Interdisciplinary Clinical Management of High Grade Arteriovenous Malformations and Ruptured Flow-Related Aneurysms in the Posterior Fossa

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Summary

Posterior fossa arteriovenous malformations are rare entities and treatment modalities technically challenging. In recent years new therapeutic options have emerged through microsurgical and endovascular means. Based on a series of six cases we describe combined interdisciplinary treatment strategies and report the outcome in a mid-term follow-up interval of 12 months. Clinical case data were collected during acute phase and follow-up including standardized angiographic control intervals during follow-up and assessment of the outcome. Treatment options included endovascular techniques as well as microsurgical techniques. All reported cases had SAH based on ruptured flow-related aneurysms in posterior fossa AVM; three out of six had multiple aneurysms. In one case we observed a *de novo* formation of two flow-associated distal aneurysms in an interval of ten years. Two patients were treated only endovascularly, one patient only surgically and three patients with combined methods. Five out of six patients had a good outcome (GOS 4 or 5). One died in the acute phase. Infratentorial AVMs are rare but characterized by a high risk of rupture and SAH, especially in conjunction with flow related aneurysms, which are predictors of poor outcome. The anatomic conditions of the posterior fossa may lead quickly to life-threatening complications due to mass effects. The present study indicates that treatment strategies in the acute phase should focus on flow-related aneurysms, followed by an elective AVM embolization and ectomy whenever possible. An experienced interdisciplinary team and the combination of tech-

niques contribute to a reduction of complications and to a better outcome.

Introduction

AVM in the fossa posterior are less frequent than their supratentorial counterparts. Only case reports and small case series have been published thus far. Consequently, the management of these entities including potential flow-related aneurysms remains a challenge. The underlying anatomy is complicated and interventional procedures may quickly lead to life-threatening complications. For a long time therapeutic options were limited to conservative and neurosurgical treatment. In recent years, through advances in microsurgical and endovascular techniques, new therapeutic options have emerged. The aim of this retrospective study is to present midterm clinical and angiographical results in the treatment of posterior fossa AVM in six case studies and to discuss therapeutic strategies, focussing on interdisciplinary treatment. The series features one case with 5 distal flow-associated superior cerebellar artery (SCA) aneurysms, which to our best knowledge is unique in the literature.

Methods and Patients

Methods

Treatment options included parent artery occlusion (PAO) with cyanoacrylate-based synthetic glue (Glubran), embolization with

↑ Figure 2 Selective depiction of 5 consecutive flow-related fusiform SCA-aneurysms, prior to PAO (patient no. 2).

← Figure 1 DSA on admission, left vertebral artery angiogram. Posterior fossa AVM with 5 consecutive flow-related fusiform SCA-aneurysms, prior to PAO (patient no. 2).

Guglielmi Detachable Coils (GDC), and embolization with Onyx (ev3 Neurovascular, Irvine, CA, USA) in case of an AVM as well as microsurgical clipping and AVM-ectomy.

All patients underwent an initial CT-scan, a diagnostic digital subtraction angiography (DSA) and following the intervention a control-DSA after one to 12 months. Conservatively treated distal aneurysms had a control-CT-angiography (CTA) during follow-up.

Case data collected included age, sex, comorbid medical conditions, presenting symptoms, clinical condition on admission (Hunt & Hess score), hemorrhage pattern on the initial CT scan (Fisher score), DSA findings with Spetzler-Martin grades of AVMs, aneurysm location on cerebellar artery (anterior inferior cerebellar artery (AICA), posterior inferior cerebellar artery (PICA) and SCA), details of treatment, postinterventional recovery and individual angiographical and clinical outcomes by Glasgow Outcome Score (GOS) at the end of the 12 months follow-up interval. GOS was assessed by a neurosurgeon.

Patients

Patient 1

A 53-year-old man experienced a sudden onset of a severe headache in combination with nausea. He was transferred to a local hospital, where a CT scan revealed hemorrhage in all internal ventricles with a focus on the fourth and

the perimesencephalic cisterns. He was immediately transferred to our center and directly treated with ventriculostomy due to an imminent obstructive hydrocephalus. Consequent DSA revealed a peripheral, saccular AICA-aneurysm on the left side. Multiple feeding arteries of an arteriovenous malformation, located on the surface of the left cerebellar hemisphere, originated from its neck (grade 4). The aneurysm was treated with complete endovascular coil-occlusion without altering blood-flow in the AVM-feeders. The post-interventional course was uneventful. On discharge the patient had only slight gait ataxia. DSA after three months showed no inflow into the embolized AICA-aneurysm. The associated cerebellar AVM was then completely embolized with Onyx in three subsequent sessions without any complications or new neurologic deficit. At the end of the follow-up ataxia had resolved. DSA after 12 months showed constant results concerning the embolized AICA-aneurysm and minor and slow filling of a single former draining vein of the embolized AVM; we decided to schedule another control DSA.

Patient 2

A 49-year-old man had an episode of nausea in the morning. A few hours later he complained of an intense headache. During transport to the hospital he lost consciousness and had to be given artificial respiration upon arrival. Neurological examination showed a comatose state with regular brainstem reflexes. CT

presented an intraparenchymal hemorrhage in the cerebellum with compression of the fourth ventricle and consecutive hydrocephalus, which was treated by ventriculostomy. DSA revealed a cerebellar AVM (grade 4) with feeding arteries originating from both SCA, dominantly from the right, and draining mostly but not exclusively to the transverse sinuses. The right SCA presented with five distal, fusiform flow-associated aneurysms proximal to the nidus. Probing towards the nidus of the AVM was not successful due to vessel elongation and tortuosity. As we characterized the distance of the aneurysms from the midbrain supply and the deep cerebellar nuclei as most probably sufficient, we decided to occlude the parent vessel proximal of the first aneurysm. For this we utilized cyanoacrylate-based synthetic glue (Glu-bran) diluted with Lipiodol (1:2.5).

The angiogram showed successful occlusion of the distal right SCA. The patient underwent consecutive surgery for elimination of the AVM. Postoperative CT-scans depicted infarction in the right SCA territory. Upon regaining consciousness the patient had dysarthrophonia and dysphagia. The postoperative course was not only complicated by an edematous swelling in the posterior fossa, necessitating decompressive craniectomy and duraplasty but also by hospital-acquired pneumonia. Thus, he remained hospitalized for 12 weeks. He recovered gradually under maximum therapeutic efforts, which included physiotherapy and logopedia. After 12 months control-DSA showed no residual AVM. Based on uninterrupted rehabilitation support during follow-up, dysphagia and dysarthrophonia had resolved, however gait-ataxia has remained.

Patient 3

A 74-year-old man lost consciousness after an initial episode of headache. He was admitted in a comatose state; a CT scan of the head revealed SAH with emphasis on the perimesencephalic cisterns and occlusive hydrocephalus, which was directly treated by ventriculostomy. Subsequent DSA led to the diagnosis of a cerebellar AVM (grade 4), mainly fed by the SCA. The origin of the SAH was a flow-related SCA-aneurysm on the main feeding artery, which was embolized with GDC in the same session. On discharge the patient had a mild hemiparesis on the left side and cerebellar ataxia. Follow-up angiography after three months revealed no recurrent aneurysm; the

AVM was unchanged. Its morphology was characterized by multiple filiform, brain-stem related feeders with a diffuse distribution pattern, rendering the AVM unsuitable for endovascular treatment. Consequently the interdisciplinary discussion favored neurosurgical treatment of the AVM.

The patient underwent consecutive surgery for elimination of the AVM via suboccipital craniotomy from the left side. The AVM was totally excised, without intraoperative complications and uneventful postoperative course. The second control-DSA 12 months after the initial SAH depicted a proper postoperative angiogram of the cerebellar arteries without any aneurysm or traces of the AVM; the mild hemiparesis and cerebellar ataxia remained unchanged.

Patient 4

A 66-year-old woman was admitted to our hospital after a sudden onset of severe headache in combination with nausea, vomiting and fluctuating vigilance. CT revealed extensive SAH and intraparenchymal hemorrhage in the right cerebellar hemisphere. Shortly after the scan she lost consciousness and had to be given artificial respiration.

Neurologic re-examination revealed a comatose state with mydriasis on the right. We decided to perform immediate decompressive craniectomy. While evacuating the intraparenchymal cerebellar hematoma an adjacent distal PICA-aneurysm was detected, being plausibly the bleeding source. T

he aneurysm was clipped. Extensive edematous swelling prevented any further inspection for other aneurysms. Via postoperative DSA a posterior fossa AVM (grade 5) with four flow-related aneurysms on different feeding arteries was identified. We refrained from any further intervention as the postoperative course was complicated by nosocomial pneumonia and meningitis, leading to a rapid deterioration of the patient's general condition. She died despite maximum therapeutic efforts 14 days after the initial SAH.

Patient 5

A 34-year-old woman experienced a sudden onset of severe headaches in combination with nausea and vomiting. Upon arrival in the emergency room, she presented fluctuating vigilance. A CT scan revealed extensive SAH with blood in the third and fourth ventricle. Ten years ear-

Figure 3 DSA on admission, right vertebral artery angiogram, early phase. Posterior fossa AVM with flow-related PICA-aneurysm on the right side (patient no. 5).

Figure 4 DSA on admission, left vertebral artery angiogram in a lateral non-standard plane to show the result of the coil-embolization of a flow-related SCA-aneurysm without superposition of adjacent arterial loops (patient no. 5).

Figure 5 DSA on admission, right vertebral artery angiogram. Postinterventional result of the coil-embolized flow-related PICA-aneurysm (patient no. 5).

Figure 6 DSA pre embolization of the AVM, left vertebral artery angiogram (patient no. 5).

lier the patient had undergone a thorough neurological and neuroradiological examination including cranial MRI and DSA due to a mild gait ataxia, which had revealed an extensive posterior fossa AVM and which had been classified as 'inoperable' (grade 6). Since then, the course had been uneventful with a stable neurological

condition; she had had no history of SAH. After immediate treatment with ventriculostomy, angiography depicted massive AVM involving major parts of the brainstem and the cerebellum. Contrary to the initial angiographical findings of ten years ago, she now showed two distal flow-related aneurysms on the right side (PICA

and SCA, respectively) while the AVM remained unchanged. Both aneurysms were completely coil-occluded in one interventional session without complications. DSA after six months revealed no recurrent aneurysm. Meanwhile, she had recovered neurologically to her initial state of mild gait ataxia. After interdisciplinary re-evaluation, the AVM was still classified as 'inoperable'. Following the patient's consideration and will to reduce the inherent risk of aneurysm-formation and recurrent SAH, the AVM was then partially embolized with Onyx in multiple subsequent interventions. Complete occlusion seemed - in view of the extent and

formation of the AVM - unlikely. A control-DSA 12 months after the SAH showed complete occlusion of the aneurysms and a reduction of AVM-size and inflow. Further partial embolization of the AVM is on going.

Patient 6

A 66-year-old man had a sudden onset of severe headache in combination with nausea while on a business-trip. He was transferred to a local hospital, where neurological examination showed a mild hemiparesis on the right side and dysarthria. A CT scan depicted SAH in the third and fourth ventricle and intrapa-

Table 1 Summary of clinical and imaging data

Case	Age/ Sex	Presentation (H&H, Fisher)	Spetzler- Martin	Aneurysm	Treatment	Clinical Outcome (GOS) & Follow-up Imaging Findings at 12 months
1	53/M	SAH (2, IV)	4	1 AICA (cerebellar AVM)	Selective coil occlusion. AVM complete embolization.	Mild ataxia resolved (GOS 5). No recurrent aneurysm. No AVM residuum.
2	49/M	SAH (5, IV)	4	5 SCA (cerebellar AVM)	PAO. AVM complete ectomy.	Persistent ataxia (GOS 4). Cerebellar infarct. No recurrent aneurysm. No AVM-residuum.
3	74/M	SAH (5, IV)	4	1 SCA (cerebellar AVM)	Selective coil occlusion. AVM complete ectomy.	Persistent mild hemiparesis and ataxia (GOS 4). No recurrent aneurysm. No AVM residuum.
4	66/F	SAH (4, IV)	5	1 PICA, 4 on different feeders (posterior fossa AVM)	Clipping of PICA- aneurysm.	Death 14 days after admission (GOS 1).
5	34/F	SAH (2, IV)	6	1 PICA, 1 SCA (posterior fossa AVM)	Selective coil occlusion. AVM partial embolization.	Recovery to initial status of mild ataxia. No new defi- cit (GOS 4). No recurrent aneurysm. AVM partially embolized.
6	66/M	SAH (3, IV)	4	1 SCA (cerebellar AVM)	PAO and AVM partial embolization followed by ectomy.	Persistent mild ataxia. Returned to work (GOS 5). No recurrent aneurysm. No AVM residuum.

parenchymal hemorrhage in the right cerebellar hemisphere. He was immediately transferred to our center and directly treated with ventriculostomy due to an imminent occlusive hydrocephalus. Subsequent DSA led to the diagnosis of a cerebellar AVM (grade 4), mainly fed by the right SCA with a flow-related SCA-aneurysm on a feeding artery, which was treated by PAO with Glubran (diluted with Lipiodol 1:2.5) in the same session. As the patient's condition improved on the following days we decided in consensus to treat the AVM with partial embolization followed by neurosurgical ectomy which was performed successfully. On discharge the patient had a mild hemiparesis on the right side and mild cerebellar ataxia. He returned to his home country for rehabilitation. A control DSA after three months depicted a proper postoperative angiogram of the cerebellar arteries without any aneurysm or traces of the AVM. During follow-up he was able to return to work, but slight ataxia has remained.

Results

Since January 2008 we have treated six patients with high grade posterior fossa AVM, ranging from grade 4 to 6 and SAH with a total of 15 flow-related aneurysms, all in distal portions of cerebellar feeding arteries. Aneurysm location was PICA in two, AICA in one and SCA in eight aneurysms. Four flow-associated aneurysms were located on peripheral portions of AVM-feeding arteries, which could not be attributed to a specific cerebellar artery unambiguously. In this context three patients had multiple flow-related aneurysms, either distributed evenly or arrayed serially.

Case no. 2 displayed five consecutively arrayed distal flow-associated SCA-aneurysms.

Case no. 4 presented five evenly distributed lesions with no more than a single aneurysm per feeding artery.

All patients presented with SAH, three of them (cases no. 2, 4 and 6) also had intraparenchymal cerebellar bleeding. Two patients (case no. 1 and 5) were treated endovascularly, one patient (case no. 4) surgically and three patients with combined methods consisting of endovascular treatment of the bleeding source and/or partial embolization of the AVM with consecutive ectomy (cases no. 2, 3 and 6). Five out of six patients with initial SAH had a good outcome (GOS 4 or 5). No recurrent aneurysms were

observed during the follow-up period nor residual AVM (one completely embolized; three surgically removed, one after partial embolization) except the inoperable lesion (case 5) which has been partially embolized. One patient died in the acute phase due to nosocomial infection.

Discussion

Posterior fossa AVMs are infrequent, comprising 7-15% of intracranial AVMs¹. Infratentorial AVM location is independently associated with hemorrhagic AVM presentation². Independent risk factors for intracranial bleeding are increasing age, deep brain location and exclusive deep venous drainage. The risk for intracranial bleeding rises to 34.4% for those harboring all three risk factors during natural history follow-up³.

Data on the role of flow-related aneurysms of infratentorial AVMs are scarce. Recent reports imply that the presence of flow-related aneurysms is also an independent predictor of poor outcome⁴. Most associated aneurysms are proximally located, mostly on the basilar head or on the junctions of one of the major cerebellar arteries⁵. These aneurysms were often treated neurosurgically in the past. Drake reported successful surgical therapy in four cases of proximal posterior fossa aneurysms in 1961⁶. Flow-related aneurysms in distal portions of cerebellar arteries are very rare entities, only few case reports exist⁷⁻¹¹.

The reported clinical outcome has improved in recent times through the introduction of microsurgical techniques and improved perioperative support^{9,11-14}.

The introduction of endovascular techniques has broadened the therapeutic spectrum. Recent studies like ISAT have shown their potential in the treatment of posterior fossa aneurysms, so that they have evolved into a first-line therapy¹⁵.

The fraction of AVM-associated aneurysms in the anterior circulation is noticeably smaller than in the posterior circulation, as demonstrated in the present case series and in literature reports^{8-10,16-18}.

We present six cases of flow-related aneurysms with an underlying posterior fossa AVM. All aneurysms were located distally and all patients presented with intracranial hemorrhage. The main hypothesis for their formation is

shear stress on the vessel wall on the feeding arteries of the AVM¹⁹⁻²¹.

Case no. 5 illustrates a de novo formation of two aneurysms in an interval of ten years on feeding arteries of the AVM and consequent SAH based on the rupture of such an aneurysm. Thus, a de novo formation of aneurysms increases the risk of hemorrhage probably independently from the inherent risk contributed by the underlying AVM. These patients should be regarded as high-risk patients and clinically followed in narrow control intervals. In daily practice it might be challenging to identify the source of a hemorrhage in case of an AVM with flow-associated aneurysms. Often uncertainty remains although careful interpretation of the bleeding pattern based on a patient's individual history might reveal valuable hints.

The morphological and intraoperative data in the present report implies that in all cases the source of the bleeding was a flow-related aneurysm and not the AVM, based on the following criteria: The bleeding pattern on the initial CT-scans²² and the intraoperative findings; in neurosurgical publications on posterior fossa AVMs intraoperative findings have predominantly identified flow-associated aneurysms as bleeding sources in case of SAH, e.g. Gacs et al.⁹. SAH is more common in aneurysm rupture than in AVM-associated bleedings²³; intraparenchymal hematoma (IPH) in combination with intraventricular hemorrhage (IVH) is - even in the absence of SAH - a previously reported characteristic of aneurysm rupture in the posterior fossa²⁴. The following individual findings support our conclusions:

Patient 1: Purely intraventricular SAH predominantly in the fourth ventricle in the presence of a flow-associated AICA-aneurysm.

Patient 2: SAH comprising the basal cisterns and the fourth ventricle combined with IPH. Such bleeding patterns have been described in neurosurgical series with intraoperative identification of flow-related SCA-aneurysms as bleeding source, e.g.²⁵.

Patient 3: SAH around the perimesencephalic cisterns in presence of a flow-associated SCA-aneurysm.

Patient 4: Extensive SAH and IPH in the right cerebellar hemisphere; identification of a ruptured flow-associated PICA-aneurysm on the right intraoperatively. This supports previously reported findings concerning flow-associated PICA-aneurysms presenting with SAH and IPH^{26, 27}.

Patient 5: Purely intraventricular SAH predominantly in the fourth and third ventricle in the presence of flow-associated PICA- and SCA-aneurysms.

Patient 6: SAH predominantly in the fourth and third ventricle in conjunction with IPH in the right cerebellar hemisphere in the presence of a flow-associated SCA-aneurysm on the right. Our observations indicate an increased risk of aneurysm rupture and SAH for these patients, in accordance with previous reports^{5,28}. There is an ongoing discussion on treatment strategies for these cases. Redekop et al. preferred an initial treatment of the underlying AVM, based on the hypothesis of a potential subsequent regression of the associated aneurysm(s)²⁹. Ha et al. reported ambiguous data for AVM-related aneurysms: although some aneurysms regressed after AVM-treatment, others increased in size despite of disappearance of the AVM-nidus³⁰.

Thompson et al. suggested immediate surgical or endovascular treatment of the associated aneurysm(s)³¹. Their proposal relied on the implied higher bleeding risk of the flow-related aneurysms.

The experiences of the present series support this strategy. In case of SAH from a distal cerebellar aneurysm with or without underlying AVM we recommend prioritizing the treatment of the aneurysm through endovascular techniques wherever applicable.

The work of Peluso et al. reported encouraging results for PAO of flow-related SCA-aneurysms³². In case of edematous swelling or a threatening mass effect of the bleeding in the posterior fossa immediate surgery is essential, combining decompression with an elimination of the bleeding source. Thus we predominantly refrained from treating the AVM in the acute phase and planed an elective treatment after rehabilitation of the patient, preferably through endovascular embolization or alternatively surgical ectomy where appropriate (*case nos. 2 and 3*).

The only exception was case no. 6 with ectomy of the AVM after partial embolization in the acute phase. This was performed after careful evaluation of the individual circumstances (foreign patient, initially on a business trip) in consensus with the patient and his family. The outcome at the end of the 12 month follow-up was good for five out of six patients in spite of previously reported poor prognosis based on the most severe underlying conditions of high

grade infratentorial AVMs combined with flow-associated distal aneurysms.

In case of a complicated incidental AVM in the posterior fossa without an associated aneurysm and no hints for a prior bleeding, we recommend continuous MRI control-exams after an initial DSA. This is the "lesson to be learned" from *case no. 5*, where we verified a *de novo* formation of multiple flow-associated aneurysms during a period of ten years, which led to SAH. In order to prevent recurrent SAH, DSA should be conducted whenever necessary to rule out a *de novo* formation of a flow-associated aneurysm.

Even if a posterior fossa AVM cannot be eliminated - due to its extent and morphology - neither by endovascular nor neurosurgical nor radiotherapeutic means like in this reported case, we recommend the immediate treatment of any flow-related aneurysm nevertheless.

Conclusion

The natural course of the posterior fossa AVM is characterized by a high risk for intracranial hemorrhage. The course is not only determined by the AVM but also independently by aneurysm formation and subsequent rupture. The anatomic conditions of the posterior fossa may lead quickly to a life-threatening condition due to mass effects.

Our experience in the present series indicates that an aggressive treatment strategy for ruptured flow-related aneurysms should be adopted in order to reduce the risk of repeated intracranial hemorrhage. As the presence of flow-related aneurysms is a predictor of poor outcome, patients should be referred as soon as possible to specialized centers where a combination of available techniques may lead to a reduction of complications and to a better outcome.

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