Complications of Angioma Surgery
—Personal Experience in 191 Patients with Cerebral Angiomas—

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Abstract

In the last years, treatment decisions of arteriovenous malformations (AVMs) were influenced by the improvement of stereotactic radiosurgery and were revolutionized by development of embolization techniques. The aim of this report was to examine the results, effectiveness, and complications associated with angioma surgery. 191 patients with AVMs were operated by the first author between 1981 and 1996. Angioma localization was distributed as follows: frontal 51 (26.7%), temporal 44 (23%), parietal 45 (23.6%), and occipital 24 (12.6%). Twelve (6.3%) AVMs were located in the cerebellum and 15 (7.9%) in other deep regions. Twenty-nine (15.2%) AVMs were associated with single or multiple aneurysms. The preoperative symptoms were hemorrhage (50.3%), seizure (33.5%), headache (23.0%), focal neurological deficits (12.6%), and other minor symptoms. In 9.9%, the disease remains preoperatively asymptomatic. Based on the Spetzler/Martin scale (S/M), 38 patients were grade I, 39 grade II, 52 grade III, 39 grade IV, and 23 grade V. The following severe complications were observed: postoperative hemorrhage in 13 (6.8%), infection in six (3.1%), infarction in two (1.0%), and death in three (1.6%). The risk for postoperative complications was related to the preoperative S/M grade of the AVM. Severe complications only occurred in AVM grades IV and V. In 62 patients with grade IV and V AVM, three patients died (4.8%) and 12 showed neurological deterioration (19.4%). Only 3/129 (2.3%) patients with grade I-III AVM deteriorated postoperatively. No severe complications were observed in preembolized and recently operated patients. Microsurgical management of cerebral AVMs seems to be a reasonably safe procedure especially in grade I-III AVMs, with a mortality of less than 2%. With enough experience and exact attention to detail, the experienced neurosurgeon can remove many of these AVMs with a minimum of risk to the affected patient. Although hemorrhage from an AVM can be disabling or deadly, the course in many nonoperated high-grade AVMs (S/M grades IV and V) can be quite benign, if compared with their surgical risk. This may justify conservative treatment or treatment with radiosurgery in some high-grade (S/M grades IV and V) angiomas, especially in elderly patients.

Key words: cerebral arteriovenous malformation, microsurgery, intracerebral hemorrhage complication, outcome

Introduction

In 1990, Ondra et al. studied long-term follow-up of untreated patients with arteriovenous malformations (AVMs) and estimated a 4% yearly hemorrhage rate for both ruptured and previously unruptured cerebral AVMs. The combined major morbidity and mortality from a hemorrhage was 2.7% annually. Death as a direct result of hemorrhage from an AVM was found in 23% of their patients with a significantly lower mean age at death (15 years) than for patients dying from other causes. In contrast, a review of the literature shows that the risk of surgery was relatively low with mortality less than 2% and morbidity less than 10%. The extensive experience reported in the 1970s, 1980s, and 1990s led to the gradual acceptance of microsurgical removal as the therapeutic principle of choice for cerebral AVMs. The rapidly technical advancements especially in the last 10 years made neurosurgeons increasingly able to expose and resect even such large AVMs, that have previously considered inoperable. A combined attempt including superselective embolization, modern microsurgery techniques, and stereotactic radiosurgery allows an adapted, individual modifiable management of all type of cerebral AVM to obtain complete removal of these lesions and consequently to eliminate the risk of hemorrhage.
the complications of operative treatment for cerebral AVMs, we undertook a retrospective analysis of the clinical data of 191 patients with cerebral angiomas to establish the risks of surgical removal of cerebral angiomas in relation to the therapeutic efficacy and to define high-risk patient groups. The relevant literature is reviewed to ascertain in comparison the influence of the surgeon's experience on the occurrence of complications. Considerations are additionally made to review complications of cerebral angioma surgery from the standpoint of their causation, treatment, and prevention.

**Materials and Methods**

Between 1981 and 1996, 191 patients with cerebral AVMs were evaluated and treated surgically by the same surgeon (W.H.). There were 87 females and 104 males ranging in age from 11 to 74 years (mean 42.1 years). The age and sex distribution is shown in Fig. 1. The localization of AVM was distributed as follows: frontal 51 (26.7%), temporal 44 (23%), parietal 45 (23.6%), and occipital 24 (12.6%). Twelve (6.3%) AVMs were located in the cerebellum and 15 (7.9%) in other deep regions (Fig. 2). Twenty-nine (15.2%) AVMs were associated with single (21) or multiple (10) aneurysms, two with moyamoya disease, two with venous angioma, two with angiographically proved vasospasm, and one with cavernoma. The preoperative symptoms were hemorrhage (96, 50.3%), seizure disorder (64, 33.5%), headache (44, 23.0%), focal neurological deficits (24, 12.6%), psychic disorders (13, 6.8%), vessel bruits (10, 5.2%), and cardiac problems (2, 1.0%). In 19 cases (9.9%), the disease remains preoperatively asymptomatic (Fig. 3). Based on the Spetzler/Martin (S/M) scale, 38 (19.9%) patients were grade I, 39 (20.4%) grade II, 52 (27.2%) grade III, 39 (20.4%) grade IV, and 23 (12%) grade V (Fig. 4).

Eighty-eight patients (46.1%) were preoperatively managed with embolization, 15 (7.9%) with irradiation, and three (1.6%) with both embolization and irradiation, while the remaining 85 patients (44.5%) received no specific treatment preoperatively. The angioma was completely resected in 184 patients (96.3%), while the angioma was only partially removable in seven cases (3.7%). Two-step operation was necessary in 12 cases (6.3%), and three-step operation in five (2.6%). The other 174 (91.1%) patients were operated on by one-step procedure.

The selection of the operative approach was based upon the presence of intracerebral hematoma, the relationship of the angioma to the surrounding brain structures on the basis of angiography and magnetic

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**Fig. 1** Distribution of age and sex in 191 patients with cerebral angiomas.
Fig. 2 Angioma localization (n = 191).

Fig. 3 Preoperative clinical symptoms (n = 191).

Fig. 4 Distribution of grades and outcome based on Spetzler/Martin scale (S/M).

The following severe complications were observed: postoperative hematoma in 13 patients (6.8%) (Fig. 5), infection in six (3.1%), infarction in two (1.0%), and death in three (1.6%). The risk for postoperative complications was related to the preoperative S/M grade of the AVM. Severe complications only occurred in AVM grades IV and V. In 62 patients with grade IV and V AVM, three patients died (4.8%) and 12 showed neurological deterioration (19.4%). Only three of 129 (2.3%) patients with grade I-III AVM deteriorated postoperatively. Postoperative bleeding was remarkably frequent in cases with AVM and associated aneurysms, namely, in 10 patients; three of these patients suffered multiple intracerebral hematomas and required reoperation. The relatively high frequency of complications in the patients with S/M grade IV and V angiomas and the complexity of the operative management in such cases, compared to
the other patients, was impressive and demonstrates the efficiency of this grade system for the estimation of the surgical outcome. Correlation of preoperative S/M grades with surgical results shows the highest improvement rate in S/M grades I-III and the lowest in S/M grades IV and V (Fig. 4). The success of surgery was not appreciably affected by the preoperative duration of the disease. In 24 patients from 64 (37.5%) patients with preoperative seizures, the seizures were postoperatively disappeared. Thirteen of 64 patients (20.3%) improved their seizure-symptoms, and 27 (42.2%) remain unchanged. Seven patients developed new seizures postoperatively (from 124 patients without preoperative seizures = 5.6%). There were no worsening of the preoperative presented seizures postoperatively. Other significant complications, such as vasospasm without prolonged persistent neurological deficits, occurred with incidence rates between 1% and 2%. There were no evidence of normal perfusion pressure breakthrough in our cases.

Discussion

AVMs occur in approximately 0.5% of the population; patients often present with hemorrhage or seizures. Already in 1928, Dandy,4 and Cushing and Bailey3 reported series of cerebral vascular malformations that surgically treated by partial coagulation or occlusion of part of their blood supply, but not by excision. Since that time and especially in the last 20 years, the technical ability to expose and resect cerebral AVMs has advanced rapidly and led to the gradual acceptance of microsurgical removal as the therapeutic principle of choice for cerebral AVMs.2,10-12,27 At present, the microsurgical complete extirpation is the most important part of the overall therapeutic concept for cerebral angiomas, which would be supported by the improvement of stereotactic radiosurgery and by development of superselective embolization techniques.5,13,24,25 The combination of these modern techniques with microsurgery allows an adapted individual access resulting in the resection of even large AVMs that have previously been considered inoperable.30

Improvement and technical development of preoperative treatment of cerebral AVM significantly reduced the risk of severe complications and allows for significant reduction of AVM size. However, an increasing number of grade V AVMs is now accessible to surgical removal and therefore, the frequency of neurological deterioration may be increased while mortality is reduced. Embolization as an adjunctive measure for surgery helps to decrease diameter of the AVM (>50%), to embolize deep small feeders, to reduce surface of AVM, to embolize “en bloc” not “piece meal,” and to localize the nidus.5,24 An increasing number of high-grade AVMs (S/M grades IV and V) is now safely accessible to surgical removal, with a more and more tolerable risk of morbidity and mortality for the majority of angioma patients. The predicted risk of surgery is now clearly less than that associated with an untreated cerebral AVM.21,22,28,29 The goal of treatment in cerebral AVM is still the complete removal, if possible, because partially resected angiomas are associated with a continued or even increased risk of bleeding because of higher perfusion pressures postoperatively.23 This goal is meanwhile easily accessible in superficial AVM, which are typically S/M grades I–III and are associated with low rates of surgical morbidity and mortality. On the other hand, management of deep AVMs (thalamus, brain stem, and basal ganglia) remains—despite all recent advances—clinically and surgically challenging and is still associated with relatively high morbidity and mortality, especially in large deep or S/M grade IV and V AVMs.

The radiosurgery is estimated to be the treatment of choice in cases with small deep AVMs (<2 cm), which reported to be successfully obliterated radiosurgically after a 2-year latency period.26 Smaller AVMs tend to present more often with hemorrhage than do large AVMs.22 There is an inverse relationship between the size of an angioma and its tendency to rupture. Spetzler et al.22 found in one series of 92 patients, that small AVMs (<3 cm) presented significantly more often with hemorrhage (82%) than did large AVMs (12%), because, unlike large AVMs, small AVMs are not associated with steal symptoms. Intraoperative pressure measurements in the AVM feeding artery demonstrated significantly higher pressure in small AVMs than that in large AVMs. Mean feeding artery pressure was significantly higher in patients with small AVMs (66 mmHg) compared to medium-sized AVMs (47 mmHg) and large AVMs (35 mmHg). We confirm these findings and we have additionally found that the most relevant factors for the postoperative outcome are the coincidence of aneurysms, the S/M grade, and the clinical situation of the patient at the time of surgery. No relevant correlation could be established between age or sex and postoperative outcome.

Postoperative hemorrhage and, to a lesser extent, edema represent the greatest and most serious problem in the early postoperative phase; avoidance of this problem is attempted in various ways: blood pressure control, sedation, adequate anticonvulsant treatment, hemodilution, and nimodipin therapy for
Table 1 Surgical results in larger series (see also Fig. 6)

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>No. of patients</th>
<th>Residual AVM</th>
<th>Morbidity</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paterson and McKissock (1956)</td>
<td>36</td>
<td>17%</td>
<td>28%</td>
<td>8%</td>
</tr>
<tr>
<td>Forster et al. (1972)</td>
<td>95</td>
<td>18%</td>
<td>7.4%</td>
<td>4%</td>
</tr>
<tr>
<td>Drake (1979)</td>
<td>166</td>
<td>?</td>
<td>?</td>
<td>11%</td>
</tr>
<tr>
<td>Suzuki and Onuma (1979)</td>
<td>147</td>
<td>?</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Wilson et al. (1979)</td>
<td>65</td>
<td>28%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Guidetti and Delitala (1980)</td>
<td>95</td>
<td>3%</td>
<td>6.3%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Parkinson and Bachers (1980)</td>
<td>100</td>
<td>0</td>
<td>20%</td>
<td>11%</td>
</tr>
<tr>
<td>Jomin et al. (1985)</td>
<td>128</td>
<td>8.5%</td>
<td>9%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Yasargil (1987)</td>
<td>414</td>
<td>?</td>
<td>5.1%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Heros et al. (1990)</td>
<td>153</td>
<td>?</td>
<td>7.8%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Pasqualin et al. (1991)</td>
<td>248</td>
<td>2%</td>
<td>9.6%</td>
<td>5%</td>
</tr>
<tr>
<td>Sundt (1990)</td>
<td>279</td>
<td>?</td>
<td>6.3%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Vinuela et al. (1991)</td>
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<td>?</td>
<td>1.98%</td>
<td>3.9%</td>
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<tr>
<td>Piepgras et al. (1993)</td>
<td>280</td>
<td>?</td>
<td>5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Morgan et al. (1993)</td>
<td>112</td>
<td>?</td>
<td>18.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Present series</td>
<td>191</td>
<td>3.7%</td>
<td>2.1%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

AVM: arteriovenous malformation.

Fig. 6 Development of morbidity and mortality of cerebral angioma surgery reported in larger series over the last 40 years (see also Table 1).

a minimum of 7 days postoperatively, which promotes a low blood pressure and the development of collateralizations, thereby prevention of the postoperative occlusive hyperemia. Major causes of complications were: elevated perfusion pressure in interrupted and occluded vessels, postoperative thrombosis of arteries and veins, and iatrogenic occlusion of vessels. There was no evidence that normal perfusion pressure breakthrough is the cause of postoperative rebleeding after AVM removal in our cases. According to our experience and to the experiences of others, we believe that events which may appear to be normal perfusion pressure breakthrough are often due to a technical mistake; either a portion of the AVM was left behind or a draining vein was taken too soon. The result in such situa-
enough experience and exact attention to detail, the I-III AVMs, with a mortality of less than 2%. With to be a reasonably safe procedure especially in grade postoperative angiography: disappearance of steal following hemodynamic changes by immediate tifocal hemorrhage postoperatively. We found the tions is the sudden onset of brain edema and/or distribution disturbances postopera- effects and of distribution disturbances postopera- and slow flow in perfused and still dilated feeders “stagnating arteries.” There were no signs of hypere- mia or hyperperfusions. We have additionally found, that angiomas with the following features have an increased risk of spontaneous bleeding: AVMs with deep venous drainage, angiomas with intranidal or multiple aneurysms, feeding by vertebobasilar system or by perforators, and location within the basal ganglia.

The relatively high frequency of complications in the patients with high-grade angiomas (S/M grades IV and V) and the complexity of the operative management in such cases compared to the patients with lower grade angiomas (S/M grades I-III) was impressive and demonstrates the efficiency of this grade system for the estimation of the surgical outcome. In a logistic regression model, the parameters of age, sex, duration of preoperative symptoms, S/M grade, neurological situation of the patients at the time of surgery, and localization of the AVM were examined with respect to their influence on the effect of surgery. Only S/M grade, neurological status of patients at the time of surgery, and localization of the lesion had an appreciable influence (p = 0.057). A comparison of the previous reported results in the relevant literature suggests that radical microsurgical excision in low-grade cerebral AVM (S/M grades I-III) is associated with excellent long-term outcome and allow the positive future perspective of angioma surgery with the growing modernization of technical abilities and subsequently improved morbidity and mortality (Table 1, Fig. 6). Although hemorrhage from an AVM can be disabling or deadly, the course in many nonoperated high-grade AVMs (S/M grades IV and V) can be quite benign, if compared with their surgical risk. This may justify conservative treatment or treatment with radiosurgery in some high-grade/high-risk angiomas, especially in elderly patients.

The preoperative embolization is very helpful in cases with large AVMs (> 6 cm) to reduce their size and to make the lesion completely removable. Microsurgery, superselective embolization, and stereotactic radiosurgery are not in competition but are complementary.

Improvement and technical development of preoperative treatment of cerebral AVM significantly reduced the risk of severe complications and allows for significant reduction of AVM size. However, an increasing number of grade V AVMs is now accessible to surgical removal and therefore, the frequency of neurological deterioration may be increased while mortality is reduced.

Conclusion

The only way to cure an AVM is to induce its total disappearance, even with combined management. Microsurgical management of cerebral AVMs seems to be a reasonably safe procedure especially in grade I-III AVMs, with a mortality of less than 2%. With enough experience and exact attention to detail, the experienced neurosurgeon can remove many of these AVMs with a minimum of risk to the affected patient. Better understanding of the indications for AVM surgery and improved familiarity with the hemodynamical situations pre-, intra-, and postoperatively should further lower the incidence of complications.

Although hemorrhage from an AVM can be disabling or deadly, the course in many nonoperated high-grade AVMs (S/M grades IV and V) can be quite benign, if compared with their surgical risk. This may justify conservative treatment or treatment with radiosurgery in some high-grade/high-risk angiomas, especially in elderly patients.

**References**


