Endovascular treatment of intracranial microarteriovenous malformations

Clinical article

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Object. Microarteriovenous malformations (micro-AVMs) are an uncommon subgroup of brain AVMs defined by a nidus measuring < 1 cm in diameter. The clinical features, angiographic characteristics, and outcomes in patients with micro-AVMs who had been treated endovascularly after presenting with hemorrhage were reviewed to identify common features affecting prognosis.

Methods. Between 1997 and 2006, 25 patients (12 females and 13 males) with 26 micro-AVMs were treated. Twenty-four patients presented with intracerebral hematoma and 1 with subarachnoid hemorrhage only. All patients underwent CT on admission, diagnostic cerebral angiography, and 1 session of endovascular treatment during the acute phase.

Results. Procedure-related complications occurred in 3 patients (12%), which caused temporary hemiparesis in 1 (4%) and no clinical sequelae in 2 patients (8%). Complete nidus obliteration was achieved at the end of the embolization in 22 (84.6%) of 26 lesions. Two recurrences were evident on follow-up angiography 6 months postembolization, resulting in a complete obliteration rate of 77% (20 of 26 lesions) after a single treatment. Late angiography was performed in 12 patients, and no further recurrences were identified.

Conclusions. Immediate complete obliteration of a micro-AVM with a high permanent cure and low morbidity rates was accomplished using endovascular treatment. Early embolization after bleeding should be considered as an alternative to resection. (DOI: 10.3171/JNS.2008.109.12.1091)

Key Words • brain • embolization • microarteriovenous malformation

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**Micro-AVMs** were originally defined by Yaşargil as brain AVMs with a nidus < 1 cm in diameter. They are rare lesions comprising ~ 7% of all cerebral AVMs and 21% of AVMs diagnosed following hemorrhagic presentation. The predominant presenting sign of micro-AVMs is intracranial hemorrhage. Although patients can be treated with surgery or radiosurgery, embolization has been proposed as a minimally invasive and effective alternative.

We present a series of 25 patients harboring micro-AVMs who presented acutely after spontaneous intracranial hemorrhage and underwent treatment with embolization. The clinical presentations, preoperative neurological assessments, and clinical outcomes are reported, as this type of AVM has been reported in only small numbers, either as a small series or as part of larger heterogeneous series.

**Methods**

We reviewed the clinical case records and imaging findings of 25 patients harboring 26 micro-AVMs (1 patient had bilateral frontal lesions) in whom embolization had been the primary treatment at 2 neurointerventional departments between 1997 and 2006. Only diagnosed lesions with nidus diameters < 1 cm on cerebral DS angiography were included in this study. Patients had been referred for endovascular treatment after a multidisciplinary team review and local surgical evaluation. Table 1 lists a summary of patient demographic data and angiographic characteristics.
### Clinical and Imaging Findings, Treatment, and Outcome in 25 Patients with Micro-AVMs

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*Venous drainage was superficial in all cases except one in which it was deep. Abbreviations: ACA = anterior cerebral artery; MCA = middle cerebral artery; PCA = posterior cerebral artery; PICA = posterior inferior cerebral artery; — = not applicable.

### Clinical Characteristics

There were 25 patients, 13 males and 12 females. The mean age at the time of treatment was 29.7 years (range 5–68 years). All patients presented after intracranial hemorrhage, 24 with ICH and 1 with SAH, ascribed to a micro-AVM. Neurological examination findings based on the GCS were recorded at the time of admission. Eight patients presented after the sudden onset of headache with symptoms of dizziness and nausea but without an altered level of consciousness (GCS Score 15). Three patients were in a coma at the time of hospital admission (GCS score of 8 in 2 patients and 12 in 1 patient). The sudden onset of neurological deficits occurred at the time of hemorrhage in 12 patients. Deficits evident on admission included cerebellar signs (3 patients), hemiparesis (5 patients), and visual disturbances (4 patients). Two patients with no focal neurological deficits were drowsy (GCS Score 14).

### Imaging Findings

**Computed Tomography and MR Imaging.** All patients underwent CT scanning on admission to the hospital, which demonstrated intraparenchymal hematoma in 24 patients and SAH in 1. The hematomas were supratentorial in 17 patients and infratentorial in 7. Twelve patients underwent MR imaging and/or MR angiography on admission. In all 25 patients there were no imaging features diagnostic of an underlying micro-AVM.

**Cerebral Angiography.** All 25 patients underwent cerebral angiography with injections to the carotid and vertebral arteries. Initial angiographic findings indicated a micro-AVM in 18 patients. In 5 patients the findings (capillary blush [2 patients] and early venous filling without opacification of a nidus [3 patients]) were considered suspicious and further angiographic studies with superselective catheterization were performed during the same hospital admission and revealed a micro-AVM. In 2 patients (Cases 15 and 21) the initial angiogram was nondiagnostic; however, given the morphological features and the site of the hematoma, catheter angiography was repeated 3 and 6 months later in 1 patient each. Repeated cerebral angiography findings in both cases were positive for micro-AVM, and endovascular treatment was administered.

The lesions were cortical (12 of 26 lesions), subcortical (11 of 26 lesions), and deep (2 within the vermis and 1 in the cerebellar hemisphere). The feeding arteries had a normal size in 5 lesions or were slightly dilated in 21. In 2 patients (Cases 9 and 23) a flow-related aneurysm was located in a very distal position but proximal to the nidus: 1 in the AICA and 1 in the SCA; an intranidal aneurysm was angiographically identified in 5 cases. In 3 cases the intranidal aneurysm was evident only after superselective angiography. A single draining vein was seen in the majority of cases (22 lesions); in 4 cases there were 2 draining veins. The draining vein had a normal size in 2 lesions and was slightly enlarged in 24. Venous drainage was superficial in 25 cases and deep and draining to the internal cerebral vein in only 1 case.

### Endovascular Treatments

When a micro-AVM was detected angiographically,
an attempt to recognize the angioarchitectural characteristics with superselective catheterization of the feeding arteries was performed. An additional aim of superselective exploration was to detect an underlying intranidal aneurysm that might be an indication for emergency embolization (Fig. 1). If the micro-AVM nidus was accessible and the lesion judged to be curable by embolization, treatment was administered with the goal of occluding the entire AVM (Figs. 2 and 3).

Twenty-five patients were endovascularly treated for 26 lesions. The median time between presentation and endovascular treatment was 2 weeks (range 1–28 weeks). In 1 patient 2 micro-AVMs (Case 22) were diagnosed but the ruptured micro-AVM was revealed only on a later angiogram, 6 months postbleeding, whereas the first diagnostic angiogram had demonstrated only the unruptured lesion. Both lesions were treated in 1 session. In another patient the micro-AVM was diagnosed late after a delayed angiogram (Case 20).

Endovascular treatment was performed after inducing a state of general anesthesia via a standard transfemoral route. Informed consent was obtained from each patient before the procedure. Microcatheters of various types and sizes of the latest technology were used to access the nidus or the main feeding artery just proximal to the nidus. In 1 patient (Case 23) presenting with SAH only, a distal flow-related aneurysm of the AICA related to a micro-AVM was considered responsible for the hemorrhage and was treated using parent vessel occlusion with NBCA in the acute phase. The patient then underwent stereotactic radiosurgery because the nidus was no longer accessible to endovascular catheterization.

Twenty-five of the lesions were embolized using NBCA (5 with Histoacryl [Aesculap, B. Braun] and 20 with Glubran 2 [GEM Srl]) as a 20–25% mixture of NBCA with lipiodol (Guerbet). In 1 patient, a cellulose acetate polymer (Onyx, ev3) was chosen because of reduced blood flow caused by catheter spasm and concern about penetration into the nidus (Case 21). The near-universal choice of NBCA by the various operators reflects the small amount of this embolic material needed to occlude micro-AVMs and its compatibility when used in the small microcatheters needed to catheterize small and tortuous pedicles. Immediate postembolization control angiograms were obtained, and follow-up DS angiography was performed 6 months after embolization after applying a local anesthetic.

Results

Procedural Complications

Procedure-related complications occurred in 3 patients (12%). In 1 patient (Case 15) a vessel was perforated by the microguidewire during superselective catheterization. This defect was immediately treated using a glue injection of the pedicle, because the catheter was already in a distal position. In another patient (Case 10) a microcatheter was inadvertently glued (using NBCA) within the feeding artery and could not be safely removed. The proximal shaft was cut and the catheter left in situ. Neither of these complications had clinical consequences.
Acute intraparenchymal hematoma occurred in 1 patient (Case 22) within 24 hours of embolization. This patient had 2 micro-AVMs, which were treated in 1 session, and the hematoma occurred due to incomplete occlusion of the nidus of the unruptured malformation. Right-sided paresis developed in this patient but completely resolved within 6 months posttreatment.

Immediate Postembolization Angiography Results

Complete nidus obliteration was achieved at the end of the embolization in 22 cases (84.6%), and incomplete occlusion in 3 cases (Cases 17, 19, and 22) because of incomplete penetration of the NBCA and in 1 (Case 23) because a proximal ruptured flow aneurysm was preferentially treated.

Angiographic Follow-Up

Twenty-three patients had a follow-up angiogram 6 months postembolization; 2 patients (Cases 10 and 22) refused follow-up imaging invitations. Twelve patients had additional angiographic evaluation 3 years after embolization. Two recurrences (Cases 12 and 15) were evident on the follow-up angiograms obtained at 6 months postembolization, reducing the complete obliteration rate after a single treatment to 77% (20 of 26 lesions). Five lesions (3 incompletely occluded lesions and 2 residual lesions on follow-up DS angiography) were further treated with radiosurgery. Scheduled follow-up cerebral angiography studies 2 years postradiosurgery for these 5 lesions have not yet been performed. There were also 5 patients with negative 6-month DS angiograms who need delayed follow-up.

Clinical Outcome

The clinical follow-up period ranged from 6 to 78 months. The majority of patients (24 of 25) experienced improvements after the hemorrhage. No permanent neurological deficits related to the procedure were evident. One patient (Case 18) with an infratentorial hematoma died 14 days postembolization. This patient subsequently underwent craniotomy and evacuation of the hematoma, which was complicated by a fatal infection. Severe neurological deficits persisted (> 2 on the modified Rankin Scale) in 1 patient. Eight patients had persistent mild neurological deficits (< 2 on the modified Rankin Scale) involving cerebellar signs in 2, upper limb weakness in 4, lower limb weakness in 1, and visual disturbances in 1.

Discussion

Angiographically demonstrated micro-AVMs are composed of a small nidus or a fistula. They are low-volume slow-flow lesions, as demonstrated by filling in the late arterial phase. The feeding artery is not usually dilated, and there is no transdural supply. Venous drainage is usually to a single draining vein of normal or slightly enlarged caliber.

Margolis and colleagues have conducted a detailed autopsy study of 4 patients with intracranial hematomas...
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caused by micro-AVMs. Other authors have subsequently reported the presence of small vascular malformations in the margins of intracranial hematomas. These lesions typically consist of a plexiform AVM nidus or multiple tiny arterioles draining into an arterialized vein (fistulous type). Deruty and associates,3 Jensen et al.,5 Willinsky et al.,17,18 Stiver and Ogilvy,12 Cellerini et al.,2 and Perrini et al.8 have described small series of patients with micro-AVMs who presented mainly with intracranial hematoma. Willinsky and associates17 have speculated that micro-AVMs have large bridging arteries that anchor the draining veins to the brain parenchyma producing outflow obstruction and increased venous pressure. Spetzler and colleagues10 have reported that feeding arteries of small AVMs have higher pressures. These malformations are generally considered to have a high risk of bleeding, but Stefani et al.11 have found no association between AVMs of a small size and hemorrhagic presentations in their analysis using a multivariate model. The propensity of micro-AVMs to bleed may also reflect the fact that their small size and flow characteristics preclude presentation with other symptoms and incidental detection on CT or MR imaging.

Neither CT nor MR imaging findings are usually diagnostic; DS angiography is the most accurate diagnostic examination, although findings are often subtle or nonspecific. In Willinsky et al.’s17 series of 13 patients DS angiography demonstrated the lesion in only 11 (85%) of 13 patients. Two lesions were visualized only after a second angiographic study 3 months later, when the hematoma had resolved. Cellerini and associates2 have described a series of 10 patients with micro-AVMs. All patients underwent 4-vessel cerebral DS angiography, and the findings were diagnostic in 5 patients, questionable in 3 (capillary blush, prolonged distal arterial opacification, venous polling, and early venous filling in the absence of a nidus), and negative in 2 patients. A second control DS angiogram (1–2 months later) demonstrated the lesion in 3 patients and showed questionable findings in 2 who then underwent superselective exploration. Perrini and colleagues8 reported on 14 patients with micro-AVMs. Cerebral DS angiography on 1 or more occasions after absorption of the hematoma showed the lesion in 11 patients (78.5%). In 3 patients the diagnosis was confirmed after superselective angiography. Stiver and Ogilvy12 reported on 12 patients with micro-AVMs. Cerebral angiograms were diagnostic for the lesions in 9 patients (75%); in 2 patients the findings were questionable, and in 1 patient negative. In the present study the initial angiogram was diagnostic of a micro-AVM in 17 of 25 patients. Therefore, angiography performed in the acute stage after hemorrhage may not demonstrate this type of vascular malformation.

The lack of visualization on the initial angiogram obtained during the acute phase may be explained by compression of the vessel lumens and/or destruction of the abnormal vessels by the hematoma, vascular thrombosis due to gross hemorrhage, and/or posthemorrhagic vascular spasm. Patients who do not have a specific cause for lobar hemorrhage, especially younger patients, should undergo repeated angiography after resolution of the hematoma.4 In the present study 2 lesions were only demonstrated angiographically 3 and 6 months postbleeding. Superselective angiography2,13,18 increases the diagnostic yield, allowing

![Fig. 3. Cerebral angiogram obtained in a 25-year-old man with a left occipital hematoma. A: Left vertebral artery injection, lateral view, showing a micro-AVM. B: Superselective injection revealing draining into the superior sagittal sinus through a slightly enlarged cortical vein. C: Cast of glue. D: Immediate postembolization left vertebral artery injection demonstrating complete occlusion of the malformation.](image-url)
a definite diagnosis and permits better evaluation of the anatomical location and the angioarchitecture of the lesion. Willinsky and colleagues described 5 patients with micro-AVMs who underwent superselective angiography. In 2 patients the procedure was useful in confirming the diagnosis and in defining the topography of the lesion. Perrini and associates reported that the diagnosis of a micro-AVM was possible in 11 patients by using standard DS angiography, and only after superselective angiography in 3 patients. In 6 of 25 patients in the present study, the initial standard DS angiography findings were considered questionable, and the diagnosis of a micro-AVM was confirmed after superselective angiography.

Treatment options for intracranial AVMs include radiosurgery, conventional surgery, and endovascular embolization. Small AVMs that fulfill the selection criteria for curative embolization are likely to be suitable for surgical removal or radiosurgery as well; in fact, the treatment outcome of these other 2 options is extremely good.

Stiver and Ogilvy reported excellent results after resection of 12 micro-AVMs, and they concluded that superficially located AVMs are best treated with surgical removal. Two patients in their study experienced a worsening neurological status, which was transient in 1 patient (8%) and associated with subtle residual deficits in the other (8%). One patient returned after 4 months with a bone flap infection, which required debridement and cranioplasty. These authors stated that micro-AVMs are very small lesions, and localization is of paramount importance to achieve complete resection of the lesion. They suggested proximal dissection along the arterialized draining vein to the nidus instead of exploration of the hematoma cavity. These also reported that stereotactic angiography was an extremely valuable adjunct for localization of micro-AVMs. Willinsky and colleagues described 13 patients with micro-AVMs inaccessible via the endovascular approach, who were treated surgically with no perioperative morbidity. Schaller and Schramm reported on 62 patients with small AVMs (< 3 cm) that had been surgically removed. These lesions were extirpated in all except 1 patient (98.4% success rate). The rate of immediate new postoperative, or worsening of preexisting, neurological deficits was 27.4%, and the rate of permanent significant neurological deficits was 3.2% at a late follow-up.

Experience with radiosurgery in the treatment of micro-AVMs is limited. The complete obliteration rate of AVMs treated with radiosurgery alone is correlated to the size of the nidus. Nataf and colleagues reported a 75% complete obliteration rate for lesions with a nidus < 1.5 cm. One micro-AVM in the series of Stiver and Ogilvy was treated with radiosurgery but required late surgery after a control angiogram 2-years postradiosurgery showed a remnant. One patient in the Willinsky et al. series underwent radiosurgery, but no outcome was reported. The latency for complete obliteration of small AVMs is also significantly smaller. In the present study 3 patients underwent stereotactic radiosurgery after failed endovascular treatment, and thus, stereotactic radiosurgery could be considered a second-choice treatment.

The typical findings of a normally sized and tortuous feeding arterial supply of micro-AVMs are the major limiting factors for successful embolization. In 1992 Willinsky et al. reported unsuccessful attempts to embolize 3 micro-AVMs. With the current technical advances in microcatheters, an endovascular approach could be considered as an alternative treatment for micro-AVMs. Although embolization of micro-AVMs can be complicated by hemorrhage due to perforation of the small-sized and tortuous feeding arteries during navigation of the microcatheter, we have shown that it is a relatively safe therapeutic approach. Given the low-flow shunt in this type of lesion, it is conceivable that the lack of mural hyalinization in the feeding vessels, when compared with larger AVMs, makes these vessels more fragile and therefore more likely to become injured from microcatheter manipulations. Perrini and associates reported a 22.2% complication rate (2 of 9 patients) due to arterial perforation. Although the sequelae was minor in 1 patient who experienced mild headache and the diagnosis was made on CT scan, the second patient had a more severe hemorrhage with intraventricular extension requiring external ventricular drainage. In our series only 1 patient had a clinically silent microperforation.

The goal of embolization in micro-AVMs is the complete and permanent obliteration of the AVM nidus. Note that NBCA remains the most commonly reported embolic material used for endovascular treatment of micro-AVMs. In the Perrini et al. series of 14 patients, only 7 underwent embolization exclusively with NBCA. In 2 patients, endovascular treatment was not performed because of vasospasm in the feeding artery in 1 and suboptimal positioning of the microcatheter in the other. Yu and associates described 10 patients with small AVMs (< 3 cm), including 1 patient with a micro-AVM; all underwent curative NBCA embolization. One of the patients had a micro-AVM that was successfully obliterated endovascularly with glue, without complications. Tanaka and Valavanis reported on 3 patients with micro-AVMs successfully treated with polyvinyl alcohol particles. In 1 of the patients who had a successful embolization in the present study, Onyx was preferred, as we thought that a less adhesive embolic agent would be safer and more effective.

The initially complete obliteration of an AVM nidus can be followed by a recurrence shortly after embolization. In the present study follow-up cerebral angiograms (6 months postembolization) showed residual lesions in 2 patients in whom the immediate postoperative angiogram had shown complete lesion obliteration. Our experience with patients with even larger AVMs has revealed that a recurrence on a delayed DS angiogram is a very rare event after embolization with NBCA mixtures. However, we have now decided to perform further follow-up angiography studies 2–3 years posttreatment in all patients to ensure that this assumption is correct. We believe that negative angiography results 3 years posttreatment could be interpreted as a permanent cure.

**Conclusions**

Endovascular catheterization and embolization were possible in the majority of patients despite the small size of the feeding arteries, the distal location of these lesions, and the initial underdiagnosis associated with micro-AVMs in the brain. A high immediate and permanent obliteration rate
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was achieved; the success of the method in treating additional lesions (flow-related aneurysms) with a relatively low complication rate supports the use of endovascular treatment. Therefore, we believe that endovascular treatment is a useful adjunct in the treatment of patients with micro-AVMs. Resection remains the most efficient approach, especially for superficially located lesions and when combined with hematoma evacuation. Stereotactic radiosurgery, given its delay in lesion obliteration, should be reserved for lesions that are inaccessible to surgery or endovascular treatment or for residual lesions that are evident on a follow-up angiogram.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References


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