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Microsurgery for ruptured cerebellar arteriovenous malformations

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Abstract. – OBJECTIVE: To summarize the clinical features of ruptured cerebellar arteriovenous malformations (AVMs) and to explore surgical methods and outcomes in ruptured cerebellar AVM patients.

PATIENTS AND METHODS: In the past 14 years, 67 patients with cerebellar AVMs were treated at our institution, accounting for 14.9% of the total vascular malformation patients in our department. In this study, we retrospectively analyzed the clinical characteristics, operation indication, surgery techniques, and prognoses of these cases.

RESULTS: Among the 67 AVM cases, the distribution of Spetzler-Martin grades was 32 Grade I, 14 Grade II, 13 Grade III, 5 Grade IV, and 3 Grade V cases. Microsurgical treatment was carried out via the retrosigmoid approach or suboccipital midline approach. After the surgery, the distribution of GOS grades was 60 Grade V, 3 Grade IV, 1 Grade III, 2 Grade II, and 2 Grade I cases.

CONCLUSIONS: Microsurgical removal should be performed in ruptured cerebellar AVM patients as early as possible once the preoperative and postoperative preparations were done. Good surgical effects were obtained by using proper surgery techniques and the right protection of critical cerebral structures. Patients with a GCS grade of ≥ 8 showed good recovery, but patients with a grade of < 8 had poor prognoses.

Key Words:
Cerebellum, Arteriovenous malformation, Surgery.

Abbreviations

AVMs = Cerebellar arteriovenous malformations; CT = Computed Tomography; MRI = Magnetic Resonance Imaging; DSA = Digital Subtraction Angiography; SCAs = Superior Cerebellar Arteries; PICAs = Posterior Inferior Cerebellar Arteries; AICAs = Anterior Inferior Cerebellar Arteries; PCAs = Posterior Cerebral Arteries.

Introduction

Cerebellar arteriovenous malformations (AVMs) comprise 10-20% of intracranial AVMs. Its main clinical feature is cerebellar hemorrhage. The risk of hemorrhage in posterior fossa vascular malformations is higher than that in supratentorial malformations[1,2]. Due to the fact that the posterior fossa cranial cavity is narrow and the cerebellum is in a deep position adjacent to the brainstem and other important structures, the treatment for AVMs is challenging and with high risk. There were 67 patients were treated at our institution from January, 2000 to November, 2014. We performed a retrospective analysis on these cases in the present study.

Patients and Methods

Patients

There were a total of 67 patients, including 40 male and 27 female patients, aging from 5 to 53 years with an average age of 31 years. Brain computed tomography (CT) and magnetic resonance imaging (MRI) were employed to detect cerebellar hematomas or cerebral hemorrhage in the fourth ventricle. The area of AVM vessels was indicated in 40 cases by MRI. AVM resection was achieved in all 67 patients and the presence of AVMs was confirmed pathologically

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(Figures 1 and 2). Digital subtraction angiography (DSA) was performed in all patients. 23 patients were angiography-negative, and 44 patients were angiography-positive. Among the 44 angiography-positive patients, 24 AVMs were supplied by a single artery, while 20 AVMs were supplied by multiple arteries. Among the AVMs, 24 cases were supplied by superior cerebellar arteries (SCAs), 29 cases were supplied by posterior inferior cerebellar arteries (PICAs), 13 cases were supplied by anterior inferior cerebellar arteries (AICAs), and 5 cases were supplied by posterior cerebral arteries (PCAs). Moreover, 18 cases had sinus confluence drainage, including 14 AVMs draining into the sigmoid sinuses, 5 AVMs draining into the straight sinuses, 7 AVMs draining into the transverse sinuses, 1 AVM draining into the superior petrosal sinus, 1 AVM draining into the cerebral vein, and 1 AVM draining into the cerebral internal vein. The distribution of Spetzler-Martin grades was 32 Grade I, 14 Grade II, 13 Grade III, 5 Grade IV, and 3 Grade V patients.

Clinical Symptoms Before Operation

Patients presented with headache, nausea, vomiting, and ataxia. All patients received emergent DSA scan for further confirmation of the diagnosis. The distribution of preoperative GCS was 30 patients with 12-15 grades, 20 patients with 9-11 grades, and 17 patients with a grade less than 8.

Operating Timing and Indications

All patients received emergency DSA diagnosis. DSA positive patients received surgical treatment within 6-72 hours after the onset. DSA negative patients were further examined by CTA or MRA. If the amount of bleeding reached 10 mL, emergent operation and pathological diagnosis were carried out. Patients with small hematomas or little amount of intraventricular hemorrhage received conservative treatment. External ventricular drainage was performed on patients with the third and fourth intraventricular hemorrhage. However, patients with progressive diseases required emergency operation. The suboccipital midline approach and the retrosigmoid approach were perfomred on cerebellar AVM patients. We aimed to resect AVMs completely and strengthen the protection of the cerebellum during surgery. Postoperative treatments included tight suture of the dura, deciding bone flap reset based on the intracranial pressure, anti-inflammatory and dehydration.

Statistical Analysis

SPSS16.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. *t*-test was applied to compare two groups. A value of $p<0.05$ was considered statistically significant.

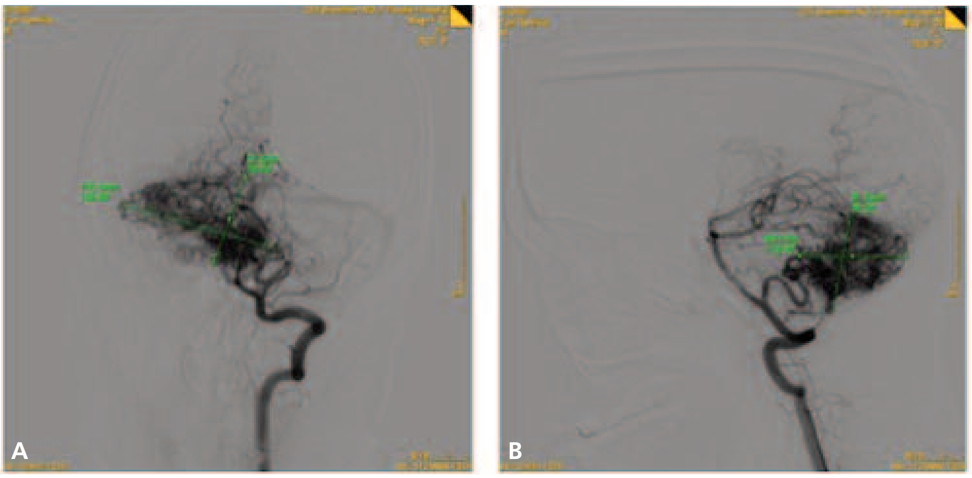

Figure 1. A large arteriovenous malformation supplied by the bilateral arteries (***A,*** AP view of the AVM measuring 10.3 cm × 5.7 cm in size; ***B,*** Lateral view of the AVM measuring 6.1 cm×6.6 cm in size). The AVM was mainly supplied by the bilateral superior cerebellar arteries and posterior inferior cerebellar artery. It was partially supplied by the right anterior inferior cerebellar artery. Sinus confluence drainage is shown. The suboccipital midline approach was performed in this patient. The fourth ventricle was protected during the surgery. The bilateral supply arteries were excised, and then the malformed vascular mass was resected along the edge of the AMV with a brain spatula.

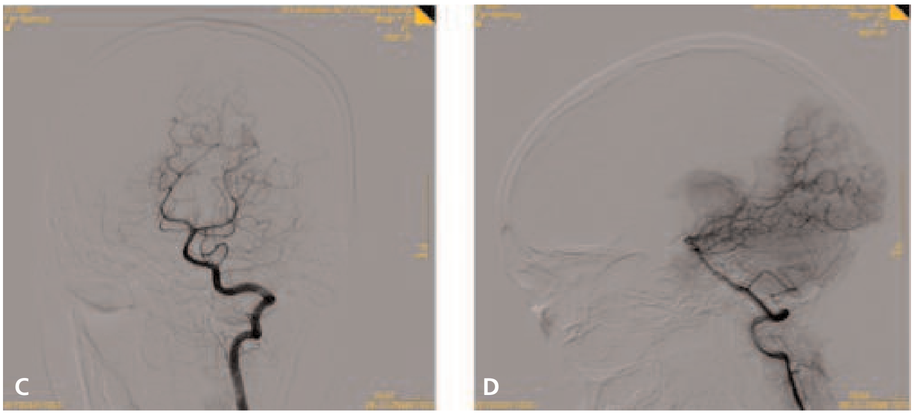

Figure 2. Postoperative angiography *C,* AP view: *D,* lateral view). The angiography shows the main branches of the vertebrobasilar artery system. AVMs were removed completely, and no residual AVM was observed.

Results

All patients received surgical treatment. Pathological diagnosis confirmed 67 patients with AVMs (Figure 1 and 2). After treatment, 64 out of 67 AVM patients survived, 2 patients died, and 1 patient was in vegetative state. The follow-up period ranged from 4 months to 13 years, and no recurrence was observed. 14 patients displayed the symptom of surgery-caused ataxia. 10 got a good recovery, 2 had poor prognoses, and 2 had transient paralysis of the posterior cranial nerves who also had dysdipsia, so tracheotomy and nasal feeding were performed. Eventually, the function of the posterior cranial nerves was regained in these two cases, and the patients were able to eat upon extubation.

According to the GOS system, 59 patients were Grade V, 4 were Grade IV, 1 was Grade III, 1 was Grade II, and 2 were Grade I after surgery. There were three patients with poor prognoses. One case had no autonomous respiration before surgery and was in a vegetative state after surgery. Another case was an elderly with a history of hypertension. Delayed hematoma occurred after surgery, which could cause death. One patient had AVM with feeding from both the supratentorial and infratentorial arteries. The patient received repeated embolization before operation but still had cerebellar parenchymal hematoma. Surgical removal of the AVM was achieved, but the outcome was bad. The patient died of complications. According to statistical analysis, 50 cases had a GCS score of ≥8, and the mean GOS after surgery was 4.6. 17 cases had a score of <8 (mean = 3.47). The difference is significant ($p<0.05$).

Discussion

Cerebellar AVMs comprise only 10% of vascular malformations. However, the cerebellum has a unique anatomical structure. The posterior fossa cranial cavity is narrow, and the cerebellum is close to the brainstem. Improper handling may lead to terrible prognoses. In the present study, we summarized the clinical features of ruptured cerebellar AVMs and aimed to explore surgical methods and outcomes in ruptured cerebellar AVM patients.

Blood supply features: Cerebellar AVMs are mainly supplied by the SCA, ATCA, and PICA. Supplication by branches from SCA is achieved superiorly and laterally. ATCAs supply AVMs on the top of the fourth ventricle. PICAs supply AVMs inferiorly. Complicate vascular malformations are fed by posterior cerebral arteries and other branches. AVMs drain upwards into the transverse, sagittal, and straight sinuses. According to the above blood supply and drainage features of cerebellar AVMs, we determined the surgical approaches based on the individual case.

Timing for cerebellar AVM operations: Some scholars believe that AVMs with the posterior fossa hemorrhage should not be treated immediately to avoid continuous damage in the brainstem and brain nuclei. It is more conducive to operation at 4-6 weeks after bleeding[6,7]. Hence, AVM surgery was never considered as an emergency operation. Although patients might be short-term stable, the situation of some patients worsened. Surgery done in a late disease stage caused significantly more postoperative complications. Therefore, we tried to operate as early as possible once the preoperative preparation was ready, which indeed gave better surgical effects. Some scholars argue that emergency operation of AVMs increases the cure rate and decreases the disability rate[7]. Indeed, our data showed that, the earlier for the AVM patients to be treated, the better the surgical effects are. We used the operation criteria for the posterior fossa cranial hematoma as the criteria for AVMs. The detailed criteria was as follows: 1) patients had conscious disturbance or progressive severer; 2) patients showed obvious changes of vital signs like breathing frequency and mode; 3) the volume of the posterior fossa cranial hematoma was up to 10 ml; 4) patients with small hematoma but significant brain edema; patients with deformed or even disappeared the fourth ventricle due to compression; and patients with supratentorial hydrocephalus. Patients with the above symptoms should be arranged for surgery as soon as possible.

Surgical approaches and skills: The standard midline suboccipital midline craniotomy or the retrosigmoid craniotomy was adopted. We lifted the bone flap of the posterior fossa bone during operations, making it easy for bone flap reset. Dorsal laminectomy of the foramen magnum or the atlas posterior arch was performed if needed to improve cerebrospinal fluid circulation. Whether resetting the bone flap depended on the preoperative GCS scores. Patients with low GCS scores had the bone flap removed, whereas patients with high scores received bone flap reset. Bone flap removal should be complete and include vascular malformations, which is the basic requirement of microsurgery. The first step was to incise the cerebellar vermis to expose the bottom of the fourth ventricle, releasing cerebrospinal fluid to reduce the intracranial pressure. In addition, this step was convenient for placing the surgical cotton rolls to protect the bottom of the fourth ventricle, especially the essential structures like the respiration center. Extra caution should be taken to avoid massive bleeding into the fourth ventricle during AVM resection and to prevent the damage to the fourth ventricle bottom during electric coagulation. The main artery for normal supply should be maintained during the surgery. The resection of arterial feeding vessels should be close to the tangled mass of vascular malformations to prevent cerebral infarction and brainstem ischemia.

The first step in an AVM surgery was to localize the lesion, followed by closing arterial feeding vessels. Resection was performed closely around the AVM. Next, the feeding arteries were cut with good surgical margin treatment. In the end, the whole vascular malformation was isolated by the draining-vein removal method. The above strategy is suitable for resection of small AVMs, but not for large AVM removal. AVMs get limited blood supply from the cerebellum, and the supply is usually from the SCA, AICA, and PICA in the vertebrobasilar artery system. AVMs are fed by the superior, lateral, and inferior arteries. The normal venous drainage goes into sinuses in the top of the cerebellum. Among 67 AVMs included in this study, 24 cases were supplied by SCAa, 29 were supplied by PICAs, and 13 were supplied by AICAs. AVMs supplied by a single artery were small in diameter. The resection of small or hidden AVMs was not hard. In operations, a cerebellar hematoma was removed to expose a malformed vascular tangle at the edge of hematoma. The tangle was then resected by the "surrounding" method, which means the resection is performed around the AVM to operate from the AVM surface to the deep site. Among 24 AVMs supplied by a single artery, 13 cases were supplied by the lateral PICA. In operations, AVMs were resected from the lateral and inferior cerebellum. 3 AVMs with a lateral AICA supply were removed from the lateral cerebellum. The other 8 AVMs fed from the lateral SCA were taken from the superior and lateral cerebellum.

Generally, AVMs are supplied by multiple arteries. In this study, there were 20 of such cases. The supply features of these large AVMs are worth studying. Cerebellum blood supply has certain characteristics, and most of the draining veins are on the top of the cerebellum. Therefore, in the present study, it was better to remove complicate AVMs, which were mainly supplied by SCAs, from the superior and lateral cerebellum. AVMs that were mainly supplied by PICAs should be resected from the inferior and lateral cerebellum. We applied the lateral method to deal with these massive AVMs. After the incision had been planned, the AVM boundary was located. The lesion was resected from the lesion surface to its deep position. The operation direction was usually the same as the source direction of a feeding artery so that its blood supply could be blocked. Intraoperative ultrasound was used to localize the AVM boundary. As the vascular wall of AVMs was usually thin, we used electric coagulator to make AVM vascular wall shrink. Bipolar electrocoagulation with wide blunt tips is the best choice. Extra caution should be taken to prevent adhesion. Electrocoagulation of a feeding artery was applied to a segment rather than a point of the vessel to avoid further bleeding. For severe AVMs supplied by the bilateral arteries, the contralateral artery was the first to be cut if the boundary of the AVM was clear. If AVM boundary was undefined at the beginning of the surgery, an aneurysm clip was used near the cerebellar midline to block the contralateral feeding artery, which was then excised in the AVM periphery. The last step was to operate on the internal upper side of the AVM, as the AVM draining veins were localized at this site. After the excision of arterial feeding vessels, the resection of AVMs could reveal significant draining veins on the top or internal top of the AVMs. Instead of cutting the draining veins, we used bipolar electrocoagulation or aneurysm clips to close the veins temporarily. The increased bleeding around an AVM or in the surgical field could expose the residual AVM, or an undetected feeding artery in a deep location. In this case, the excision should be extended towards the bleeding side. In contrast, if AVMs had no significant changes, the draining veins were cut and completely electro-coagulated after AVM removal. The veins could be closed by aneurysm clips if needed. Alternatively, the internal carotid was pressured to detect blood leaking and further determine whether AVM removal was complete. In some cases, AVMs were severe and adjacent to important structures, such as the brainstem. For these AVMs, we isolated them from the side close to the brainstem after cutting the main feeding vessels. The operation was performed right at the margins of or even inside the AVMs to reduce brainstem damage. However, this approach could frequently caused extra bleeding (Figures 1 and 2).

Among the 67 cases we studied, only one case with AVM that was extremely large and supplied by both the supratentorial and infratentorial arteries. Also, it was directly fed by the internal carotid and the vertebrobasilar artery. It is challenging to operate on such AVM and the prognosis is often poor. Supratentorial arterial embolization was carried out to decrease blood supplied to AVMs. Next, the infratentorial vascular tangle was operatively excised. Then the infratentorial and cerebellar AVM was then resected via the posterior midline approach. However, the surgical effect was not good, and the patient often had a poor prognosis.

Some authors believe that Spetzler-Martin Grade I and II patients are suitable for surgical treatment, as the risk of post-operative permanent neurological disorders a is smaller than that of the other treatments[3]. Patients with a grade of ≥III might receive surgical treatment or intravascular interventional treatment depending on whether deep artery perforator is observed[4]. Grade IV and V patients have poor prognoses no matter whether deep artery perforator happens[7]. For patients who required immediate treatment, embolization can be done first, followed by detailed surgical plans based on their individual situations[3,5]. However, Grade V patients with bleeding after embolization are likely to have poor prognoses. In this study, there was one Grade V patient undergoing repeated embolization, and sudden hemorrhage in the posterior cranial fossa occurred. Surgical treatment was performed, and yet the outcome was not good. In this study, the surgical effect for Grade I and II patients was satisfying, which was consistent with the previous reports. Moreover, Grade III and IV patients also showed good surgical results, which might be due to early operation and the protection of important structures, such as the brainstem during surgery. The Spetzler-Martin grades are closely related to postoperative neurologic deterioration, which suggest that AVMs with low grades have good long-term prognoses after microsurgery. According to statistical analysis, there was no significant difference in prognoses between patients with diverse Spetzler-Martin grades ($p>0.05$). However, patients with high preoperative GCS scores had better prognoses than patients with low scores, and the difference is statistically significant ($p<0.01$). Some patients with low Spetzler-Martin grades might have low GCS scores, which weakened the difference caused by Spetzler-Martin grading. It might be also related to the anatomy characteristics of AVMs, such as narrow posterior fossa cranial cavity and the close position to the brainstem. The analysis included emergency intensive patients, which might also contribute to the non-significant results in the above analysis. Therefore, our results suggest that the Spetzler-Martin grading system is suitable for evaluating the surgical risk of cerebellar AVMs and the occurrence rate of complications, but prognoses are closely associated with preoperative GCS scores.

Conclusions

Overall, cerebellar vascular malformations were well treated by microsurgery. Patients with high GCS scores showed good prognoses, but patients with low scores had poor prognoses. Full preoperative preparation, proper operation timing, and reasonable application of surgery skills are critical factors to ensure effective surgery treatment.

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Conflict of Interest

The Authors declare that they have no conflict of interests.

References

1) Rodríguez-Hernández A, Kim H, Pourmohamad T, Young WL, Lawton MT. Cerebellar arteriovenous malformations: anatomic subtypes, surgical results, and increased predictive accuracy of the supplementary grading system. Neurosurgery 2012; 71: 1111-1124
2) Gong SF, Jiang TP, Li WP. Microsurgery of brainstem cavernomas. Chinese Journal of Microsurgery 2012; 6: 506-507.
3) Pik JH, Morgan MK. Microsurgery for small arteriovenous malformation of the brain: Result of 110 consecutive cases. Neurosurgery 2000; 47: 571-577.
4) Morgan MK, Drummond KJ, Grinnell V, Sorby W. Cerebral AVM surgery: risks related to lenticulostriate arterial supply. J Neurosurgery 1997; 86: 801-805.
5) Hamilton MG, Spetzler RF. The prospective application of a grading system for arteriovenous malformation. Neurosurgery 1994; 34: 2-6; 6-7.
6) Sinclair J, Kelly ME, Steinberg GK. Surgical Management of Posterior Fossa Arteriovenous Malformations. Neurosurgery 2006; 58: 189-201.
7) Neacsu A, Cirea AV. General considerations on posterior fossa arteriovenous malformations (clinics, image and therapy). J Med Life 2010; 3: 26-35.