Cerebellar Arteriovenous Malformations: Clinical Feature, Risk of Hemorrhage and Predictors of Posthemorrhage Outcome

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OBJECTIVE: **We aimed to summarize the clinical presentation, risk of hemorrhage, and predictors of posthemorrhage outcome in patients with cerebellar arteriovenous malformations (AVMs).**

METHODS: **We searched our AVM database at Beijing Tiantan Hospital and identified 225 patients with cerebellar AVMs between the year 2000 and 2015. The clinical presentation and hemorrhage risk were analyzed in all patients. Further analysis of predictors for immediate posthemorrhage outcome was performed in patients with ruptured AVMs. Posthemorrhage modified Rankin Scale (mRS) scores were dichotomized into nonsevere outcome (mRS ≤3) and severe outcome (mRS >3). Univariate and multivariate logistic regression analyses were applied to test the risk factors of hemorrhage and predictors of severe outcome.**

RESULTS: **Of the 225 patients, 197 (88%) presented with hemorrhage. Patients with initial hemorrhage were much younger than those with unruptured AVMs (univariate: $P = 0.003$; multivariate: $P = 0.002$). Single arterial supply (odds ratio [OR], 2.846; 95% confidence interval [CI], 1.022–7.922) and exclusively deep venous drainage (OR, 3.361; 95% CI, 1.045–10.813) were the other 2 independent risk factors for hemorrhagic presentation. Regarding the neurologic outcome immediately after hemorrhagic presentation, we used 3 models of multivariate logistic regression. Severe neurologic outcome (mRS >3) was associated with eloquent or deep AVM location, associated aneurysm, and the presence of intraventricular hemorrhage (all $P < 0.05$).**

CONCLUSION: **Cerebellar AVMs have an aggressive nature of hemorrhage. Younger age, single feeding artery, and exclusively deep venous drainage were independent risk factors for hemorrhagic presentation. Eloquent location, associated aneurysm, and presence of intraventricular hemorrhage may predict severe immediate posthemorrhage outcome.**

INTRODUCTION

Previous studies on brain arteriovenous malformations (AVMs) only included a small proportion of cerebellar AVMs and often combined them with brainstem AVMs as posterior fossa AVMs.[1-9] Posterior fossa AVMs account for only 7%–15% of all brain AVMs,[1,3,10-15] with an incidence rate of 2 cases per 10,000 persons in the population.[1,3,5,14,16] Compared with their supratentorial counterpart, posterior fossa AVMs are more likely to present with hemorrhage, varying between 72% and 92%.[1,3,9,14,17] However, conflicting data exist regarding which subgroup (the cerebellar AVMs or the brainstem AVMs) contributes more to the higher hemorrhage rate.[18-20] It is commonly accepted that infratentorial AVM location is significantly associated with hemorrhagic presentation.[5,12,21] However, it remains unclear regarding the causes for the greater rate of hemorrhagic presentation in cerebellar AVMs.[11,22] AVM size,[23,24] deep venous drainage,[5] venous stenosis,[25,26] and hemodynamic changes[27] were proposed to be associated with hemorrhagic presentation in posterior fossa AVMs. There is also an assumption that the

Key words
- Cerebellar arteriovenous malformations
- Clinical presentation
- Hemorrhagic risk
- Neurologic outcome

Abbreviations and Acronyms
AICA: Anterior inferior cerebellar artery
AUROC: Area under the receiver operating characteristic
AVM: arteriovenous malformation
IVH: Intraventricular hemorrhage
mRS: Modified Rankin Scale
PICA: Posterior inferior cerebellar artery
SCA: Superior cerebellar artery

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Citation: World Neurosurg. (2016) 92:206-217.
http://dx.doi.org/10.1016/j.wneu.2016.05.006

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

majority of posterior fossa AVMs are "silent AVMs" and will not be detected until they rupture.[1,18] It is also commonly accepted that posterior fossa AVMs rarely present with seizures.[1,3,4,9,12,13,17,18,25,28-30] Recent studies found that the percentage of patients presenting with AVM-related seizures approximated the percentage difference in hemorrhagic presentation between patients with cerebellar and supratentorial AVMs.[5,31] The greater risk of hemorrhagic presentation in cerebellar AVMs may be due to their lack of seizures.[31] Hemorrhagic presentation from posterior fossa AVMs pose an increased risk of morbidity and mortality.[14,32-35] Fults and Kelly reported that patients with posterior fossa AVMs had poor prognosis, with a mortality rate of 66.7% after initial hemorrhage.[34] Other authors also reported a high hemorrhagic mortality rate for posterior fossa AVMs.[1,2,35] However, the literature has not pointed out which subgroup (cerebellar AVMs or brainstem AVMs) contributes more to the high hemorrhagic mortality. The predictors for severe outcomes after initial hemorrhage have been rarely described. In this study, we retrospectively reviewed our AVM database at Beijing Tiantan Hospital between 2000 and 2015 to identify patients with cerebellar AVMs and summarize the clinical features, hemorrhagic risk, and predictors of immediate posthemorrhage outcomes.

METHODS

Patient Population

Our prospectively maintained brain AVM database was searched to identify patients with cerebellar AVMs between January 2000 and December 2015. Ultimately, 225 patients were identified to harbor a cerebellar AVM that were confirmed by digital subtraction angiography. The patient characteristics (sex, age at diagnosis, and initial presentation) and the AVM features (size, location, angioarchitecture, associated aneurysms, and Spetzler-Martin grade) were collected. AVM locations involving deep cerebellar nuclei or cerebellar peduncles were defined as eloquent AVM locations. Associated aneurysms included any prenidal (feeding artery) aneurysm or intranidal aneurysm. An AVM hemorrhage was confirmed by brain computed tomography and/or magnetic resonance imaging. Of the 225 patients, 197 patients presented with hemorrhage. For the ruptured AVM patients, the immediate posthemorrhage modified Rankin Scale (mRS) scores within 2 days after hemorrhage were collected. Severe posthemorrhage outcome was defined as an mRS score >3 and nonsevere outcome was an mRS score ≤ 3. This study was approved by the Institutional Review Board of Beijing Tiantan Hospital Affiliated with Capital Medical University.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences software (version 20.0; SPSS Inc., Chicago, Illinois, USA). Patient demographics and AVM characteristics were summarized using descriptive statistics for continuous variables and categorical variables. The variables included age; sex; AVM size (categorized as small <3 cm in diameter and large ≥ 3 cm); anatomic location (cortical or deep location); eloquent or noneloquent location; pattern of venous drainage (categorized as superficial, deep and superficial and deep; or exclusively deep and not exclusively deep); patterns of feeding artery (single or not single); and associated aneurysm. Of the 225 patients, there were 197 patients with ruptured AVMs and 28 patients with unruptured ones. The comparison of patient characteristics between the 2 groups (ruptured and unruptured AVM groups) was analyzed using Student's *t*-tests for continuous variables and chi-square tests for categorical variables. To determine the risk factors for hemorrhagic presentation, we analyzed patient characteristics by univariate and multivariate logistic regression analyses using hemorrhagic presentation as the binary response. To assess the predictive ability of the multivariate model, we measured the area under the receiver operating characteristic (AUROC) curve based

Table 1. Summary of Characteristics of 225 Patients with Cerebellar Arteriovenous Malformations (AVMs) According to Initial Hemorrhagic Presentation

Characteristic	All Patients (n = 225)	Nonhemorrhage (n = 28)	Hemorrhage (n = 197)	*P* Value
Age (years), mean ± standard deviation	29.4 ± 15.1	37.4 ± 11.9	28.3 ± 15.2	0.003
Sex, number (%)				0.229
Female	97 (43)	9 (32)	88 (45)	
Male	128 (57)	19 (68)	109 (55)	
AVM size, number (%)				0.007
Small (<3 cm)	135 (60)	10 (36)	125 (64)	
Large (≥3 cm)	90 (40)	18 (64)	72 (36)	
Cortical or deep location, number (%)				1.000
Cortical	128 (57)	16 (57)	112 (57)	
Deep	97 (43)	12 (43)	85 (43)	
Eloquent location, number (%)				0.686
Yes	89 (40)	10 (36)	79 (40)	
No	136 (60)	18 (64)	118 (60)	
Single artery supply, number (%)				0.001
Yes	147 (65)	10 (36)	137 (70)	
No	78 (35)	18 (64)	60 (30)	
Venous drainage, number (%)				0.011
Exclusively deep	83 (37)	4 (14)	79 (40)	
Not exclusively deep	142 (63)	24 (86)	118 (60)	
Associated aneurysm, number (%)				0.121
Yes	42 (19)	2 (7)	40 (20)	
No	183 (81)	26 (93)	157 (80)	