Arteriovenous Malformation

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1.1 General Principles of Simulation and Target Definition

- The goal of cerebral arteriovenous malformation (AVM) stereotactic radiosurgery (SRS) is nidus obliteration to eliminate the risk of intracranial hemorrhage.
- AVM SRS is typically performed in a single fraction using a stereotactic head frame for patient immobilization.
- The target volume for arteriovenous malformation (AVM) stereotactic radiosurgery (SRS) is the nidus, excluding the feeding arteries and draining veins (Fig. 1.1).
- Two factors must be remembered when considering the dosimetric parameters of AVM SRS. First, AVM are congenital lesions and do not invade the surrounding brain parenchyma. Thus, increasing the target volume by several millimeters to encompass disease spread that cannot be imaged is not needed or desirable (GTV=CTV). Second, there is often wide variability in defining the nidus volume between different observers. Therefore, conformality indices do not apply well to the radiosurgical treatment of cerebral AVM.

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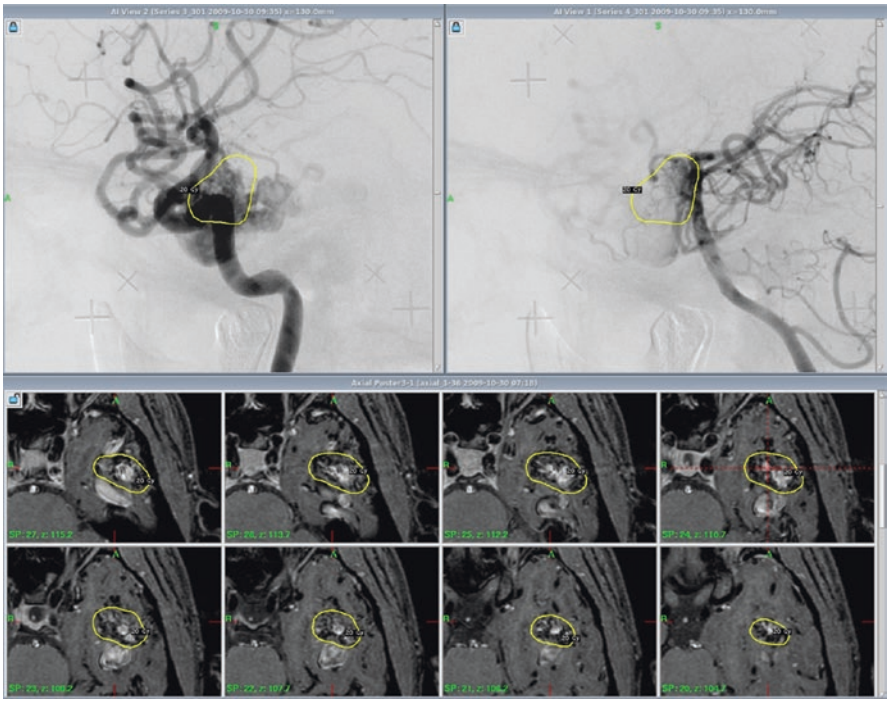

Fig. 1.1 Dose planning for a 29-year-old man with a left temporal AVM who presented with headaches. The volume treated was 3.8 cm^3; the AVM margin dose was 20 Gy. Note the treatment volume excludes the adjacent draining veins

- Catheter-based cerebral angiography remains the gold standard for accurate definition of the AVM by showing not only the nidus shape but also the temporal filling of nidus relative to angiomatous feeding arteries and draining veins. In addition, angiography also shows coexisting abnormalities such as feeding artery and intra-nidal aneurysms.
- The addition of axial imaging, typically gadolinium-enhanced SPGR or T2-weighted MRI allows a better understanding of the three-dimensional shape of the AVM increasing the conformality of dose planning.

1.2 Dose Prescriptions

- Increasing radiation dose directly correlates with the chance of AVM obliteration [1, 2]. The rate of obliteration ranges from 60 to 70% for AVM margin doses of 15–16 Gy, from 70 to 80% for AVM margin doses of 18–20 Gy, and 90% or more for AVM margin doses over 20 Gy.

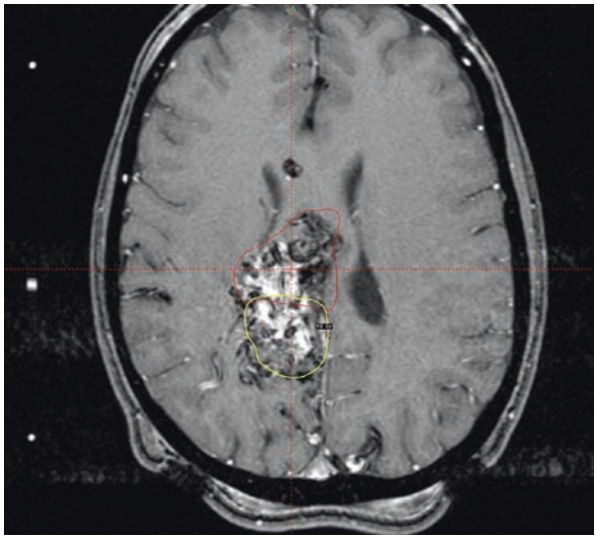

Fig. 1.2 Dose planning for a 43-year-old woman who had an intraventricular hemorrhage and was found to have a large right-sided AVM involving the corpus callosum and frontal and parietal lobes. The AVM was treated with volume-staged SRS using two stages to cover a total volume 19.9 cm^3. The anterior portion was covered during the first SRS, and the posterior portion was covered during the second SRS. The AVM margin dose was 16 Gy

- While higher radiation doses increase the chance of obliteration, the likelihood of adverse radiation effects (ARE) also rises at higher radiation doses and larger AVM volume [3–5]. Patients with deeply located AVM are at greater risk for neurologic deficits secondary to imaging changes noted on MRI after SRS.
- To account for the conflicting goals of increased obliteration while minimizing the chance of ARE, small-volume AVM (≤4.0 cm^3) are generally prescribed margin doses of 20–25 Gy, medium-volume AVM (4–10 cm^3) are prescribed 18–20 Gy, and larger volume AVM (>10 cm^3) are prescribed 15–18 Gy. AVM >14 cm^3 are considered for volume-staged SRS (VS-SRS) [6–9] (Fig. 1.2).
- Patients with AVM located in deep locations are generally treated with 15–18 Gy.
- If initial SRS does not result in obliteration after 3–5 years, then repeat SRS is often performed. Dose prescription for repeat AVM SRS usually ranges between 15 and 18 Gy.

1.3 Treatment Planning Techniques

- Dose planning should cover the entire nidus with prescribed radiation dose. The majority of Gamma Knife cases are prescribed at the 50% isodose line, whereas linear accelerator-based procedures typically are prescribed to higher isodose lines.
- VS-SRS of large AVM allows a higher radiation dose to be delivered to the nidus while reducing the radiation exposure to the adjacent brain. The time between the different stages usually is 2–6 months.

1.4 Side Effects

- Neurologic decline after AVM SRS can occur secondary to intracranial hemorrhage (ICH) or ARE.
- Patients remain at risk for ICH until the nidus is obliterated, which generally requires 1–5 years. Numerous reports have shown that the risk of AVM bleeding during this latency interval is either unchanged or reduced [10–12].
- Radiation-induced changes (RIC) noted in the first 1–2 years after AVM SRS (areas of increased signal on T2-weighted MRI) are noted after 30–50% of patients and are distinct from radiation necrosis [13] (Fig. 1.3). Most are asymptomatic and resolve without treatment.
- Patients with symptomatic RIC (headaches, seizures, focal deficits) can usually be managed with corticosteroid therapy.
- Late ARE develop 5 or more years after SRS and are characterized by perilesional edema or cyst formation [14–15] (Fig. 1.4). Symptomatic late ARE may require surgical removal to improve the patient's neurologic condition.

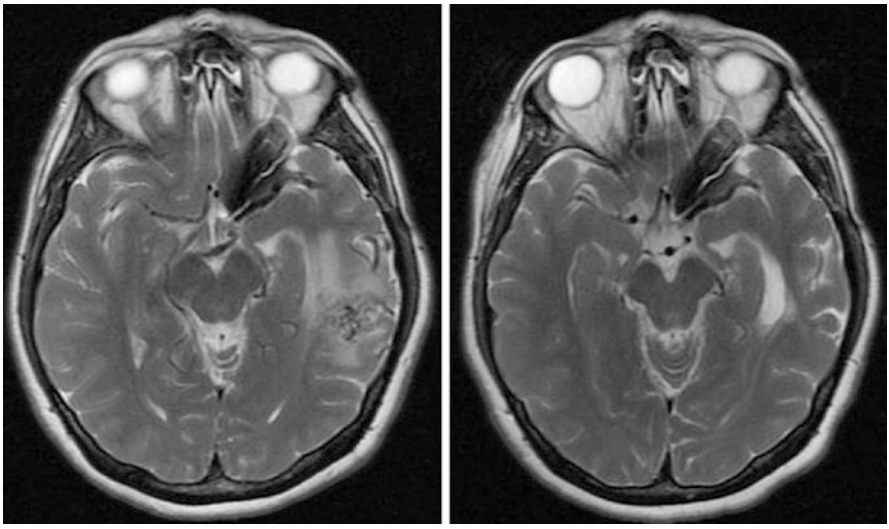

Fig. 1.3 Axial T2-weighted MRI after SRS of a left temporal AVM (AVM volume, 13.8 cm^3; AVM margin dose, 15 Gy). (Left) MRI performed 1 year after SRS shows edema surrounding the AVM. The patient was asymptomatic. (Right) MRI performed 3 years after SRS shows the nidus to be no longer visible and the edema has resolved

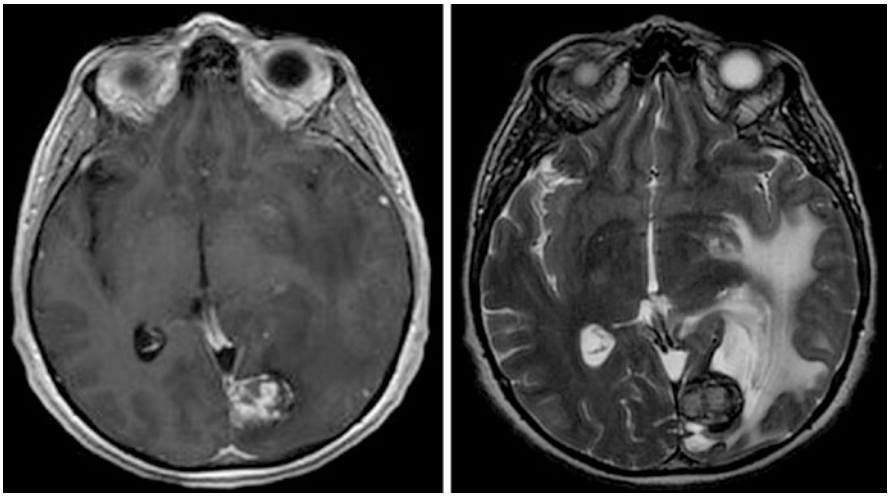

Fig. 1.4 Axial gadolinium-enhanced (left) and T2-weighted (right) MRI 15 years after initial SRS and 11 years after repeat SRS of a left occipital AVM showing late ARE. The patient had progressive visual loss and headaches and underwent resection of the obliterated AVM with improvement in her symptoms

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