Arteriovenous Malformations: Classification to Cure

Francisco A. Ponce, MD, and Robert F. Spetzler, MD

Cerebral arteriovenous malformations (AVMs) represent one of the most surgically challenging disease entities that neurosurgeons face. With the addition of endovascular techniques and stereotactic radiosurgery to our armamentarium, the management of cerebral AVMs has evolved over time. In 1986, the Spetzler-Martin grading system was introduced to assist in the complex decision-making process for how to manage AVMs.[1] The routine use of this grading system at our institution has paralleled the evolution in our management of AVMs, and a treatment paradigm has emerged. In this review, we highlight the natural history and management strategies for this disease and discuss a recent simplification of the original classification system.[2]

NATURAL HISTORY

The most common presenting event of AVMs is hemorrhage, which occurs in about half of the patients.[3] The rupture rate of AVM is between 2%/y and 4%/y.[4–9] Some authors have posited that smaller AVMs rupture at a higher rate than larger AVMs as a result of the pressure sink produced by the latter.[10,11] The following equation, derived by Brown,[12] is a useful bedside tool: 105 − (patient's age in years) = (estimated lifetime risk of hemorrhage). After the initial hemorrhage, the risk of rehemorrhage is 6%/y for the first year. The risk then returns to baseline. The risk of serious morbidity or mortality after hemorrhage is 30% to 35%, and the mortality rate after the first, second, and third hemorrhagic events is 10%, 15%, and 20%, respectively. Other common presentations include seizure (25%), headaches (20%), and focal symptoms (15%).[3]

TREATMENT

Ultimately, the goal of treatment is to improve on the natural history of AVMs. Before treatment is begun, all management risks must be considered, including those associated with diagnosis, surgery, radiotherapy, and interventional radiology. These risks also include both early and late complications and any remaining risk of further hemorrhage. We recently reported a classification system for AVMs that includes a treatment paradigm that may serve as a guide to selecting treatment.[2]

AVM GRADING SYSTEM

The most important decision remains appropriate patient selection. To this end, the Spetzler-Martin grading scale was introduced in 1986.[1] This scale is a 5-tier system based on 3 criteria: size of the lesion, eloquence of the adjacent tissue, and venous drainage (Table 1). Other recognized factors contributing to the risk of hemorrhage include the patient's age[13] and clinical status,[14] the involvement of perforating vessels,[13,15] and the compactness of the nidus.[16] These factors were included in grading systems that preceded the Spetzler-Martin classification and in modifications proposed for expanding that classification.[5,17] However, expansion is associated with dilution; adding new variables reduces the number of patients assigned to each category, in turn reducing statistical power. Adding tiers and variables also may make the use of such systems more cumbersome.

At the Barrow Neurological Institute, we recommend microsurgical removal of grade I and II AVMs and, in general, conservative management of grade IV and V AVMs. Caveats to the latter include partial treatment for AVM-associated aneurysm or steal phenomenon, recurrent hemorrhages, or the presence of neurological deficits localized to the affected brain region. Indeed, we perceive no practical difference within these respective pairs, and we have proposed condensing the original classification from 5 to 3 tiers to reflect this consideration (Table 2).[2] In the new system,[2] grades I and II become class A, grade III becomes class B, and grades IV and V become class C. The advantages of this modification include simplification, a larger sample size for each group for analysis of clinical series, and a system that reflects current decision making. Condensing tiers also makes it easier to achieve statistical significance with fewer patients—convenient given the rarity of this disorder. Furthermore, this system allows comparisons with all previously published studies that have used the Spetzler-Martin system.

The initial premise of the 3-tier system is that it reflects a simple treatment paradigm whereby similar management strategies are used for various grades within the 5-tier system. Given that the 5-tier system was initially validated by showing

0148-396X

TABLE 1. Spetzler-Martin Grading System[a]

Feature	Points Assigned
Size of AVM	
Small (< 3 cm)	1
Medium (3-6 cm)	2
Large (> 6 cm)	3
Eloquence of adjacent brain	
Noneloquent	0
Eloquent	1
Pattern of venous drainage	
Superficial only	0
Deep	1

[a]From Spetzler RF, Martin NA. A proposed grading system for arteriovenous malformations. *J Neurosurg.* 1986;65(4):476-483. Used with permission from the *Journal of Neurosurgery*.[1]

its correlation with surgical outcomes, we conducted an analysis of previously published data in which AVM surgical outcomes were stratified on the basis of Spetzler-Martin grade to determine whether the correlations held for the 3-tier system. We found that the smallest differences existed between grades I and II (insignificant) and between grades IV and V (significant but correspondingly small relative risk).[2] Thus, when considered as a tool for estimating surgical risk, those combinations of grades are associated with similar surgical risk. We also showed that the new system retains the predictive accuracy of outcomes validated in the 5-tier system for the studies evaluated.[2]

TREATMENT MODALITIES

Recommendations for management are made on a case-by-case basis. Although microsurgical removal remains the standard for definitive treatment, endovascular neurosurgery and stereotactic radiosurgery are also established treatment modalities for AVMs. We do not recommend partial treatment except in the context of steal phenomenon and AVMs associated with a feeding-vessel aneurysm because it may worsen the natural history of the AVM.[18]

TABLE 2. Three-Tier Classification of Cerebral Arteriovenous Malformations[a]

Class	Spetzler-Martin Grade	Management
A	I, II	Surgical resection
B	III	Multimodality treatment
C	IV, V	No treatment

[a]Exceptions for treatment of Class C AVMs include recurrent hemorrhages, progressive neurological deficits, steal-related symptoms, and AVM-related aneurysms. From Spetzler RF, Ponce FA. A 3-tier classification of cerebral arteriovenous malformations. *J Neurosurg.* 2011;114(3):842-849. Used with permission from the *Journal of Neurosurgery*.[2]

Microsurgical Resection

Microsurgical resection is the first line of treatment for class A AVMs. In our practice, neuronavigation and intraoperative digital subtraction angiography are used in the treatment of all AVMs. During the past decade, we have also adopted the routine use of microscope-integrated indocyanine green (ICG) fluorescent angiography during resection of AVMs.[19] This quick, safe, inexpensive technique facilitates resection by providing immediate high-resolution identification of surface feeding arteries and draining veins. It can also be used to distinguish AVM vessels from normal vessels and arteries from veins on the basis of the timing of the fluorescence. Because ICG angiography provides only a surface view, it is less useful with deep-seated lesions or when AVM vessels are not on the surface. Traditional angiography is thus required to confirm the absence of residual early venous drainage. Angiography with ICG complements rather than replaces digital subtraction angiography, although ICG may decrease the need for multiple angiographic studies during a single case. Some pearls that we have found particularly useful for microsurgical resection include (1) absolute hemostasis with bipolar cauterization, rather than with tamponading with telfas, because persistent bleeding usually indicates persistent AVM; (2) alternating the use of 2 nonstick bipolar forceps while 1 sits in ice water, given the requirement for prolonged coagulation for hemostasis of AVM vessels; and (3) patience.

Endovascular Embolization

Although endovascular therapy is typically used as an adjunct to surgery, reports of curative embolization are increasing.[20,21] Onyx (ev3, Irvine, California) has been an excellent addition to the endovascular armamentarium, although it is still occupies mass. When Onyx is used as an adjunct to surgical resection, it can be cut or removed with an ultrasonic aspirator. However, its administration is not free of risk. One study showed that 16% of patients with class A AVMs suffered a decline in their modified Rankin Scale score after embolization.[22]

Stereotactic Radiosurgery

Stereotactic radiosurgery can produce an angiographic and clinical cure in many patients, particularly in those with small AVMs. However, radiosurgery offers no protection from hemorrhage for at least 2 years and may leave a residual lesion. Furthermore, radiation necrosis remains a risk. One advantage is that the effect of radiation in reducing the size of the AVM or modifying the quality of the AVM vessel walls may make surgery easier to perform.[23]

CONCLUSIONS

Cerebral AVMs are curable in a subset of patients. The key to good outcomes is appropriate patient selection. For some patients, it is in their best interest to be managed conservatively. Although microsurgical resection is appropriate for class A AVMs, a multimodal approach is typically used for class B AVMs and for class C AVMs that are not appropriate for observation. Case-by-case treatment strategies draw on the advantages of microsurgery, endovascular embolization, and stereotactic radiosurgery. The newly introduced 3-tier system can provide a guide to management; however, it is not intended to replace individualized analysis and treatment.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Spetzler RF, Martin NA. A proposed grading system for arteriovenous malformations. *J Neurosurg*. 1986;65(4):476-483.
2. Spetzler RF, Ponce FA. A 3-tier classification of cerebral arteriovenous malformations. *J Neurosurg*. 2011;114(3):842-849.
3. Citow JR, Macdonald RL, Kraig RP, Wollmann RL. *Comprehensive Neurosurgery Board Review*. New York, NY: Thieme; 2000.
4. ApSimon HT, Reef H, Phadke RV, Popovic EA. *A Population-Based Study of Brain Arteriovenous Malformation: Long-Term Treatment Outcomes: 17th World Congress of Neurology*. London, UK: Lippincott Williams and Wilkins; 2001:2794-800.
5. de Oliveira E, Tedeschi H, Raso J. Comprehensive management of arteriovenous malformations. *Neurol Res*. 1998;20(8):673-683.
6. Fults D, Kelly DL Jr. Natural history of arteriovenous malformations of the brain: a clinical study. *Neurosurgery*. 1984;15(5):658-662.
7. Ondra SL, Troupp H, George ED, Schwab K. The natural history of symptomatic arteriovenous malformations of the brain: a 24-year follow-up assessment. *J Neurosurg*. 1990;73(3):387-391.
8. Pollock BE, Flickinger JC, Lunsford LD, Maitz A, Kondziolka D. Factors associated with successful arteriovenous malformation radiosurgery. *Neurosurgery*. 1998;42(6):1239-1244.
9. Redekop G, TerBrugge K, Montanera W, Willinsky R. Arterial aneurysms associated with cerebral arteriovenous malformations: classification, incidence, and risk of hemorrhage. *J Neurosurg*. 1998; 89(4):539-546.
10. Duong DH, Young WL, Vang MC, et al. Feeding artery pressure and venous drainage pattern are primary determinants of hemorrhage from cerebral arteriovenous malformations. *Stroke*. 1998;29(6):1167-1176.
11. Miyasaka Y, Kurata A, Irikura K, Tanaka R, Fujii K. The influence of vascular pressure and angiographic characteristics on haemorrhage from arteriovenous malformations. *Acta Neurochir (Wien)*. 2000;142(1):39-43.
12. Brown RD Jr. Simple risk predictions for arteriovenous malformation hemorrhage. *Neurosurgery*. 2000;46(4):1024.
13. Batjer HH, Devous MD Sr, Seibert GB, Purdy PD, Bonte FJ. Intracranial arteriovenous malformation: relationship between clinical factors and surgical complications. *Neurosurgery*. 1989;24(1):75-79.
14. Luessenhop AJ, Gennarelli TA. Anatomical grading of supratentorial arteriovenous malformations for determining operability. *Neurosurgery*. 1977;1(1):30-35.
15. Morgan MK, Drummond KJ, Grinnell V, Sorby W. Surgery for cerebral arteriovenous malformation: risks related to lenticulostriate arterial supply. *J Neurosurg*. 1997;86(5):801-805.
16. Spears J, Terbrugge KG, Moosavian M, et al. A discriminative prediction model of neurological outcome for patients undergoing surgery of brain arteriovenous malformations. *Stroke*. 2006;37(6):1457-1464.
17. Lawton MT, Kim H, McCulloch CE, Mikhak B, Young WL. A supplementary grading scale for selecting patients with brain arteriovenous malformations for surgery. *Neurosurgery*. 2010;66(4):702-713.
18. Han PP, Ponce FA, Spetzler RF. Intention-to-treat analysis of Spetzler-Martin grades IV and V arteriovenous malformations: natural history and treatment paradigm. *J Neurosurg*. 2003;98(1):3-7.
19. Killory BD, Nakaji P, Gonzales LF, Ponce FA, Wait SD, Spetzler RF. Prospective evaluation of surgical microscope-integrated intraoperative near-infrared indocyanine green angiography during cerebral arteriovenous malformation surgery. *Neurosurgery*. 2009;65(3):456-462.
20. Katsaridis V, Papagiannaki C, Aimar E. Curative embolization of cerebral arteriovenous malformations (AVMs) with Onyx in 101 patients. *Neuroradiology*. 2008;50(7):589-597.
21. Yu SC, Chan MS, Lam JM, Tam PH, Poon WS. Complete obliteration of intracranial arteriovenous malformation with endovascular cyanoacrylate embolization: initial success and rate of permanent cure. *AJNR Am J Neuroradiol*. 2004;25(7):1139-1143.
22. Weber W, Kis B, Siekmann R, Jans P, Laumer R, Kuhne D. Preoperative embolization of intracranial arteriovenous malformations with Onyx. *Neurosurgery*. 2007;61(2):244-252.
23. Steinberg GK, Chang SD, Levy RP, Marks MP, Frankel K, Marcellus M. Surgical resection of large incompletely treated intracranial arteriovenous malformations following stereotactic radiosurgery. *J Neurosurg*. 1996; 84(6):920-928.