Reporting Terminology for Brain Arteriovenous Malformation Clinical and Radiographic Features for Use in Clinical Trials

Joint Writing Group of the Technology Assessment Committee, American Society of Interventional and Therapeutic Neuroradiology; Joint Section on Cerebrovascular Neurosurgery, a Section of the American Association of Neurological Surgeons and Congress of Neurological Surgeons; and Section of Stroke and the Section of Interventional Neurology of the American Academy of Neurology

“This if you wish to converse with me,” said Voltaire, “define your terms.” How many a debate would have been deflated into a paragraph if the disputants had dared to define their terms!

—Will Durant: The Story of Philosophy

The goal of this writing group is to provide guidelines for use in the design of clinical trials, that can aid in providing sufficient uniformity of definitions for appropriate selection and stratification of patients, as well as analysis of data. We emphasize that this document is not to be construed as a standard-of-care or intended for current routine clinical grading or classification, such as the Spetzler-Martin surgical scoring system. The reporting standards presented in this document represent an “ideal” and are intended for use in research protocols rather than in quality assessment of individual practice. The definitions represent one set of possible guidelines for constructing a reportable research data set; they are not intended to represent the only ones of importance or interest to collect in clinical trials, ie, they are not proposed as a minimally acceptable set of data.

Rather, our intent is to facilitate the production of scientifically rigorous results that are capable of being reliably compared between related studies. In some cases, the definitions used are arbitrary or operational but have been recommended by consensus of the writing group for the sake of consistency in reporting.

Evaluation and treatment of brain arteriovenous malformations (BAVMs) is often a multidisciplinary exercise involving neurosurgeons, neuroradiologists, radiotherapists, and numerous other medical specialists. A recent review by an AHA writing group has surveyed the literature to develop current guidelines for the clinical management of BAVMs. Despite these tremendous efforts to synthesize existing knowledge on this topic, there remain inconsistencies with nomenclature and definitions of terms for research purposes.

This lack of consistency in data reporting by investigators is a major challenge for progress in treatment of BAVMs. A set of well-considered definitions can allow different investigators to publish results that are directly comparable. The intent of this writing group is to formulate a set of definitions based on current practice and imaging technology that may serve as a frame of reference for future reports and of future clinical trials.

One of the major challenges to research of BAVMs is the lack of widely accepted prognostic systems other than the Spetzler-Martin scale for estimating surgical treatment risk. Systems are just being developed for radiosurgery. Design of definitive clinical trials would be aided by better understanding of the natural history and treatment risks associated with BAVMs. Careful definitions of prognostic variables and outcomes will be required in this effort. A recent study suggested a poor interobserver agreement on basic morphological attributes, emphasizing the importance of clear, simple, and reproducible definitions of terms for risk or prognostication variables. These definitions should include categories or ratings detailed enough to distinguish clinically important differences. In addition to providing some basic points of agreement between investigators, these definitions are meant to stimulate critical discussion of a set of difficult issues with regard to the anatomic and clinical classification of BAVMs. Table 1 shows an overview of the definitions.

Use of the terms that are self-referential or that presuppose mechanism, such as “cerebral steal,” are discouraged. Neuropathological signs or symptoms and angioarchitectural descriptions are preferred that are nonjudgmental in terms of mode of presentation, mechanism, or structure.

Whenever possible, we have recommended reporting continuous data rather than categorical data. For example, we recommend that BAVM sizes be reported in millimeters rather than some categorical grouping of small, medium, and large. It is always possible to go from continuous to categorical data, but it is not possible in the other direction. Many of...
the responses require multiple attributes, which is denoted as “choose all applicable.”

It is not currently known how the rare occurrence of multiple BAVMs in a single patient influences the natural history of the disease. Therefore, each lesion should be characterized separately.

Each section of clinical and radiographic features below (A1 through D6) is listed, in corresponding outline format, in Table 1. A summary of the fields and their ranges is given in Table 2.

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### A. General Definitions

An operational definition of BAVM is an abnormal tangle of vessels that results in arteriovenous shunting (nonnutritive blood flow) demonstrated by 4-vessel cerebral contrast angiography, which is generally considered the diagnostic gold standard. BAVM may coexist with other vascular disorders, such as moyamoya disease or hereditary hemorrhagic telangiectasia. BAVM does not include pure vein of Galen AVMs, cavernous malformations, dural arteriovenous fistulas (DAVF), venous malformations, venous varices, or any of the other rarer types of cerebrovascular anomalies. BAVM is the preferred and more precise term than cerebral, which excludes more caudal structures, and older and imprecise terminology such as “true” AVM or “pial” AVM (some BAVMs do not reach any pial surface). Further, “cerebral” AVM might be abbreviated as CAVM, which might lead to confusion with cavernous malformation. It is not the purpose of this writing group to make the definitive definition of BAVM (a set of attributes that all BAVMs and only BAVMs possess), and there will continue to be cases of mixed lesions, which defy classification into a simple scheme.

### A.1. Clinical Presentation

**Comment**

Clinical presentation is obtained from the neurological history. It is the clinical picture of the event that brought the patient to a medical encounter that directly led to the discovery of the BAVM. The clinical presentation should be temporally related to the imaging study (see below), which confirms the presence or absence of bleeding. Each component can be answered in either a yes or no fashion. It should always be clear in reporting whether hemorrhage was part of the initial presentation, whether or not other signs and symptoms were present. For this reason, each of the presentation categories should have a response.

**Incidental**

Presentation would refer to a clinical presentation that was clearly unrelated to the BAVM regarding the indication for imaging. e.g., blunt head trauma after a motor vehicle accident. *Hemorrhage* refers to bleeding into the brain or its surrounding spaces. *Seizure* refers to any type of partial or generalized seizure activity. *Focal neurological deficit* refers to a deficit that may or may not be related to seizure or hemorrhage. *Other* would refer to other precipitating signs or symptoms leading to the discovery of the BAVM that may be related to the presence of the lesion, such as a bruise.

Of all of the presenting signs and symptoms, headache is the most subjective. It deserves some special mention because it is not at all clear what percentage of headaches are actually related to the BAVM. It may be worthwhile detailing the nature of the headache in terms of sudden, new-onset, change in frequency or character as opposed to chronic, unchanged headaches.
**TABLE 2. Proposed Fields and Ranges, A1–D6**

**A. General definitions**

A.1. Clinical presentation

Choose all applicable (yes/no):
- Incidental
- Hemorrhage
- Seizure
- Focal neurological deficit
- Headache
- Other

A.2. Date of presentation (date)

A.3. Imaging source and date (date)

**B. Location and size**

B.1. Lesion side

- Right
- Left
- Midline

B.2. Handedness

- Right
- Left
- Ambidextrous

B.3. BAVM size (integer; mm)

B.4. BAVM location

Choose all applicable:
- Cortical
- Subcortical
- Ventricular
- Corpus callosum
- Frontal
- Temporal
- Parietal
- Occipital

B.5. BAVM eloquence

Choose all applicable:
- NOT eloquent
- Sensorimotor cortex
- Visual cortex
- Language cortex
- Thalamus/hypothalamus/basal ganglia

B.6. BAVM border with adjacent brain

- Compact (sharp)
- Diffuse

B.7. BAVM hemorrhage

B.7.1. Evidence of NEW BAVM hemorrhage (yes/no)

B.7.2. Age of NEW BAVM hemorrhage (integer; day)

B.7.3. Is NEW BAVM hemorrhage symptomatic? (yes/no)

B.7.4. Evidence of OLD BAVM hemorrhage (yes/no)

B.7.5. Age of OLD BAVM hemorrhage (integer; mo)

B.7.6. Was OLD BAVM hemorrhage symptomatic? (yes/no)

B.7.7. Hemorrhage location

Choose all applicable:
- Ventricular
- Parenchymal
- Subarachnoid

B.7.8. Hemorrhage size (integer; mm)

**C. Venous drainage**

C.1. Superficial vs deep venous drainage

- Both superficial and deep
- Superficial only
- Deep only

C.2. Periventricular drainage (yes/no)

C.3. Number of draining veins leaving nidus (integer; count)

C.4. Number of veins reaching sinus (integer; count)

C.5. Venous stenosis/occlusion (integer; percentage, where 100% = occlusion)

C.6. Venous ectasia (dilatation) (yes/no)

C.7. Venous reflux (yes/no)

C.8. Sinus thrombosis/occlusion (integer; percentage, where 100% = occlusion)

**D. Arterial supply**

D.1. Feeding arteries

Choose all applicable:
- Anterior choroidal a.
- Posterior choroidal a.
- Anterior cerebral a. cortical branches
- Superior cerebellar a.
- Anterior cerebral a. penetrators
- Anterior inferior cerebellar a.
- Middle cerebral a. cortical branches
- Posterior cerebral a. cortical branches
- Middle cerebral a. penetrators
- Frontal
- Posterior cerebral a. penetrators
- Parietal
- Other a.

D.2. Arterial aneurysms

D.2.1. Number of arterial aneurysms (integer; count)

D.2.2. Arterial aneurysms location

Pick all applicable to any aneurysm:
- Flow-related
- Proximal
- Not flow-related
- Distal
- Nidal

D.2.3. Arterial aneurysms hemorrhagic history (yes/no)

D.2.4. Arterial aneurysms hemorrhagic (date)

D.3. Number of vessels to be embolized (integer; count)

D.4. Moyamoya-type changes (yes/no)

D.5. Pial-to-pial collateralization

Choose all applicable:
- Same territory
- Between territories
- None

D.6. Intravascular pressure measurements (integer; mm Hg)
Rationale

Because hemorrhage is the most important presentation of AVMs, both in terms of occurrence as well as morbidity, a clear dichotomy between hemorrhagic and nonhemorrhagic presentations should be made. Evidence exists that prior bleeding increases the risk of subsequent hemorrhage, but this has not been incontrovertibly demonstrated, and there are data that suggest no influence of initial presentation on subsequent hemorrhage rate. Incidental presentation is also particularly important, as there may be a trend toward detecting more asymptotic lesions with the increasing availability of tomographic brain imaging.

A. Location and Size

B. Date of Presentation

Comment

The date of presentation (DOP) is defined as the date on which the patient experienced signs or symptoms that led, as a proximate cause or instigation, to medical evaluation resulting in definitive diagnosis of BAVM. DOP may not be synonymous with date of evaluation but should be logically and temporally related.

Example

Patient presents with a grand mal seizure on January 1. Evaluation by primary care physician on January 8 leads to CT scan, which confirms a structural lesion. MRI on January 9 strongly suggests the presence of BAVM. Four-vessel cerebral contrast angiography on January 23 confirms diagnosis. DOP is January 1.

Related concepts would include “index date” and “diagnosis date.” The index date would be the medical encounter through which the “date of presentation” was learned (January 8 in the example above). The diagnosis date would be January 23.

Rationale

Date of presentation is necessary to assess natural history aspects of lesion. It is also used to calculate age at presentation, which may be associated with both natural history and treatment risks. There is commonly a time lag between the date of presentation and definitive diagnosis of BAVM.

A.2. Date of Presentation

Comment

The imaging source and date (IS&D) of the CT, MRI, MRA, 4-vessel diagnostic cerebral angiography, superselective cerebral angiography, etc, nearest in time to the patient’s presentation should be reviewed.

Rationale

Anatomic information may be dependent on the imaging modality used to obtain it. The most obvious example would be BAVM size that can be estimated by angiography or MRI. MRI will tend to overestimate size of the nidus because adjacent arterial and venous structures may not be adequately delineated from the true nidus (BAVM size is broken out into both because of its central importance to risk assessment; see below).

The source of the data collected can introduce other bias, possibly unknown, into the interpretation. IS&D is important to note because there may be significant differences in the times of obtaining multiple imaging modalities.

B. Location and Size

B.1. Lesion Side

Comment

Side refers to BAVM location in the brain when the lesion is located exclusively on one side or other. If the BAVM involves a midline structure bilaterally, it would be classified as midline. If there were multiple AVMs, each one would be described separately.

Rationale

Side of lesion will influence treatment risk in some cases with lesions in the dominant hemisphere.

B.2. Handedness

Comment

Handedness is obtained from the neurological history.

Rationale

An estimation of hemispheric dominance can be gleaned, potentially influencing treatment risk.

B.3. BAVM Size

Comment

Size, measured in millimeters, is ideally recorded from 2 sources: both MRI and angiography (Figures 1 and 2). The size, in 3 dimensions, is measured on the pretreatment MRI in sagittal, coronal, and axial views, which includes the BAVM’s largest diameter. If the 3-dimensional geometry is such that the longest axis is misrepresented by L×W×H measurements in the standard projections, then the dimensions can be inferred from the slice thickness and “stacking” multiple levels in the standard projections (Figure 3).

The size in 3 dimensions is measured on the pretreatment angiogram in lateral and anteroposterior projections, or in whatever additional projections are available that include the BAVM’s largest diameter. Sizing markers can be placed on both sides of the head during angiography, but magnification errors with angiography must be carefully considered.

From these dimensions, a calculation can be made to estimate BAVM volume in milliliters with the ABC/2 formula.

Rationale

BAVM size may be an important element of risk assessment for natural history risk. Larger dimension is especially important because it appears to have the strongest correlation with hemorrhagic presentation, given multiple dimensions.

It is definitely a risk factor or treatment risk, both for surgery and radiosurgery. Although BAVM can usually be estimated from standard views on MRI and angiography, if the longest axis cannot be obtained, then the dimensions can be estimated as described above.
B.4. BAVM Location

Comment
Anatomic locations are for general grouping purposes. The brain location (topographic location) may be distinct from the vascular supply location. There is considerable overlap with “eloquence.” Multiple sites are possible.

Rationale
Certain areas may have different treatment risk (also covered under “eloquence”) and natural history risk. 3,13,25,26

Axial
Sagittal
Coronal

Figure 1. Determination of BAVM size from A-P (anteroposterior) and lateral cerebral angiography.

B.5. BAVM Eloquence

Comment
Language cortex is defined as left hemisphere unless additional clinical data suggest otherwise. The locations listed are primarily as per the Spetzler-Martin score,1 the only difference being the addition of “thalamus/hypothalamus/basal ganglia” and “other eloquence.” Multiple sites are possible. Although we have not added it to the list, the question was raised of whether nondominant parietal lobe should be considered eloquent, as visuospatial deficits may be underrecognized but disabling.

Rationale
Eloquence of adjacent tissue is a critical piece of information for treatment planning. The Spetzler-Martin score is the most widely used system in current practice. Unfortunately, it reflects anatomic considerations only. Ideally, there would be some validated sensitive and specific indicator of eloquence, ie, functional MRI testing or positron emission tomography. Until such means are routinely available, the anatomic method is simple and reproducible at the expense of precision and accuracy.

The operational definition proposed above is recommended despite the fact that true function can only be known by some type of pharmacological, physiological, or neurological provocative testing. Particularly in the case of AVMs, function may reside in nonclassic locations.27–29 If eloquence has been determined physiologically by functional MRI, Wada testing, or brain mapping, this information can be reported whenever possible. The same would apply to clues to altered functional anatomy that may have become apparent from either the natural history or response to treatment, eg, a
bleed or a resection resulting in an unexpected neurological deficit.

**B.6. BAVM Border With Adjacent Brain**

*Comment*
MRI islands or peninsula of normal brain tissue within the BAVM nidus protruding into what is surgically or radiosurgically treatable BAVM nidus, as opposed to sharply demarcated border with neighboring parenchyma (Figure 4).

*Rationale*
The border with adjacent brain may have implications for surgical resection and response to radiosurgery.

**B.7. BAVM Hemorrhage**

**B.7.1. Evidence of NEW BAVM Hemorrhage**

*Comment*
Evidence of NEW BAVM hemorrhage is noted if there appears to be blood products on MR or CT likely to be associated with BAVM presentation.

**B.7.2. Age of NEW BAVM Hemorrhage**

*Comment*
The age of the hemorrhage is estimated in number of days.

**B.7.3. Is NEW BAVM Hemorrhage Symptomatic?**

*Comment*
The imaging evidence should be consistent with the patient’s clinical presentation. The main criterion for symptomatic is a direct temporal relationship to the indication for imaging.

**B.7.4. Evidence of OLD BAVM Hemorrhage**

*Comment*
Evidence of OLD BAVM hemorrhage includes all instances of CT or MR evidence of bleeding that is NOT temporally related to imaging for current signs and symptoms. In addition to such blood of indeterminate age, it would also include indirect evidence of old hemorrhage, ie, encephalomalacia adjacent to the lesion consistent with a prior hematoma, as well as hemosiderin found incidentally at microsurgical resection.

**B.7.5. Age of OLD BAVM Hemorrhage**

*Comment*
Estimate age of hemorrhage in months; if >1 year, choose “12.”

**B.7.6. Was OLD BAVM Hemorrhage Symptomatic?**

*Comment*
Is the imaging evidence of old BAVM hemorrhage consistent with any prior symptoms (transient focal neurological abnormalities, prior seizure of any type with no other known precipitating causes) or not related to any known prior symptoms or events?

*Rationale*
The writing group recognizes that the relationship of imaging signs of hemorrhage may be a difficult judgment, as many lesions have bled silently as evidenced by hemosiderin deposits seen during microsurgical resection. Nonetheless, it is a judgment that investigators must make in order to define the clinical behavior of a class of lesions that may be at higher natural history risk. “Unknown” may be appropriate to this categorization.

**B.7.7. Hemorrhage Location**

**B.7.8. Hemorrhage Size**

*Comment*
The hemorrhage size is recorded in millimeters using the same guidelines as for BAVM size. From these dimensions, a calculation can be made to estimate intraparenchymal hemorrhage size in ml using the ABC/2 formula of Rashmi et al.

*Rationale*
The anatomic site of bleeding may be important for the pathophysiologic consequences of the blood products that remain extravascular, ie, subarachnoid; or in terms of potential for interruption of tissue function, ie, parenchymal versus intraventricular.

**C. Venous Drainage**

*Comment*
The writing group recognizes that descriptions of the complex venous drainage of many BAVMs may defy simple rules. A large number of systems have been proposed, especially in terms of hemorrhagic risk, but it is clear that abnormalities in venous drainage are strongly associated with hemorrhagic events.
C.1. Superficial Versus Deep Venous Drainage

Comment
The definition proposed by Spetzler and Martin is recommended (Figure 5, panel A). Superficial drainage is considered present “if all the drainage from the BAVM is through the cortical venous system. The venous pattern is considered deep if any or all of the drainage is through deep veins (such as the internal cerebral veins, basal veins, or precentral cerebral vein). In the posterior fossa, only cerebellar hemispheric veins that drain directly into the straight sinus, torcula, or transverse sinus are considered to be superficial.”

Rationale
Abnormalities of venous drainage directly affect the propensity for spontaneous rupture and relate to surgical and radiosurgical risk.

Whereas any deep venous drainage appears to increase risk for microsurgical resection, there is evidence that exclusively deep venous drainage may increase risk of spontaneous hemorrhage in the natural course. Therefore, identifying the separate components (deep versus superficial) may have utility in differentiating treatment versus natural history risks.

C.2. Periventricular Drainage

Comment
Sometimes termed subependymal, periventricular venous drainage refers to venous drainage that is distinct from other deep venous drainage into the Galenic system; internal cerebral vein; basal vein of Rosenthal; superficial cerebellar veins (Figure 5, panel B). In the rare instance where periventricular draining veins egress into a superficial sinus, this should still be a “yes” response.

Rationale
Periventricular drainage may represent a lower risk in the natural history if bleeding can egress into the ventricular system. It may, however, also increase risk if these structures are more fragile or under higher pressure. Presence of periventricular drainage may indicate increased surgical risk because these lesions may be larger and transcortical. Periventricular location of the nidus may also be important for natural history.

C.3. Number of Draining Veins Leaving Nidus

Comment
The number of discrete venous channels that actually leave the nidus should be reported (Figure 5, panel C).
Rationale
The number of draining veins appears to be inversely related to venous pressure.20,32,34,38–40

C.4. Number of Veins Reaching Sinus
Comment
The number of draining veins are counted which reach any of the following sinuses: superior sagittal, straight, transverse, sigmoid, cavernous, superior petrosal or inferior petrosal (Figure 5, panel C). Veins draining into any parasitized sinuses such as occipital or marginal sinuses may be included in this count.

Rationale
Counting the number of veins reaching any venous sinus is a method to simplify the complex venous anatomy, and appears to be correlated with hemorrhagic risk,20 similar to “number of draining veins leaving nidus.”

C.5. Venous Stenosis/Occlusion
Comment
Venous stenosis/occlusion is defined as narrowing of any draining vein outflow pathway in two angiographic views (Figure 5, panel D). The venous outflow tract immediately proximal is used as the denominator in this relative index. If there is nonuniformity of venous caliber, the draining vein’s diameter at the exit from the nidus should be used. Percent stenosis is therefore equal to the narrowest diameter of the vein (measured in millimeters) divided by the largest diameter of the vein just proximal to the stenosis (measured in millimeters).

Rationale
Venous stenosis/occlusion appear to be associated with hemorrhagic presentation.41

C.6. Venous Ectasia (Dilatation)
Comment
Because “venous stenosis/occlusion” may miss various patterns of venous caliber change, an additional relative index is proposed (Figure 5, panel D). “Venous ectasia” is any change in venous caliber in the venous runoff or drainage from the BAVM, with a >2-fold caliber change in any draining venous channel.

Rationale
Venous ectasia may be associated with hemorrhagic presentation.31 This general marker of venous irregularity will identify lesions that might be difficult to quantitate in terms of stenosis because of nonuniformity of draining vein caliber.

C.7. Venous Reflux
Comment
Reversal of flow in any venous outflow pathway in a direction other than the normal pathway, which is defined as toward the closest venous sinus (Figure 5, panel E).

Rationale
Venous Reflux may be associated with hemorrhagic presentation.31

C.8. Sinus Thrombosis/Occlusion
Comment
Defined as a filling defect in a dural venous sinus that could be thrombosis or occlusion and excludes arachnoid granulations.

Rationale
Abnormalities in venous drainage appear to be associated with hemorrhagic presentation and venous hypertension.

D. Arterial Supply
D.1 Feeding Arteries
Comment
A feeding vessel is defined as an arterial structure that angiographically demonstrates a contribution of flow (as evidenced by contrast opacification) to the arteriovenous shunt. Feeding arteries may be parent arteries that give rise to vessels that directly or indirectly supply flow to the BAVM. Multiple vessels are possible. Penetrators (perforators) refer to vessels that are normally end arteries; branches refer to other named or unnamed branches that normally go on to divide further.

Rationale
The arterial anatomy may be associated with several aspects of natural history risk (many territories suggesting recruitment of new inflow and low pressure)25 or increased treatment risk (involvement of deep perforating arteries that increase risk of microsurgical resection).

D.2 Arterial Aneurysms
Comment
Flow-related is an operational term describing an aneurysm which lies on an pathway that carries nonnutritive blood flow (contrast) supplying the BAVM shunt (Figure 6, panels A and B). Aneurysms are defined as saccular luminal dilatations of the parent feeding vessel. “Nidal” is defined as contiguous with the vascular mass included in the BAVM size measurement (Figure 1), but the aneurysm may extend past the margin of the actual measured BAVM mass (Figure 6, panel C).

For location, “proximal” versus “distal” refers to the circle of Willis. “Proximal” aneurysms would be located on the vessel or branch points of the circle of Willis or proximal to it, and include the internal carotid arteries; anterior and posterior communicating arteries; first portions of the anterior (A1) or posterior cerebral (P1) arteries; basilar arteries; or vertebral arteries (panel C). “Distal” refers to other more distal locations that are beyond the circle of Willis (panel D).

D.2.1. Number of Arterial Aneurysms
D.2.2. Arterial Aneurysms Location
Rationale
Arterial aneurysms are recognized to have the propensity to rupture and bleed, including those associated with BAVMs.21,25,33,42 There is some controversy whether the
initial presentation or rebleeding rate is affected by the presence of aneurysms and there is still an evolving understanding of unruptured aneurysms. The main distinction is between arteries which are presumably exposed to higher flow rates than normal (termed flow-related aneurysms) and those that are not.

**D.2.3. Arterial Aneurysms Hemorrhagic History**

**Comment**
Has the patient ever bled from any of the aneurysms that could be localized as a source of hemorrhage other than the BAVM?

**Rationale**
Although with distal and nidal aneurysms it may not be possible to differentiate the source of BAVM versus aneurysmal hemorrhage, it may be possible with locations that are more distant from the nidus (more proximal or in a different, neighboring circulation). This item is recommended to be recorded because it addresses the question of whether a BAVM that presents with an aneurysmal subarachnoid hemorrhage is incidental or not. If the aneurysm is intranidal, then most would agree that it would NOT be incidental. If the aneurysm was in the contralateral hemisphere, one might consider the discovery of the BAVM to be incidental. The closer a symptomatic aneurysm is to the BAVM nidus, the less clear this “incidental” versus “hemorrhagic” distinction becomes. Hence, by recording this information, future studies might determine more precisely how the natural history of associated aneurysmal bleeds is related to the natural history of BAVM bleeds.

**D.2.4. Arterial Aneurysms Hemorrhagic Date**

**Comment**
If the patient has ever bled from any of the aneurysms, give first and subsequent dates.

**D.3 Number of Vessels to Be Embolized**

**Comment**
This is a priori assessment of how many arterial pedicles will be cannulated and then embolized (Figure 7).

**Rationale**
The type of endovascular therapy may vary with the embolic agent and may influence the choice of number of vessels to be...
treated. Nevertheless, risk of treatment-related complications may be related to the degree of instrumentation and navigation of the cerebral vasculature. By estimating the number of feeding vessels to be treated, some prospective index of procedure-related risk may be obtained.

D.4 Moyamoya-Type Changes
Not exclusively moyamoya disease, rather this is a pattern of angiographic changes that suggest occlusion or near-complete stenosis of associated feeding arteries. This pattern includes recruitment of collateral supply to compensate for the occluded or stenotic arterial segment. A more precise but unwieldy nomenclature would be “collateral small vessel recruitment due to distal feeding vessel arteriopathy with stenosis or occlusion.”

Rationale
This angiographic pattern suggests a unique vascular biologic response that might be intuitively associated with a differing type of clinical behavior.

D.5 Pial-to-Pial Collateralization

Comment
Recruitment of neighboring pial-to-pial collaterals not considered part of the BAVM nidus (target for radiosurgery, resection or embolization; Figure 8). This may be either between or within long circumferential territories. For example, it might be collateral recruitment at a borderzone between branches of the middle cerebral artery (MCA) and posterior cerebral artery (PCA) or between adjacent territories of one artery, such as between parietal branches of MCA.

Rationale
Pial-to-pial collateralization is associated with decreased pressure in feeding arteries, and there is evidence that size and pressure are related. The distinction is made for “between territories” and “within territories” because it may be related to the degree of pressure reduction in the nidus and, for example, may be an indirect indicator of hemorrhagic risk.

D.6 Intravascular Pressure Measurements

Comment
Some groups have used intravascular cerebral pressure measurements for both research and clinical purposes. Pressure measurements, however, should not be construed as a standard of clinical care.

If pressures are measured in a particular practice or protocol, it is probably most meaningfully obtained during the patient’s initial superselective angiography session, the first embolization prior to the injection of any embolic material or during surgery if no previous embolization has been performed. In this way the physiological measurement will be more indicative of the natural history before any treatment effect may interact with the hemodynamic state of the BAVM.

Pressure measurement has been described for both intraoperative direct puncture of vessels and endovascular measurement through microcatheters. The reader is referred to these references for technical details but a few points can be mentioned in brief.

The pressure transducer system should be zeroed and calibrated taking into account any difference between the height of the head above the right atrium. This is primarily an issue for microcatheter rather than direct needle punctures. For example, during transfemoral angiography, a calibration pressure can be obtained as the microcatheter is passed through the coaxial or guiding catheter in the neck (Figure 9, panel A). Simultaneous pressures can be recorded with the tip of the microcatheter visualized approximately 1 cm past the orifice of the guiding catheter. This should give equivalent pressures in both the guiding catheter and microcatheter, thus verifying the integrity of the transducer system.

Feeding artery pressure can be measured at a point distal to which there are no nutritive vessels (panel B). For example, this might be the point at which embolic material would be injected. Free flow of contrast should indicate that the catheter tip is not wedged. Pressures are recorded in millimeters of mercury, relative to the right atrium as the zero level for atmospheric pressure.

Rationale
Increased feeding artery pressure has been associated with hemorrhagic presentation. If and when it is validated as a predictor of future hemorrhagic risk, intravascular
pressure measurement may be an attractive variable to use as a risk factor because, like BAVM size, it is theoretically obtainable in all patients as a continuous value, making generation of statistical models more effective.

There are several unresolved issues related to pressure measurements that suggest their use primarily for research purposes, rather than patient-specific clinical use. For example, if there are several measurements possible, which pressure should be reported? These will have to be worked out in future studies. Most previous studies that have examined hemorrhagic risk and pressure measurement have looked at either the lowest, initial pretreatment pressure from endovascular procedures or the first and presumably only intraoperative arterial puncture.

A surrogate for intravascular pressure, intravascular contrast transit time, has also been described. Transit-time methods, for both contrast angiography and MR techniques, may offer a means of estimating distal cerebral pressures without the need for intracranial catheter navigation. Further validation of such noninvasive methodologies may make intravascular pressure estimation more widely applicable.

Summary
We wish to emphasize that these definitions span a broad range of possibly relevant clinical and radiographic parameters to be considered in research studies. We do not endorse these guidelines as “minimal criteria” for all reporting of research data related to BAVMs. For example, some of the angioarchitectural features described herein are based on reasoned speculation. Additionally, some features may be relevant to a given research question, but not relevant to others.

These operational definitions have been chosen by consensus of the writing group for the sake of consistency in reporting clinical trials and observational studies. They are intended for use in research protocols. These definitions can allow different groups to publish results that are directly comparable.

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The writing group consisted of the following contributors: Richard P. Atkinson, MD (Mercy Healthcare, Sacramento, Calif); Issam A. Awad, MD (Yale University School of Medicine, New Haven, Conn); H. Hunt Batjer, MD (Northwestern University, Chicago, Ill); Christopher F. Dowd, MD (University of California, San Francisco); Anthony Furlan, MD (The Cleveland Clinic Ohio); Steven L. Giannotta, MD (University of Southern California, Los Angeles, Calif); Camilo R. Gomez, MD (University of Alabama, Birmingham); Daryl Gress, MD (University of California, San Francisco); George Hademenos, PhD (The American Heart Association National Center, Dallas, Tex); Van Halbach, MD (University of California, San Francisco); J. Claude Hemphill, MD (University of California, San Francisco); Randall T. Higashida, MD (University of California, San Francisco); L. Nelson Hopkins, MD (State University of New York at Buffalo); Michael B. Horowitz, MD (University of Pittsburgh [Pa]); S. Claiborne Johnston, MD, MPH (University of California, San Francisco); Michael T. Lawton, MD (University of California, San Francisco); Michael W. McDermott, MD (University of California, San Francisco); Adel M. Malek, MD, PhD (Brigham and Women’s Hospital, Boston, Mass); J.P. Mohr, MD (Columbia University, New York, NY); Adnan I. Qureshi, MD (State University of New York at Buffalo); Howard R. Rina, MD (Barrow Neurological Institute, Phoenix, Ariz); Wade S. Smith, MD, PhD (University of California, San Francisco); John Pile-Spellman, MD (Columbia University, New York, NY); Robert F. Spetzler, MD, F.A.C.S. (Barrow Neurological Institute, Phoenix, Ariz); Thomas A. Tomisz, MD (University of Cincinnati [Ohio]); and William L. Young, MD (University of California, San Francisco).

References


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