Angioarchitectural Characteristics Associated with Complications of Embolization in Supratentorial Brain Arteriovenous Malformation

J. Pan, H. He, L. Feng, F. Víñuela, Z. Wu, and R. Zhan

ABSTRACT

BACKGROUND AND PURPOSE: Embolization is an important therapeutic technique in brain arteriovenous malformations; however, little has been reported on the factors contributing to complications. We retrospectively reviewed a large series of supratentorial brain AVMs to identify the angioarchitectural characteristics that might be associated with the complications of embolization and poor clinical outcomes.

MATERIALS AND METHODS: The clinical and angiographic features of 130 consecutive patients with supratentorial brain AVMs embolized with ethylene-vinyl alcohol copolymer in our hospital from 2005–2008 were retrospectively reviewed. None of these patients had prior embolization. Complications were classified as transient neurologic deficits, persistent neurologic deficits, and death. Univariate and multivariate analyses were conducted to assess the angiographic features in patients with and without complications.

RESULTS: Twenty-three complications occurred in 130 embolization procedures, 13 (10%) were transient neurologic deficits (9 ischemic and 4 hemorrhagic), 9 (6.92%) were persistent neurologic deficits (7 ischemic and 2 hemorrhagic), and 1 death occurred. By univariate analyses, eloquent cortex (OR, 2.57; 95% CI, 1.08–3.42) and exclusive deep venous drainage (OR, 4.56; 95% CI, 1.28–9.67) were correlated with procedural complications. The impactation of eloquent cortical location (P = .001) and exclusive deep venous drainage (P = .035) on complications were also demonstrated by multivariate analysis. Eloquent cortex mainly resulted in permanent ischemic neurologic deficit; occlusion of drainage vein was significantly correlated with periprocedural hemorrhage in supratentorial brain AVMs with subtotal and partial embolization.

CONCLUSIONS: In a retrospective study on supratentorial brain AVMs with first-time embolization, 6.92% of patients had permanent neurologic deficit or death. Eloquent cortical location and exclusive deep venous drainage were associated with complications.

ABBREVIATIONS: sbAVM = supratentorial brain arteriovenous malformation; EVOH = ethylene-vinyl alcohol copolymer; PVA = polyvinyl alcohol
rologists for the therapeutic option on the basis of CT, MR imaging, and DSA. A total of 130 consecutive patients with sbAVMs were diagnosed and embolized with Onyx for the first time during the period January 1, 2005 to December 31, 2008, and their demographic, clinical, and angioarchitectural data were reviewed retrospectively. Patients with prior treatment (surgical removal, embolization, radiosurgery) were excluded from the study.

Initial sbAVM presentation was defined as hemorrhage, ischemic neurologic deficit, headache, seizures, and incidental findings. Angioarchitectural characteristics such as location and size of AVM, arterial feeders and coexisting aneurysms, venous drainage, and venous morphology were retrospectively evaluated.

AVM locations were grouped into eloquent cortex, noneloquent cortex, midline region (ventricle, corpus callosum), and deep region (basal ganglia, internal capsule, and thalamus). Spetzler-Martin grade was assessed in each AVM, and sizes were classified into small (3 cm), medium (3 cm and 6 cm), and large (6 cm). Arterial feeders were categorized as terminal and perforating. Terminal feeding arteries were prominent arteries that connected directly to the nidus, whereas perforating feeders referred to the pattern of several small, short arteries arising from a large parent artery and penetrating brain parenchyma to reach the AVM nidus. The presence of coexisting arterial aneurysms was divided into perinidal and intranidal aneurysms. Remote flow-related or unrelated aneurysms were not taken into account in this study. Venous drainage was noted as deep, superficial, and combined groups. Venous morphology was described according to the presence or absence of ectasia and stenosis. Ectasia was defined as focal dilations that were at least twice the size of the venous diameter. A 50% focal reduction of the venous diameter was considered as a significant stenosis.

Embolization degree was classified into partial (<90%), subtotal (≥90%), and complete (100%) embolization. Neurologic deficits were assessed by a neurosurgeon/neurologist according to NIHSS. CT and MR imaging were performed after embolization to identify postprocedural hemorrhage and ischemia. Postprocedural mRS was assessed, and complications of embolization were categorized as transient (new onset of neurologic deficit that resolved completely within 7 days) and persistent neurologic deficit. Neurologic deficits were further divided into ischemic and hemorrhagic.

The data were managed and analyzed by use of SPSS software (version 13.0; IBM, Armonk, New York). We conducted analyses stratified by each variable (age, sex, nidus size, etc) to evaluate its impact on complications of embolization. Furthermore, multivariate analyses (backward conditional logistic regression) were conducted after the adjustment for some variables that demonstrated and correlated with a significantly increased risk of embolization complications in univariate analyses to assess the effect of modification and interaction among potential risk factors. A probability value of <.05 was considered statistically significant in each analysis.

RESULTS

Of the 130 patients with sbAVM who underwent embolization, there were 78 men and 52 women, ranging from 5–64 years of age (mean, 30.27 ± 12.45 years). Initial presentations included 79 spontaneous hemorrhages, 11 ischemic manifestations, 13 headaches, 20 seizures, and 7 nonsymptomatic (Table 1).

The preprocedural angioarchitectural characteristics are summarized in Table 2. Most the sbAVMs were medium-sized (61.54%) and located in noneloquent cortices (47.69%). Perforating feeders were found in 35 cases (26.92%), whereas 16 patients (12.31%) had exclusive deep venous drainage. Coexisting aneurysm was noted in 37 cases, of which, 30 (23.08%) were in-

| Table 1: Demographic and clinical characteristics of 130 patients with sbAVM embolization |
|---|---|
| Characteristics | No. (%) |
| **Sex** | |
| Male | 78 (60%) |
| Female | 52 (40%) |
| **Age, y** | |
| <18 | 27 (20.77%) |
| 18–49 | 100 (76.92%) |
| ≥50 | 3 (2.31%) |
| **Initial presentation** | |
| Hemorrhage | 79 (60.77%) |
| Ischemia | 11 (8.46%) |
| Headache | 13 (10%) |
| Seizures | 20 (15.38%) |
| No symptoms | 7 (5.38%) |

| Table 2: Preprocedural angioarchitectural characteristics of 130 patients with sbAVM embolization |
|---|---|
| Angiographic Features | No. (%) |
| **Location** | |
| Elloquent cortex | 44 (33.85%) |
| Noneloquent cortex | 62 (47.69%) |
| Midline | 12 (9.23%) |
| Deep | 12 (9.23%) |
| **Size** | |
| ≤3 cm | 32 (24.62%) |
| 3–6 cm | 80 (61.54%) |
| ≥6 cm | 18 (13.85%) |
| **No. of feeders** | |
| 1 | 17 (13.08%) |
| 2 | 28 (21.54%) |
| ≥3 | 85 (65.38%) |
| **Arterial feeders classification** | |
| Terminal | 95 (73.08%) |
| Perforating | 35 (26.92%) |
| **No. of draining veins** | |
| 1 | 55 (42.31%) |
| 2 | 37 (28.46%) |
| ≥3 | 38 (29.23%) |
| **Venous drainage classification** | |
| Exclusive superficial | 79 (60.77%) |
| Exclusive deep | 16 (12.31%) |
| Combined | 35 (26.92%) |
| **Venous morphology** | |
| Venous reflux | 35 (26.92%) |
| Venous ectasia | 29 (22.31%) |
| Venous stenosis | 46 (35.38%) |
| **Coexisting aneurysm** | |
| Intranidal | 30 (23.08%) |
| Perinidal | 7 (5.38%) |
| **Spetzler-Martin classification** | |
| I–II | 50 (38.46%) |
| III | 36 (27.69%) |
| IV | 30 (23.08%) |
| V | 14 (10.77%) |
Table 3: Hemorrhagic complications in 38 sbAVMs with obliteration of draining vein

| Complication | Embolization | Subtotal |
|--------------|--------------|----------|
| Hemorrhage   | 0            | 2 (0)    |
| No hemorrhage| 8            | 8 (4)    |

Note: — χ² test.

Table 4: Complications of embolization in 130 patients with sbAVMs

| Complications | No. (%) |
|---------------|---------|
| TND           | 6 (4.62%) |
| Ischemic      | 4 (3.08%) |
| Hemorrhagic   | 2 (1.54%) |
| PND           | 1 (0.77%) |

Note: — TND indicates transient neurologic deficit. PND, persistent neurologic deficit.

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DISCUSSION

Endovascular embolization is an important part of the multimodality treatment for brain AVMs. Improvements in microcatheter technology and embolic agents, especially n-BCA and EVOH, have led to an increased curative rate of brain AVMs. Furthermore, embolization can reduce the size and flow of AVMs, ultimately resulting in the recovery from their initial hemorrhage or ischemic event.

Spetzler-Martin classification of 130 sbAVMs significantly changed after embolization (Table 6), with significantly more patients in grade I than before the procedure (33.33% versus 16.31%, P < .05), and patients in other grades decreased. There were significantly more patients with an mRS of 0 and fewer patients with an mRS of 1 after embolization (Table 6), partly attributed to the recovery from their initial hemorrhage or ischemic event.
improving the safety and efficacy of microsurgery and radiosurgical treatment for brain AVMs.14–18 In this series of 130 sbAVMs that underwent embolization for the first time, there was complete embolization in 28 patients (21.54%) and subtotal embolization in 26 patients (20%). In addition to the cases of complete obliteration of brain AVMs, patients in Spetzler-Martin grade I increased significantly after embolization (preprocedural, 16.31% versus postprocedural, 15.69%; P < .05). This result suggested that vessel-related complications in the univariate model. In the multivariate model, contrast extravasation was more, by progressively blocking draining veins in an AVM model, with embolization complications in the univariate model. In the multivariate model, contrast extravasation was more, by progressively blocking draining veins in an AVM model, with embolization complications in the univariate model. 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Although hemorrhage results in poorer outcome, ischemic events were the most common complications of AVM embolization. 

Sixteen patients (12.31%) in our series had cerebral infarction after embolization, with persistent neurologic deficits in 7 patients. Because of rapid shunting and complex angioarchitecture, perinidal or intranidal normal arteries were very difficult to identify, and neurologic deficits could result from occlusion of these arteries. The present study revealed that sBAVMs located in eloquent cortices had a significantly higher rate of post-procedural persistent ischemic neurologic dysfunction.

In addition to AVM location, other angioarchitectural characteristics that contribute to nonmanipulated complications of embolization remain controversial. Haw et al reviewed 306 consecutive patients and 513 embolization sessions from 1984–2002 at the University of Toronto and suggested that the factors associated with complications included the presence of a high-flow fistula or fistulous component to the nidus, eloquent cortex involvement, or venous glue embolization. The long interval of data collection (1984–2002) could have undermined the validity of these conclusions because significant advancement in the embolization technique occurred during this time period. Among all angiographic parameters investigated in 168 consecutive patients and 295 embolization sessions, Ledezma et al found that Spetzler-Martin grades III–V were significantly associated with unfavorable outcomes and embolization complications. Gabin et al revealed that embolization complications were 0% (grade II), 5% (grade III), 15% (grade IV), and 22% (grade V) in their 125 patients studied on Spetzler-Martin classification. On the other hand, studies of Hartmann et al and Kim et al failed to demonstrate the correlation between Spetzler-Martin grade and embolization complication and found that embolization sessions were the primary factor for postprocedural complications.

To eliminate the statistical bias caused by embolization sessions, we studied the complications of first-time embolization of 130 sBAVMs and demonstrated that postprocedural complications were associated with eloquent cortical location (OR, 2.57; 95% CI, 1.08–3.42) and exclusive deep venous drainage (OR, 4.56; 95% CI, 1.28–9.67) but not with Spetzler-Martin classification in univariate and multivariate models. The result suggested that the required multiple sessions in large AVMs but not the AVM size itself might be associated with procedural complications. Ogilvy et al found that the higher complication rate in sBAVMs with exclusive deep venous drainage could be related to the relative lack of a collateral drainage pathway, making them prone to venous outflow obstruction by embolic agents. This observation may also be confounded by the deep location of these AVMs. Thus, sBAVMs with functional cortex and exclusive deep venous drainage would be more difficult to treat and would be at greater risk for embolization complications than the other types of sBAVMs.

CONCLUSIONS
Embollization is a safe treatment technique for supratentorial AVM, with the development of flow-directed microcatheters and liquid embolic agents. Eloquent cortical location and exclusive deep venous drainage were significantly associated with embolization complications, and venous outflow occlusion in cases with subtotal and partial embolization might be a predictive factor for periprocedural hemorrhage.

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