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Microsurgery of Intracranial Arteriovenous Malformations: Results in 46 Patients

İntrakraniyal Arteriovenöz Malformasyonların Mikrocerrahisi: 46 Hastanın Sonuçları

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ABSTRACT

OBJECTIVE: To assess the importance of microsurgery in 46 consecutive patients with intracranial arteriovenous malformations (AVMs).

METHODS: Forty-six patients underwent microsurgical removal of their AVMs in our clinic from 1992 to 2003. There were 26 males and 20 females. Thirty-two patients (69.5%) presented with hemorrhage. Three patients had associated aneurysms. Their presentation, pre-operative neurological status, post-operative outcome and determinants of post-operative outcome were analyzed.

RESULTS: Post-operative mortality was 6.5% and morbidity was 8.7%. Neurological improvement was observed in 9 patients (19.6%). Of 43 patients having control angiographies, 38 had angiographically confirmed total removal of their AVMs. Three patients were reoperated. We advised embolization to one patient and radiosurgery to another one. Three associated aneurysms were clipped in the same session. The pre-operative neurological status, Spetzler-Martin grade of AVM and the presence of hemorrhage were found to be determinative factors about outcome.

CONCLUSION: Microsurgery is an effective treatment with reasonable safety for the majority of AVMs. Microsurgical removal also provides immediate protection against the risk of serious hemorrhage .

KEY WORDS: Arteriovenous malformations, microsurgery, intracranial hemorrhage

ÖZ

AMAÇ: İntrakraniyal arteriovenöz malformasyonu (AVM) olan 46 hastada mikrocerrahinin etkisini değerlendirmek.

YÖNTEM: Kliniğimizde 1992-2003 yılları arasında toplam 46 hastanın AVM'si mikrocerrahi yöntemle çıkartıldı. Olguların 26'sı erkek, 20'si kadındı. Otuz iki hasta (%69.5) kanama ile başvurdu. Üç hastada eşlik eden anevrizma vardı. Hastaların başvuru şikayetleri, preoperatif nörolojik durumları, AVM'lerin Spetzler-Martin dereceleri, postoperatif sonuçları ve sonucu etkileyen faktörler incelendi.

BULGULAR: Postoperatif mortalite %6.5, morbidite %8.7 idi. Dokuz hastada (%19.6) nörolojik iyileşme gözlendi. Kontrol anjiografileri olan 43 hastanın 38'inde AVM'lerin total çıkartıldığı görüldü. Üç hasta tekrar ameliyat edildi. Bir hastaya embolizasyon, diğerine radyocerrahi önerildi. Eşlik eden üç anevrizma aynı seansta kliplendi. Preoperatif nörolojik durumun, AVM'nin Spetzler-Martin derecesinin ve kanamanın varlığının sonucu etkileyen faktörler olduğu saptandı.

SONUÇ: Mikrocerrahi AVM'lerin çoğunda güvenli ve etkilidir. Ayrıca ciddi kanama tehlikesine karşı hemen korunmayı sağlar.

ANAHTAR SÖZCÜKLER: Arteriovenöz malformasyon, mikrocerrahi, intrakraniyal kanama

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INTRODUCTION

Intracranial arteriovenous malformations (AVMs) are among the most challenging entities that confront neurosurgeons. These complex vascular lesions remain among the most difficult lesions to treat. The current treatment options are microsurgery, radiosurgery and endovascular intervention, either alone or in conjunction with each other. Therapeutic decisions for brain AVMs are commonly based on a comparison between the risks of the natural course of the lesion and the risks of the various treatment modalities (2, 15, 16, 28). Successful treatment of brain AVMs requires extensive preoperative planning, multimodality treatment options and postoperative surgical care. The surgical treatment of AVMs of the brain is primarily intended to eliminate the continued risk of serious hemorrhage and progressive neurological deterioration. The goal is to resect the AVM without interfering with the normal vascular supply and intact neural tissue. In this study we report our experience with 46 patients who underwent microsurgical AVM resection.

MATERIAL AND METHODS

Forty-six cases with intracranial AVMs treated by microsurgery over a period of 11 years (from 1992 to 2003) were reviewed retrospectively. There were 26 males (56.5%) and 20 females (43.5%) with ages ranging from 8 to 73 years (mean 37). Thirty-two patients (69.5%) presented with hemorrhage (intraparenchymal hematoma in 24 cases, intraventricular bleeding in 5 cases and subarachnoid hemorrhage in 3 cases), 7 patients (15.2%) with seizure, 5 patients (10.8%) with headache and 2 patients (4.3%) with ischemic neurological deficits (Table I). The localization of these AVMs is outlined in Table II. The patients' clinical status at the time of surgery was assessed in three grades (Grade 1: neurologically normal, Grade 2: minor neurological deficits, Grade 3: major neurological deficits) using the scale described before. Twenty-two patients (47.8%) were neurologically normal, 15 patients (32.6%) had minor deficits and 9 patients (19.6%) had major deficits. All had computed tomography and cerebral angiography, and 37 patients had magnetic resonance imaging. Table III summarizes the classification according to the Spetzler-Martin grading system. Of all AVMs, 4 (8.7%) were Grade 1, 14 (30.4%) were Grade 2, 17 (37.0%) were Grade 3, 7 (15.2%) were Grade 4 and 4 (8.7%) were Grade 5. Two patients had aneurysms of the feeding arteries (one patient had a distal middle cerebral artery aneurysm and the other had a distal posterior cerebral artery aneurysm) and one patient had a posterior inferior cerebellar artery (PICA) aneurysm in association with AVMs. One patient underwent endovascular embolization two times, 21 and 18 months before surgery. The mean time interval between hemorrhage and surgery was 24 days (4 days to 6 months) in cases with

Table I. Presentation of patients

Hemorrhage	32 (69.5%)
Epilepsy	7 (15.2%)
Headache	5 (10.8%)
Ischemia	2 (4.3%)

Table II. Localization of AVMs

Frontal	10 (21.8%)
Parietal	9 (19.6%)
Occipital	9 (19.6%)
Temporal	4 (8.7%)
Sylvian	2 (4.3%)
Paraventricular	4 (8.7%)
Parasagittal	4 (8.7%)
Thalamic	2 (4.3%)
Cerebellar	2 (4.3%)

Table III: Classification according to the Spetzler-Martin grading system

AVM diameter	
Small (< 3cm)	17
Medium (3-6cm)	22
Large (> 6cm)	7
Deep venous drainage	17
Eloquent location	29
Spetzler- Martin score	
1	4
2	14
3	17
4	7
5	4

hemorrhage. All patients underwent microsurgical excision of AVMs and the associated aneurysms were clipped during the same session; craniotomy was performed for a PICA aneurysm. Forty-three patients had angiography 2 weeks postoperatively. Forty-one of these 43 patients were followed postoperatively for at least 6 months. The mean follow-up period was 52 months with a range of 6 months to 11 years. Statistical analysis was with the Statistical Package for Social Sciences (SPSS) for Windows, version 10.0. Mc Nemar's test and Kappa coefficient were used for analyzing the concordance of outcomes with preoperative neurological status and Spetzler-Martin grade of AVMs. The chi-square test was used for the analysis of outcomes according to the presence of hemorrhage.

RESULTS

Postoperative mortality was 6.5% (3 of 46 cases). One patient whose AVM was Spetzler-Martin Grade 5, died two days after the surgery because of diffuse brain edema. Two patients died as a result of systemic diseases; one who had bronchial asthma preoperatively died from acute respiratory distress syndrome three months after the surgery, and one patient with chronic renal disease died from renal failure a month after the surgery.

Postoperative angiographies of 43 patients showed complete removal of AVMs in 38 patients. Three of them were reoperated on and postoperative angiography ensured complete removal of the residual malformation. We advised radiosurgery to one patient and endovascular embolization to another one; both were lost to follow-up.

Table IV shows the neurological status of 43 patients at postoperative 6 months. Postoperatively, 4 patients (8.7%) had new neurological deficits. Neurological improvement was observed in 9 patients (19.6%). Except the mortality, there is a statistical concordance (correlation) between the patients' clinical condition at the time of surgery and neurological outcome (p>0.05 in Mc Nemar's test, Kappa coefficient=0.511). Preoperative neurological status was found to be a determinative factor about outcome.

Comparison of the postoperative neurological outcome according to the Spetzler-Martin grade is outlined in Table V. Postoperative outcome was concordant with the Spetzler-Martin grade of the AVMs (p>0.05 in Mc Nemar's test, Kappa coefficient=0.250). The neurological deficits increased in correlation with the Spetzler-Martin grade of the AVMs.

Table IV. Neurological status of patients, both preoperative and postoperative, at 6 months*

Preop. neurological status (number of cases)		Postop. neurological status			
		Grade 1	Grade 2	Grade 3	Exitus
Grade 1	**(22)**	15	3	1	3
Grade 2	**(15)**	3	12	0	0
Grade 3	**(9)**	3	3	3	0
Total	**(46)**	21	18	4	3

*p>0.05 in Mc Nemar's test, Kappa coefficient=0.511

Table V. Comparison of postoperative status according to the Spetzler-Martin grade*

Spetzler-Martin (number of cases)		No deficit	Mimor deficit	Major deficit	Exitus
1	(4)	4	0	0	0
2	(14)	7	7	0	0
3	(17)	4	10	2	1**
4	(7)	4	0	2	1**
5	(4)	2	1	0	1
Total	(46)	21	18	4	3

*p>0.05 in Mc Nemar's test, Kappa coefficient=0.250
** These patients died because of systemic diseases.

When analyzing both the preoperative and the postoperative neurological condition according to the presence of hemorrhage (Table VI), there was a statistical significance between the patients with hemorrhage and the group having no hemorrhage (p<0.001).

Table VI. Comparison of postoperative neurological status according to the presence of hemorrhage*
Group A: Patients with hemorrhage

Preop. neurological status (number of cases)		Postop. neurological status			
		Grade 1	Grade 2	Grade 3	Exitus
Grade 1	**(9)**	3	2	1	3
Grade 2	**(14)**	3	11	0	0
Grade 3	**(9)**	3	3	3	0
Total	**(32)**	9	16	4	3

Table VI. Comparison of postoperative neurological status according to the presence of hemorrhage* Group B: Patients with no hemorrhage

Preop. neurological status (number of cases)	Postop. neurological status			
	Grade 1	Grade 2	Grade 3	Exitus
Grade 1 (13)	12	1	0	0
Grade 2 (1)	0	1	0	0
Grade 3 (0)	0	0	0	0
Total (14)	11	3	0	0

* $p<0.001$

Illustrative Cases

Case 1: This 27-year-old male patient presented with a right fronto-parietal intracerebral hemorrhage with clinical signs of unconsciousness and left-sided hemiparesis. Angiography showed a right frontoparietal AVM with a nidus 7 cm in diameter, supplied by branches from the right anterior cerebral artery (ACA) and middle cerebral artery (MCA) and draining into the superior sagittal sinus, transverse sinus and internal cerebral vein (Figure 1). The patient improved clinically and was operated 10 days after the hemorrhage. The AVM was excised totally and post-operative angiography showed no evidence of residual malformation (Figure 2).

Case 2: This 22-year-old female patient presented with generalized tonic-clonic epileptic seizures. Physical and neurological examinations were

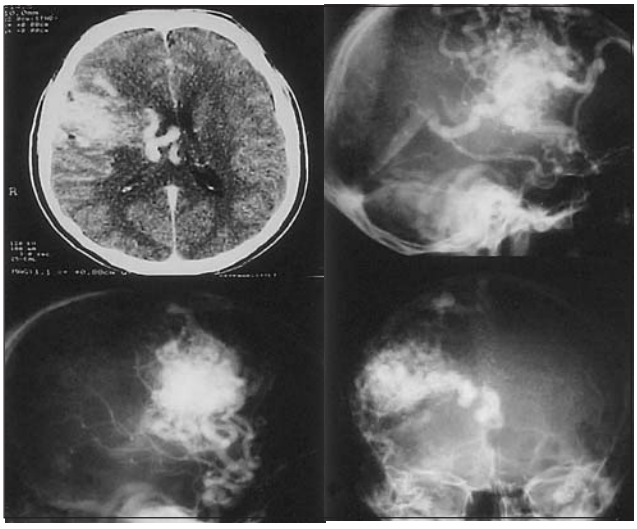

Figure 1: Pre-operative axial CT and right internal carotid artery angiography of Case 1 showing Spetzler-Martin Grade 5 AVM.

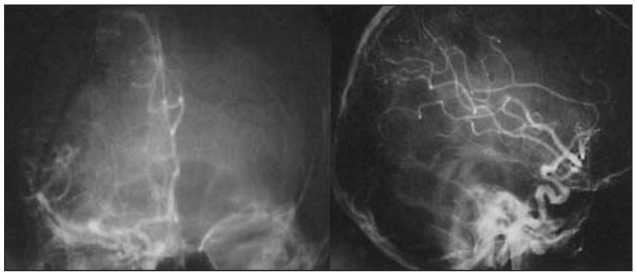

Figure 2: Post-operative angiography of right internal carotid artery of Case 1 showing complete removal of AVM.

normal. MRI revealed right parietal AVM. Cerebral angiography showed right parietal AVM with a diameter of 4cm, feeding from the right ACA, MCA and posterior cerebral artery (PCA) and draining into the superior sagittal sinus and transverse sinus (Figure 3). The patient was operated and the AVM was resected totally. Post-operative angiography result is shown in (Figure 4).

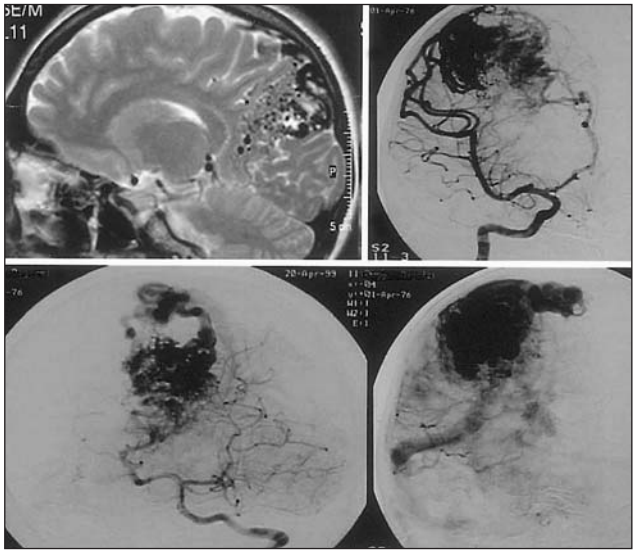

Figure 3: Pre-operative T2-weighted MR and angiography of right internal carotid artery and left vertebral artery of Case 2 showing Spetzler-Martin Grade 4 AVM.

Case 3: This 31-year-old male patient was admitted to the emergency clinic with a history of loss of consciousness. His Glasgow Coma Score (GCS) was 11 (E3M5V3). The CT scan showed a right cerebellar hematoma. After clinical improvement in a few days, cerebral angiography was performed and showed a right cerebellar AVM with a nidus 3.5 cm in diameter, feeding from the right PICA and draining into right sigmoid sinus (Figure 5). It was resected totally on the 11th day after admission. Post-operative angiography showed complete removal (Figure 6).

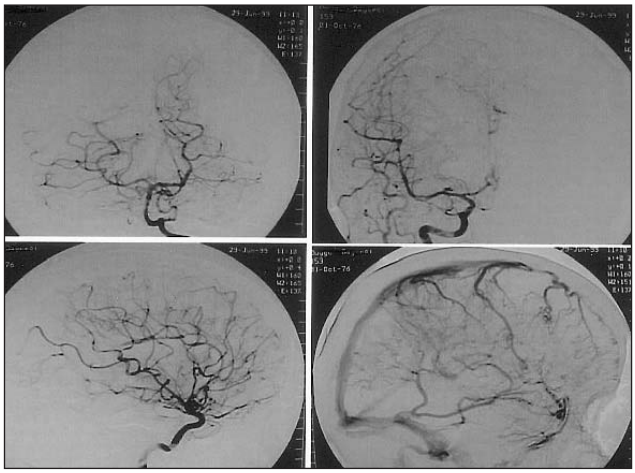

Figure 4: Post-operative angiography of right internal carotid artery and left vertebral artery of Case 2 showing no residual malformation.

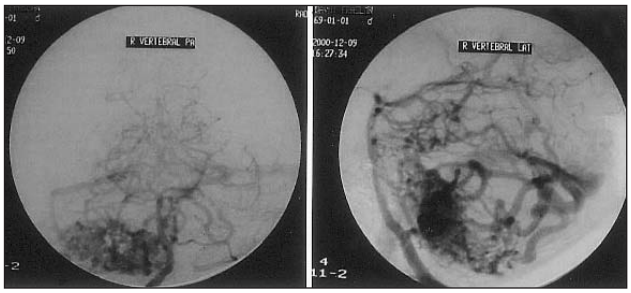

Figure 5: Pre-operative angiography of right vertebral artery of Case 3 showing Spetzler-Martin Grade 4 AVM.

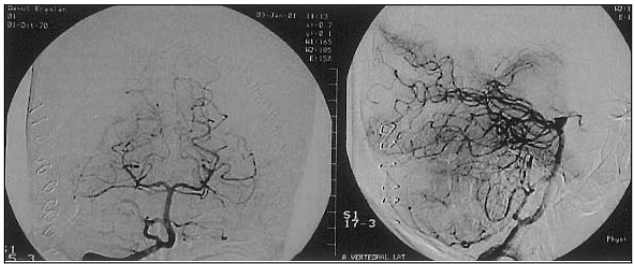

Figure 6: Post-operative angiography of right vertebral artery of Case 3 showing complete removal of AVM.

Case 4: This 29 year-old female patient had complaints of acute onset of severe headache, nausea and vomiting. Neurological examination revealed right homonymous hemianopsia and right-sided hemiparesis. Left occipital intracerebral hematoma was seen on the CT scan. Cerebral angiography demonstrated left occipital AVM with a diameter of 4cm, feeding from the distal branches of the MCA and draining into the transverse sinus, together with a coincidental left PICA aneurysm (Figure 7). The AVM was totally excised during surgery and the aneurysm was clipped in the same session via another craniotomy. Post-operative cerebral angiography showed no residual malformation (Figure 8).

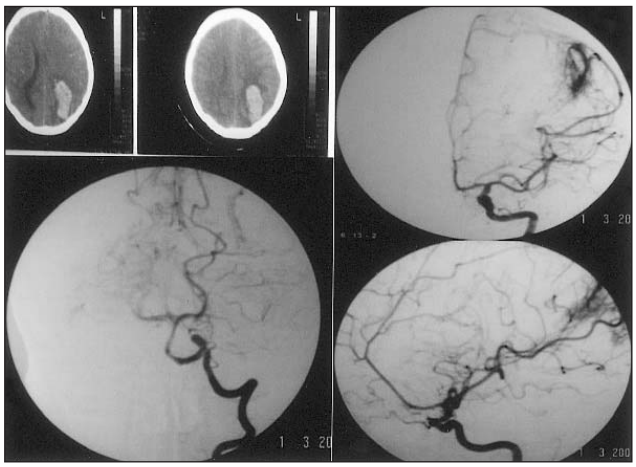

Figure 7: Pre-operative axial CT and left internal carotid artery and left vertebral artery angiography of Case 4 showing Spetzler-Martin Grade 3 AVM and left PICA aneurysm.

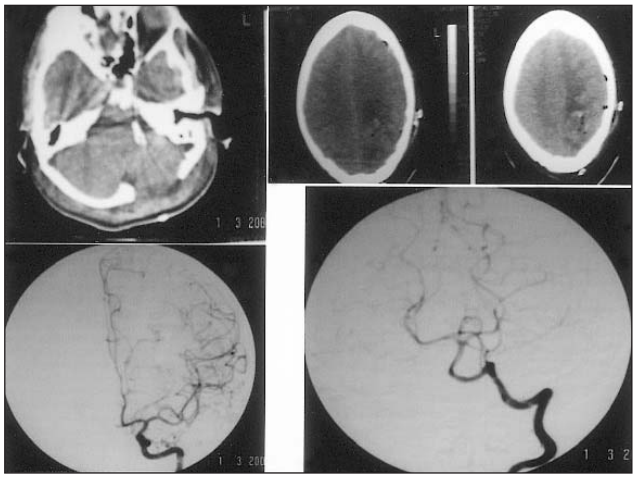

Figure 8: Post -operative axial CT and left internal carotid artery and left vertebral artery angiography of Case 4 showing aneurysm clip and no residual malformation.

DISCUSSION

The primary indication to treat an AVM is to prevent a serious hemorrhage and its associated morbidity and mortality. The management options currently include microsurgery, radiosurgery and endovascular interventions, either alone or in combination (2-5, 7, 10-12, 15, 16, 18, 20-23, 25, 28, 29). The main goal in the treatment of a brain AVM is simply complete removal or occlusion of the

malformation and restoration of normal cerebral blood flow with reasonable safety.

There is still no perfect classification for AVMs. We prefer the Spetzler-Martin grading system which is used to grade AVMs according to size, location and venous drainage (24). This grading system has, for over a decade, served as a mode of communication between neurosurgeons and other subspecialties involved in the treatment of these complex lesions.

The risk of the offered treatment should not exceed that of the natural course, which is assumed to have an annual rate of hemorrhage of 2% to 4%, rising to 6% in the first year after an initial bleed, and an annual rate of morbidity of 3% and mortality of 1% (1, 2, 15, 19, 28). Once an AVM is detected, treatment decisions are based on knowledge of natural history which however remains incompletely understood as well. The presence of certain factors such as the AVM size, location, the presence of associated aneurysms, the characteristics of the venous drainage (deep, single and stenotic) and high intranidal blood flow pressures seem to predict a greater propensity for future or recurrent hemorrhage, although the exact risk posed by a given lesion remains highly variable (2, 14, 15, 20, 27).

It is important to determine the benefits of the treatment in an individual case. The patient and the family have the right to be fully informed about the results of the treatment modalities and the estimated natural course. Their wishes and attitude towards the problem should be taken into account during the decision-making process.

Microsurgery offers an immediate chance of saving a patient from hemorrhage and progressive neurological deterioration. In cases with an intracerebral hematoma, evacuation of the hematoma can lead to neurological improvement as seen in nine of our patients. In cases with an aneurysm, treating both lesions at a single operation is the best option. There are still some contraindications, particularly when the patient's age, condition and the anatomic features of the AVM are taken into account (2, 15, 18, 20, 23, 28). Of our three patients who died postoperatively, two patients had systemic disease and the other's AVM was Spetzler-Martin grade 5.

The aim of embolization is to decrease the size of the nidus and to decrease flow to facilitate its removal. With the improvements in endovascular techniques it is sometimes possible to obliterate the nidus entirely, especially in small AVMs. Embolization has a significant role in the multimodality treatment of cerebral AVMs by either enabling or facilitating subsequent microsurgical or radiosurgical treatment, especially in large AVMs. In fact endovascular treatment is not without complications, and there are some reports on the risk of recanalization (7, 9, 10, 16).

Radiosurgery has a well-documented role in the treatment of brain AVMs with a diameter less than 3 cm but requires a latency period lasting 6 months to 2 years to achieve the beneficial effects of focused radiation and for the onset of total obliteration. The delay in occlusion is associated with a rebleeding rate of 3% per year prior to obliteration. In other words, the patient is still at risk and subject to the natural history of the AVM as if it was untreated during this latency period. There is also the risk of a radiation-induced increase in symptoms and delayed radionecrosis (3, 4, 8, 12, 13, 16, 21, 22, 29).

The association between embolization and radiosurgery has been well documented (5, 11). Decreasing the size of the lesion by embolization can make it amenable to radiosurgery, but there are still no long-term results. Some authors recommend staged embolizations for complex AVMs with high flow especially to prevent the complication of perfusion breakthrough (25).

It is established that partially occluded or resected AVMs still pose a threat of a serious hemorrhage, even more than present during its natural course. Partial resection or obliteration does not protect against the risk of bleeding and only complete removal or obliteration can eliminate such a risk (2, 15, 17, 28). Controversy remains over whether to undertake any treatment at all, especially in very large complex malformations. Some authors recommend not treating grade 4 and 5 AVMs unless there is an associated aneurysm or progressive neurological deficits related to the vascular steal. It is also reported that the annual hemorrhage risk of high grade AVMs is 1.5%, which appears to be lower than that reported for grades 1 through 3 AVMs (6).

Aneurysms associated with AVMs are reported to occur in 3% to 25% of the cases (26,30). Associated aneurysms were detected in three of our patients. All

of them presented with hemorrhage. The aneurysms were on the feeding arteries in two cases with one of the AVMs Spetzler-Martin grade 3 and the other grade 4. The third case with a Spetzler-Martin grade 2 AVM in the left occipital region had a PICA aneurysm on the same side.

We prefer to carry out elective surgery at least 10 days after the bleeding in cases presenting with hemorrhage unless urgent evacuation of an intracerebral hematoma with mass effect, especially in association with a deterioration of consciousness, is indicated.

The treatment modalities must be individualized for each patient by a multidisciplinary team where the neurosurgeon plays a determining role. Which modality will be chosen for a particular patient depends on several factors such as the Spetzler-Martin grades of these lesions, locally available expertise and experience, and patient's clinical tolerance and preference after being informed on the chances for cure and the risks associated with each of these treatment options. Results of our series support the conclusion that microsurgery, carrying a reasonable risk of mortality and morbidity, can be recommended as the first choice of treatment especially for low grade AVMs. Microsurgical removal provides immediate and precise protection against further hemorrhage, thus decreasing the rate of mortality and morbidity. A true comparison between an operated and unoperated group is impossible. It is not ethical to make a prospective randomized study to search for the value of therapeutic modalities. Our opinion is to offer microsurgery first except for those cases in which the risk of surgery is high due to patient's age, poor medical condition or the localization and extent of the lesion. Although we do not have extensive experience, we consider embolization to be a useful preoperative adjunct especially to reduce the size and flow of the AVM. We advise radiosurgery for smaller, deep-seated AVMs where surgical removal carries a greater risk. Multimodality treatment with radiosurgery, endovascular interventions and microsurgery can be used to achieve good results in most patients with high grade lesions and in those with AVMs of the pericentral area, basal ganglia, thalamus or brain stem.

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