Stereotactic Radiosurgery Guideline for the Management of Patients with Intracranial Arteriovenous Malformations

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Abstract

Our objective was to provide guidelines about the use of stereotactic radiosurgery in symptomatic patients with imaging-identified arteriovenous malformations (AVMs) of the brain. We reviewed evidence-based medicine and clinical experience with radiosurgery for AVM of the brain to develop guidelines and provide scientific foundation for patients and physicians. Major recommendations include the definition of AVM patients suitable for various management strategies ranging from observation to surgical excision to endovascular embolization and stereotactic radiosurgery. The optimal dose range for volumetric conformal AVM stereotactic radiosurgery has been largely established based on location and volume of the AVM. The relationship to prior embolization or prior surgery has been evaluated. The role of repeat radiosurgery has been assessed for those patients with incomplete obliteration of their AVM after 3 years have elapsed. The causes of failure of stereotactic radiosurgery have also been identified. A clinical algorithm for the potential role of stereotactic radiosurgery for a symptomatic brain AVM was defined. The guidelines provide a framework for professional judgment and treatment selection alternatives.

Once identified, arteriovenous malformations (AVMs) may be suitable for 1 or more of 4 management strategies: observation, endovascular embolization, surgical excision or stereotactic radiosurgery [1–5]. AVM management depends on the risk of subsequent hemorrhage, which is determined by the anatomical (magnetic resonance imaging, MRI, and angiography), historical and demographic features of the individual patient [6]. Young age, prior hemorrhage, small AVM size, deep venous drainage and high flow may make subsequent hemorrhage more likely. Observation may be most appropriate for large-volume AVMs (average diameter 4–5 cm), especially for patients who have never bled. Studies of the natural history of AVMs suggest an annual hemorrhage rate of 2–4% with an annual 1% mortality rate from AVM bleeding. A second strategy is endovascular embolization, which is often used as an adjunct preceding surgical removal of the AVM via craniotomy and at times before stereotactic radiosurgery [7–12]. Other
vascular anomalies may be associated with AVMs including the presence of proximal intracranial or intranidal aneurysms. Such aneurysms may pose additional risk factors to patients. Surgical management is an option for patients with resectable AVMs, although incomplete surgical removal may prompt eventual radiosurgery. Embolization prior to radiosurgery is thought to be beneficial in some cases, but in other cases may lead to less reliable recognition of the target volume suitable for radiosurgery. Recanalization of embolized AVM components may require subsequent retreatment for portions of the AVM previously thought to be occluded by successful embolization. Stereotactic radiosurgery is considered for patients with unresectable AVMs.

Although there are several published reports on long-term outcomes after AVM radiosurgery [13–20], no guidelines are available for medical professionals to make an evidence-based decision. We developed a radiosurgery practice guideline that provides treatment recommendations for use by medical and public health professionals as well as patients with the diagnosis of brain or dural AVM.

Methods

Computerized searches of published literature (primary sources), hand searches of published literature (secondary sources) and searches of electronic clinical databases were performed. Medline and Pubmed searches were completed for the years 1971 to March 2011. Search terms included 'arteriovenous malformation,' 'AVM,' 'vascular malformation,' 'stereotactic radiosurgery.' Bibliographies from recently published reviews were reviewed and relevant articles were retrieved.

Outcomes Considered

Total obliteration of the AVM within 3 years was the primary end point of interest. Additional outcome end points included resolution or an improvement in seizure disorders if present, resolution or reduction in vascular headache syndromes, prevention of bleeding risks from the AVM (estimated to vary between 1 and 10% per year depending upon prior bleeding history, location and volume). Improvement in the existing neurological deficits, maintenance of quality of life, employability and prevention of adverse radiation effects were also considered.

Major Recommendations

Patient Selection

- Patients with intracranial AVM defined by modern neurodiagnostic imaging, including computed tomography (CT), MRI and cerebral angiography, should be considered for radiosurgery, surgical removal and endovascular embolization. AVM patients typically present with one or more of the following: brain
hemorrhage (especially when located in deep anatomical locations of the brain), persistent seizures, vascular headaches or progressive neurological deficits.

- The selection of patients suitable for various management strategies is dependent on prior bleeding history, age of the patient, existing comorbidities, anatomical location and clinical history.
- Some patients may have had prior intracranial surgery for blood clot (hematoma) evacuation or partial AVM resection. The safe interval between surgery and stereotactic radiosurgery is not known, but it is reasonable to perform radiosurgery once the patient has achieved a stable neurological recovery or plateau (generally within 2–3 months after the intracranial hemorrhage or prior surgery).
- Some AVM patients will have been previously treated by embolization for volumetric reduction or flow reduction. The optimal time between prior embolization and radiosurgery is not known, but generally waiting for a period of several weeks is considered beneficial in order to reduce the likelihood of vascular ischemic complications or residual cerebral edema sometimes associated with embolization followed by early radiosurgery.

**Treatment/Management**

- AVMs are considered suitable for 4 management strategies alone or in combination: observation only, surgical excision, endovascular embolization (designed to reduce either a selected volume or flow through the AVM) and stereotactic radiosurgery.
- Stereotactic radiosurgery is typically employed alone but may also be employed in combination with prior surgery or embolization in selected circumstances [21]. Patients who undergo single-stage stereotactic radiosurgery most often have AVMs with an average diameter of 3 cm (0.1–10 cm³). Prospective stereotactic radiosurgery volumetric staging is frequently performed for symptomatic patients with AVM volumes of 10–15 cm³ in the absence of other acceptable risk management strategies [22].

**Imaging for Radiosurgery**

- High-resolution stereotactic MR images supplemented by cerebral angiography are optimal for dose planning (fig. 1). Some centers use CT angiograms instead of cerebral angiography.
- Aneurysms within the AVM or on feeding arteries may be identified occasionally. Intranidal aneurysms may increase the annual bleeding rate of an AVM, but the recognition of intranidal aneurysms is highly subjective. Patients with aneurysms proximal to the AVM should be considered for either clipping or coiling to prevent hemorrhage from aneurysm during the latency interval after AVM management. Although there is no consensus on the timing of coiling or clipping, our preference is to perform AVM radiosurgery first in order to reduce the impact of MR artifacts produced by clips or coils – if it is unclear what vascular anomaly bled.
Dose Selection
- The optimal dose range for volumetric conformal stereotactic AVM radiosurgery has been largely established based on location and volume of the AVM. Doses at the margin of the AVM typically range from 16 to 25 Gy in a single fraction, when the 3-dimensional volume of the AVM is defined by stereotactic guidance during the procedure itself [23–25]. Stereotactic volumetric axial plane imaging (MRI or CT) supplemented by conventional or digital subtraction angiography is usually necessary for complete conformal dose planning. AVM obliteration rates are significantly improved when the AVM marginal dose is ≥18 Gy.
- Dose selection depends on location, volume, estimated adverse radiation risks, preexisting neurological conditions and bleeding history. Depending upon the technology used, the margin of the AVM dose is usually 50–70% of the central target dose within the AVM. A sharp fall-off of the radiation dose outside of the target volume is required.

Medical Management
Patients usually receive a single dose (40 mg) of methylprednisolone at the conclusion of the radiosurgery procedure. They can continue to take their other medications (e.g. antiepileptics, analgesics) during and after the procedure as recommended by their physicians.