Classification Schemes for Arteriovenous Malformations

Jason M. Davies, MD, PhD[a], Helen Kim, PhD[b,c], William L. Young, MD[a,b,c,d], Michael T. Lawton, MD[a,c,*]

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• Grading system • Spetzler-Martin

Judicious patient selection is essential to avoid surgical complications and poor neurologic outcomes with microsurgical resection of brain arteriovenous malformations (AVMs). The wide variety of AVM anatomy, size, location, and clinical presentation makes patient selection for surgery a difficult process. Neurosurgeons have analyzed their surgical experiences to identify factors that determine the risks of surgery to assist them in this selection process. Numerous classification schemes have been developed, each with its own emphasis, accuracy, advantages, and disadvantages. Some are complex and others simple, each striving to predict surgical risk and to achieve bedside applicability. These classification schemes have value because they transform complex decisions into algorithms. In this review, the important grading schemes that have contributed to management of patients with brain AVMs are described, and our current approach to patient selection is outlined.

PRE–SPETZLER-MARTIN CLASSIFICATION SCHEMES

The first major AVM grading scheme developed by Luessenhop and Gennarelli[1] in 1977 formulated a grade from I to IV based on the number of feeding arteries for which there is standardized nomenclature. The score was determined by counting the number of tertiary arteries feeding the AVM from a single vascular territory, like the middle cerebral artery (MCA), anterior cerebral artery (ACA), or posterior cerebral artery (PCA) territory. When the AVM was supplied by multiple territories, the grade was determined by the vascular territory with the largest number of feeders. No additional grade was assigned for large AVMs with more than 4 arteries, because these lesions were deemed inoperable. There were several exceptions in this scheme: lenticulostriate vessels were counted as named arteries; choroid plexus-based AVMs were deemed grade III because they are supplied by 1 anterior and 2

[a] Department of Neurological Surgery, University of California San Francisco, 505 Parnassus Avenue, M780, San Francisco, CA 94143-0112, USA
[b] Department of Anesthesia and Perioperative Care, University of California San Francisco, 521 Parnassus Avenue, C450, San Francisco, CA 94143-0648, USA
[c] Center for Cerebrovascular Research, University of California San Francisco, 1001 Potrero Avenue, Box-1371, San Francisco, CA 94110, USA
[d] Department of Neurology, University of California San Francisco, 505 Parnassus Avenue, M798, San Francisco, CA 94143-0110, USA
* Corresponding author.
E-mail address: lawtonm@neurosurg.ucsf.edu

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posterior choroidal arteries; and corpus callosum AVMs were deemed grade II when supplied by pericallosal arteries and grade III when supplied by the PCA. The investigators made allowances for clinical status to supplement anatomic grading scale, but clear guidelines for integrating clinical and anatomic factors were lacking. Surgical results in 49 patients showed that grade I AVMs were associated with low risk, higher-grade AVMs were associated with increasing risks, and grade IV AVMs were managed nonoperatively.

Luessenhop and Rosa[2] simplified this grading scheme in 1984 by considering only the angiographic size of the AVM, which was believed to be easier than counting arterial feeders. The new grades were assigned based on nidus diameter: grade I, less than 2 cm; grade II, 2 to 4 cm; grade III, 4 to 6 cm; and grade IV, greater than 6 cm. The original classification scheme excluded AVMs in the cerebellum, brain stem, and region of the vein of Galen malformations, whereas the new scheme included cerebellar AVMs. In a surgical series consisting of 90 patients, the investigators showed low morbidity and mortality with grades I and II AVMs, and therefore recommended surgical resection for these lesions, with minimal consideration of nidus location, age, or comorbidities. The investigators recommended more conservative management of patients with high-grade lesions (grade III and IV) and careful consideration of these other anatomic and clinical factors.

Shi and Chen[3] presented an alternative classification scheme in 1986 that considered AVM size, location and depth, arterial supply, and venous drainage. Each of these 4 aspects was divided into 4 grades. Specifically, size was graded as less than 2.5 cm (grade I), 2.5 to 5 cm (grade II), 5 to 7.5 cm (grade III), or greater than 7.5 cm (grade IV). Location and depth were graded as superficial/nonfunctional (grade I), superficial/functional (grade II), deep (grade III), and deep/vital (grade IV). Arterial supply was graded as single superficial branch of MCA or ACA (grade I), multiple superficial branches of MCA or ACA (grade II), PCA branches or deep MCA or ACA branches (grade III), and branches of all 3 cerebral arteries or vertebrobasilar artery (grade IV). Venous drainage was graded as single superficial (grade I), multiple superficial (grade II), deep (grade III), and deep with variceal dilatation (grade IV). The final AVM grade was "matched to the appropriate highest grade when at least 2 criteria are in that grade," or was a mixed or intermediary grade if only one was in the highest grade. Although this classification scheme has 4 grades, this method of grading led to 6 different groupings in the investigators' surgical series of 100 patients. Excellent results were achieved in patients with grade I, I to II, and II AVMs, with increasing morbidity/mortality in patients with AVMs grade II to III, III, and III to IV. This classification scheme incorporated similar anatomic features as the Spetzler-Martin[4] scheme, but it failed to gain acceptance because of its complexity, with grading within grades and mixed final grades.

SPETZLER-MARTIN CLASSIFICATION SCHEME

In 1986, Spetzler and Martin[4] published what has become the predominant classification scheme for brain AVMs. After considering a range of factors including size, number of feeding arteries, location, operative accessibility, shunt flow, vascular steal, location, and venous drainage, these investigators settled on a simplified scheme using only size, eloquence of surrounding brain parenchyma, and venous drainage pattern. Simplicity, applicability at the bedside, and accurate outcome prediction were the investigators' principal objectives.

Each factor in the grading scale was scored independently. Size was divided into 3 categories, with small AVMs less than 3 cm assigned 1 point, medium AVMs 3 to 6 cm assigned 2 points, and large AVMs greater than 6 cm assigned 3 points. Venous drainage was considered superficial if it drained into cortical veins and convexity sinuses and assigned 0 points, or deep if it drained into veins that coursed to the vein of Galen (ie, internal cerebral veins, basal veins of Rosenthal, and precentral cerebellar vein) and assigned 1 point. AVM eloquence was assessed anatomically based on the presumed function of surrounding brain tissue, with 1 point assigned to lesions located in sensorimotor cortex, language areas, visual cortex, hypothalamus, internal capsule, brain stem, cerebellar peduncle, or deep cerebellar nuclei. AVMs not in these regions were assigned 0 points for eloquence. The final AVM grade was the sum of points across the 3 domains, with a range from I to V. AVMs that are too complex for resection, like intrinsic brain stem and holohemispheric AVMs, were deemed grade VI.

The Spetzler-Martin grading system was initially evaluated in a retrospective analysis of the investigators' surgical experience in 100 consecutive surgically resected AVMs. Outcomes were categorized as "no deficit," "minor deficit" (including temporary worsening of neurologic function, mild ataxia, or mild increase in brain stem deficit), or "major deficit" (including aphasia, hemianopsia, or hemiparesis). There were no major deficits and only 1 minor deficit in patients with low-grade AVMs (grades I and II, **Table 1**). Patients with