%]), or other clinical events including incidental AVM diagnoses (n = 12 [4.0%]). The annual rupture rate of AVMs in this