Microsurgical Outcome of Cerebellar Arteriovenous Malformations: Single-Center Experience

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■ OBJECTIVE: **We aimed to describe our single-center experience in treating cerebellar arteriovenous malformations (AVMs) with microsurgical resection.**

■ METHODS: **During a 16-year period, 181 patients with cerebellar AVMs were surgically treated at the Department of Neurosurgery in Beijing Tiantan Hospital. Patient functional status was evaluated using modified Rankin Scale (mRS) scores both before treatment and at the last follow-up. The mRS scores at the last follow-up were dichotomized as good outcome (mRS <3) and poor outcome (mRS ≥3). The treatment modalities, post-treatment complications, obliteration rate, and follow-up outcomes were analyzed.**

■ RESULTS: **Of the 181 patients, 172 (95%) patients presented with initial hemorrhage and 62 (34%) patients experienced rehemorrhage before microsurgical treatment. Complete obliteration of the AVMs was achieved in 177 (97.8%) patients. Good functional outcome was achieved in 144 (80%) of the patients. The surgical mortality rate was 4.4% (8/181), and overall mortality rate was 6.6% (12/181). Poor outcome was significantly associated with increasing age ($P = 0.035$; odds ratio [OR], 1.030; 95% CI 1.002—1.060), presurgical mRS ≥3 ($P = 0.029$; OR, 2.563; 95% CI 1.101—5.968), eloquent AVM location ($P = 0.015$; OR, 3.058; 95% CI 1.244—7.516), and presurgical rehemorrhage ($P = 0.008$; OR, 3.266; 95% CI 1.358—7.858).**

■ CONCLUSION: **Good outcome can be achieved by microsurgical resection in most patients with cerebellar AVMs. Increasing age at surgery, poor presurgical functional status, eloquent AVM location, and presurgical rehemorrhage are independent predictors of poor outcomes after AVM resection. We recommend early surgical resection for all surgically accessible cerebellar AVMs to prevent subsequent hemorrhage and resultant poor neurologic outcomes.**

INTRODUCTION

Cerebellar arteriovenous malformations (AVMs) comprise a small proportion (<15%) of brain AVMs.[1,2] Due to their rarity, the treatment outcomes for cerebellar AVMs have been described with limited reports in the literature. Previous studies tend to report the treatment outcomes of cerebellar AVMs in combination with brainstem AVMs as posterior fossa or infratentorial AVMs.[3-11] However, cerebellar AVMs may be different from brainstem AVMs regarding treatment outcomes. The treatment modalities and treatment timing for cerebellar AVMs have not been described clearly in the literature compared with their supratentorial counterparts. For supratentorial AVMs, according to previous studies and our experience, microsurgical resection is recommended as the preferred treatment modality for patents with low Spetzler-Martin (S-M) grade AVMs (S-M grade I—II and superficial S-M grade III).[12,13] Radiosurgery, embolization, and observation are treatment alternatives for patients with deep-seated, higher S-M grade (IV and V) AVMs or patients with surgical contraindications, especially for patients with unruptured and surgically inaccessible AVMs.[12] However, cerebellar AVMs are different from supratentorial AVMs in their natural history, treatment selection, and treatment outcomes.[4,6,11,14,15] Cerebellar AVMs have a more aggressive nature of hemorrhage. For untreated brain AVMs, the overall annual rupture rate ranged from 2.10%—4.12%, according to a recent review of the natural history of brain AVMs.[16] According to a recent review of the literature on posterior fossa AVMs, the annual rupture rate was reported as high as 11.6%.[1] In our recent publication in **WORLD NEUROSURGERY**, the annual

Key words
- Cerebellar arteriovenous malformations (AVMs)
- Microsurgery
- Treatment outcome

Abbreviations and Acronyms
AVM: Arteriovenous malformation
CTA: Computed tomographic angiography
DSA: Digital subtraction angiography
mRS: Modified Rankin Scale
SRS: Stereotactic radiosurgery

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rupture rate for untreated cerebellar AVMs was 8.6% after a mean follow-up period of 4.2 years.[17] Cerebellar AVM hemorrhage may result into high rates of morbidity and mortality due to the narrow confines of the posterior fossa and high concentration of adjacent vital structures.[3,4,11,14,18] The mortality rate was reported up to 66.7% for ruptured posterior fossa AVMs.[11] Due to these aggressive natures of cerebellar AVMs, the indications of microsurgical resection should be broadened compared with that for supratentorial AVMs. The treatment selection should be based on the evaluation of the treatment outcomes against the natural history of cerebellar AVMs. However, the literature has provided limited accounts for treatment outcomes of cerebellar AVMs. And posterior fossa AVMs still pose a high risk of treatment-related complications, despite the rapid progress in microsurgery, radiosurgery, and endovascular embolization in the past 2 decades. To investigate the microsurgical outcomes of cerebellar AVMs, we retrospectively reviewed 181 patients with surgically treated cerebellar AVMs from our AVM database at Beijing Tiantan Hospital between 2000 and 2015.

METHODS

Patient Population

This study was approved by the Institutional Review Board of Beijing Tiantan Hospital Affiliated to Capital Medical University. We searched our prospectively maintained AVM database at Beijing Tiantan Hospital for patients with surgically treated cerebellar AVMs between January 2000 and December 2015. All cerebellar AVMs were confirmed by preoperative digital subtraction angiography (DSA) and postoperative pathologic examination. Inclusion criteria were patients who received microsurgical resection of cerebellar AVMs alone or following other treatment modalities. Patients who did not receive microsurgical resection of their cerebellar AVMs were excluded from this study. Ultimately, of the 225 patients with DSA confirmed cerebellar AVMs, 181 patients received microsurgical resection. Patient characteristics and AVM features of the 181 surgically treated cerebellar AVM patients were collected. Patient demographics included age at presentation, sex, and initial presentation. AVM features included AVM location, size, angioarchitecture, presence of associated aneurysms, and Spetzler-Martin grade. AVM location were categorized as eloquent (deep nuclei or cerebellar peduncles) and noneloquent (cerebellar hemispheric or vermis) locations. AVM size was categorized as small ($<$3 cm) and large ($\geq$3 cm). Venous drainage was dichotomized into those with exclusively deep venous drainage and those without exclusively deep venous drainage. Feeding arteries were classified as single and not single patterns. Hemorrhagic presentation was confirmed by brain computed tomography or/and magnetic resonance imaging studies. Treatment modality and postoperative outcomes were described and analyzed. Preoperative and follow-up functional states were evaluated with modified Rankin Scale (mRS) scores.

Treatment Consideration

Considering that the high rate of hemorrhagic presentation and subsequent hemorrhage in patients with cerebellar AVMs may cause high morbidity and mortality in the narrow confines of the posterior fossa, we recommended treatment for almost all cerebellar AVMs. For patients with hemorrhagic presentation, microsurgical resection was recommended as the first-line treatment. For patients presenting with life-threatening hematoma in the posterior fossa, emergency hematoma evacuation with or without AVM resection was performed on the basis of the availability of complete radiologic angiography. For patients without hematoma mass effect and those with only hematoma evacuation, microsurgical resection of the AVMs was deferred for about 4–12 weeks after hemorrhagic presentation. For patients with obstructive hydrocephalus, external ventricular drainage was performed before other treatments. Then a ventriculoperitoneal shunting may be performed if the patients presented with persistent symptomatic hydrocephalus after microsurgical treatment. Most of the patients with AVM-associated aneurysms were treated at an early stage using microsurgical clipping or endovascular treatment. Although we recommended microsurgical resection as the first-line treatment for most cerebellar AVMs, the ultimate treatment modality and treatment timing were decided by patient preference. As we stated in our previous publication on the natural history of cerebellar AVMs in WORLD NEUROSURGERY,[17] for patients without life-threatening posterior fossa hematoma, many patients would like to defer the treatment due to the fact that they could return to work or school with or without minor deficit after a period of rehabilitation. As a result, 54 patients experienced a subsequent hemorrhage before any treatment and 5 patients died due to rehemorrhages. For the 225 patients with cerebellar AVMs, 181 patients received surgical resection (surgical resection only or multimodality treatment) of their AVMs, 21 patients received radiosurgery alone or endovascular therapy alone or both, 5 patients died due to rehemorrhages before any treatment, and 18 patients were treated conservatively until our last follow-up. Overall, 62 of the 181 surgically treated patients experienced a second hemorrhage before AVM resection, including 46 patients with a second hemorrhage before any treatment and 16 patients with a subsequent hemorrhage after prior endovascular treatment or radiosurgery.

Outcome Evaluation

The follow-up period was defined as the time period from microsurgical treatment to the last follow-up. The mean follow-up period was 6.4 years (range: 3 months to 15.6 years). Treatment outcome was evaluated using the following variables: obliteration rate, treatment-related complications, and mRS at the last follow-up. The obliteration rate was based on postoperative DSA or CTA, which were often performed 3–7 days after surgery. Treatment-related complications were recorded after surgery. Good neurologic outcome was defined as an mRS score $<$3, and poor outcome was defined as an mRS $\geq$3.

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 (mean $\pm$ standard deviation) and categorical variables (count and percentage). In analyses of neurologic outcomes, the patients were dichotomized into 2 groups: those with good outcome and those with poor outcome. Univariate analyses were