

Single Case – General Neurology

Volume-Staged Radiosurgery for Large Arteriovenous Malformation

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Keywords

Arteriovenous malformation · Volume-staged radiosurgery · Digital subtraction angiography

Abstract

Large arteriovenous malformations (AVMs) are challenges in management because of outcomes and adverse affects. Volume-staged radiosurgery has been an appropriate approach when removal resection and embolization are not recommended. A 53-year-old gentleman was diagnosed with a large intracranial AVM with persistent headache and short-term seizure. Brain magnetic resonance and angiograph showed a bulky volume of AVM nidus. Removal resection and embolization were not recommended because of high risk of adverse affects. The patient was treated by volume-staged radiosurgery. One year post-treatment, obliteration for right internal carotid artery was completed. Volume-staged radiosurgery is a potential treatment option for large AVM with controlled and obliteration efficacy, especially to AVMs which are not appropriate for removal surgery and embolization.

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Arteriovenous malformations (AVMs) are congenital vascular anomalies comprised of an abnormal number of blood vessels that are abnormally constructed. The blood vessels directly shunt blood from arterial input to the venous system without an intervening capillary network to dampen pressure. The annual incidence of AVM recognition is thought to be 10,000 patients per year in the United States [1].

In making a decision for management strategies, we often employ a decision tree algorithm as shown in Figure 1 [2].

Surgical removal is arguably the best option for small- to medium-sized lesions, defined as Spetzler-Martin (Table 1) grades I–III, occurring in noneloquent and superficial regions of the brain, particularly those with a history of hemorrhage [3]. Complete resection is curative and eliminates the risk of hemorrhage without a latent period. Large lesions, usually Spetzler-Martin grades IV and V, have substantially higher surgical complication rates and remain a therapeutic challenge. The overall prevalence or natural history of large AVMs is not well known, but such lesions have also been associated with increased rates of hemorrhage [4]. In most reports, lesion size is defined by the greatest maximal dimension of the AVM nidus, and the incidence of AVMs larger than 2.5–3 cm varies from 30 to 62% in natural history studies [5].

For larger-volume AVM (average diameter 4–5 cm), observation may be the only reasonable strategy in view of the risks of even multimodality management [6]. This may be especially true for patients who have never bled previously.

Different treatment paradigms for large inoperable AVMs include single-stage stereotactic radiosurgery (SRS), embolization (definitively, pre-SRS, or post-SRS), SRS with planned salvage of surgery or repeat SRS, proton-based SRS, fractionated SRS, dose-staged SRS, and volume-staged (VS)-SRS, which is an alternative approach where the nidus is divided into separate volumes and treated in separate sessions while minimizing overlap between stages [3].

Outcomes after radiosurgery may be predicted based on volume, location, age, angio-architecture, and dose delivered [7]. SRS is an excellent management strategy for patients with AVMs 30 mm in average diameter (for a single procedure). Staged procedures are used for larger vascular malformations or for those that were incompletely obliterated 3 years or more after an initial procedure.

VS-SRS has been described as a way to potentially improve rates of obliteration and decrease the normal tissue 12-Gy volume by 27.3% and the overall 12-Gy volume by 11% compared with a hypothetical single session of SRS [8].

In this study, we introduce a 53-year-old gentleman with large AVM diagnosis, AVM at eloquent site, affected functionally. Removal surgery and endovascular intervention were not available.

Case Report

A 53-year-old gentleman presented with persistent headache in the past 2 years. He had previously hypertension history, was treated permanently by calcium blocker, without history of vision blur and seizure. He came to the Neurosurgery Department because of increasing headache and short-term seizure. Brain magnetic resonance imaging (MRI) showed a large

AVM at right brain lobular, maximum diameter of the AVM nidus was 6.48 cm (Fig. 2). In digital subtraction angiography (DSA), there were many large and high-flow supplying arteries (the largest was the right internal carotid artery) (Fig. 3). The diagnosis was inoperative large AVM, Spetzler-Martin grade V, inappropriate for embolization. We decided to use VS-SRS with an interval time of 3–6 months. The AVM had been divided into two halves (anterior and posterior) based on the posterior edge of anterior clinoid as landmark. Dose to anterior half was 15 Gy and posterior half was 15 Gy after calculated doses for coverage and organs at risk. Planning target volumes were defined as GTV +2 mm (Fig. 4). Simulation was performed by using specific radiosurgery thermomask. Computed tomography simulation and MRI were recorded by 1-mm slice thickness; plans were calculated by dosimetrists and software Monaco 5.1. MRIs and DSA were taken before treatment, between 2 stages, and 3, 6, 12, 18 months after the second stage. Follow-up time was 24 months at the time of report.

First fraction (first stage) was on September 28, 2017, with 15 Gy delivered to the anterior half of the whole AVM. Coverage was >95% prescriptive dose to 100% of volume, maximum dose was 1,847 cGy (<140% prescriptive dose) (Fig. 5).

Forty-eight hours after the first fraction, he felt mild headache, without seizure or dizziness, and the symptom disappeared after 24 h treated by steroid (dexamethasone 8 mg b.i.d.).

After 4 months, he came for continuous treatment. MRI before the second stage showed reduction of whole AVM toward treated half by 20% (Fig. 6). We decided to make some modifications: alleated borderline between two halves anteriorly (toward treated half) by 2 mm, and decreased dose for second stage at posterior half to 13 Gy, to assure protection to organs at risk (chiasm, right optic nerve).

The second stage was performed on February 26, 2018 (5 months apart).

Discussion

The Spetzler-Martin AVM grading scale is based on size, location, and venous drainage of intracerebral AVM. The scale is calculated by adding the points for each category. The range is 1–5. The lower the score, the better the outcome. In our case, other indications such as removal surgery and embolization were not available because of high risk of hemorrhage and Spetzler-Martin grade V. Decision on VS-SRS was appropriate. Volume and maximum diameter of AVM nidus were massive, unsafe to adjacent organs at risk if using either single fraction radiosurgery or fractionated routine radiotherapy.

In a subgroup of 48 patients with AVMs larger than 15 mL, Pan et al. [9] found an obliteration rate of 25% after 40 months. In their single radiosurgery strategy, the average margin dose was 17.7 Gy and 16.5 Gy for AVMs with volumes 10–20 mL and more than 20 mL, respectively. In their follow-up examinations, they observed 37% moderate and 12% severe adverse radiation effects in patients with AVMs larger than 10 mL [9]. Miyawaki et al. [10] reported that the obliteration rate in patients with AVMs larger than 14 mL treated using LINAC-based radiosurgery was 22%. Inoue and Ohye [11] reported an obliteration rate of 36.4% and hemorrhage rate of 35.7% in the subgroup of AVMs larger than 10 mL treated by radiosurgery.

The probability of developing post-radiosurgery imaging changes depends on marginal dose and treatment volume. The volume of tissue receiving 12 Gy or more (the 12-Gy volume)

is the single factor that seems to have the closest correlation with the probability of developing imaging changes [12]. Location does not seem to affect the risk of developing imaging changes but has a marked effect on whether or not these changes are associated with symptoms. Post-radiosurgery imaging changes (new areas of high T2 signal in brain surrounding the irradiated AVM nidus) develop in approximately 30% of patients 1–24 months after radiosurgery [13].

In the present case, post-radiosurgery imaging change was at 4 months after first-stage treatment (whole volume reduced 20%) without symptoms (Fig. 6). This is appropriate due to dose of 15 Gy at anterior half.

Delayed complications of radiosurgery include the risk of hemorrhage despite angiographically documented completely obliterated AVMs, the risk of temporary or permanent radiation injury to the brain such as persistent edema, radiation necrosis, and cyst formation, and the risk of radiation-induced tumors. Cyst formation after AVM radiosurgery was first reported by Japanese investigators who reviewed the outcomes of patients initially treated in Sweden [14]. Delayed cyst formation has been reported in other recent long-term follow-up studies [15].

Time was a factor contributing to response and obliteration capacity evaluation. Though two stages of treatment had been accomplished, DSA at 6 months still showed remaining shunts (Fig. 7a), while MRI showed complete response. Obliteration evidence presented in DSA only at 12 months after treatment (Fig. 7b, c).

In conclusion, VS-SRS is a potential treatment option for large AVM with controlled and obliteration efficacy. However, indication should be made after very careful discussion by neurosurgeons, endovascular specialists, and radio-oncologists and requires much experience before applying to treatment.

Statement of Ethics

This study was approved by the Ethical Committee Board of Hue Central Hospital. The authors confirm obtaining written consent from the patient for publication of the manuscript.

Conflict of Interest Statement

The authors declare no financial disclosures or conflicts of interest.

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Author Contributions

P.N. Tuong and N.T. Xuan carried out and confirmed the diagnosis, provided the details of the case, and contributed to the design of the report. P.N. Tuong and N.T. Xuan drafted the manuscript. All authors read and approved the final version of the manuscript.

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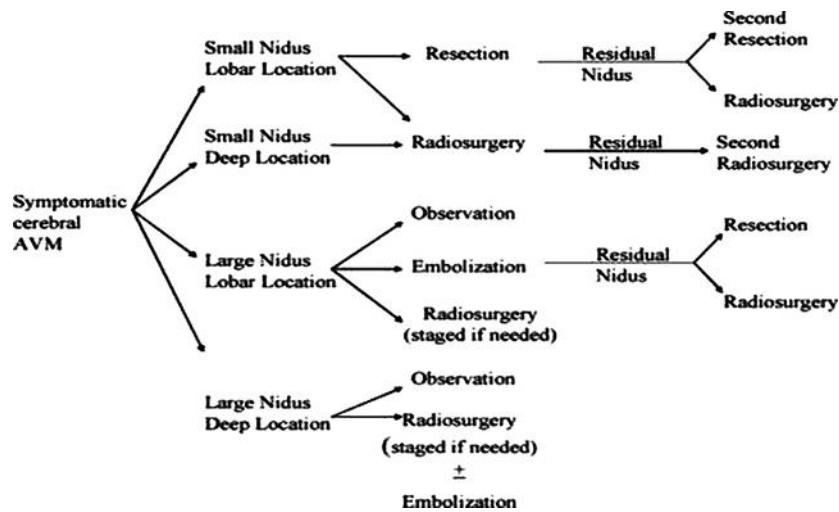


Fig. 1. Treatment strategy for AVM.

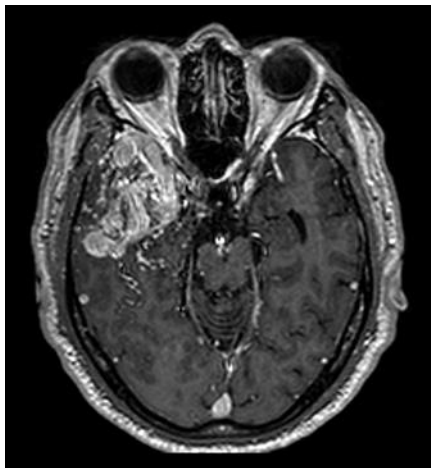


Fig. 2. Pre-treatment MRI.

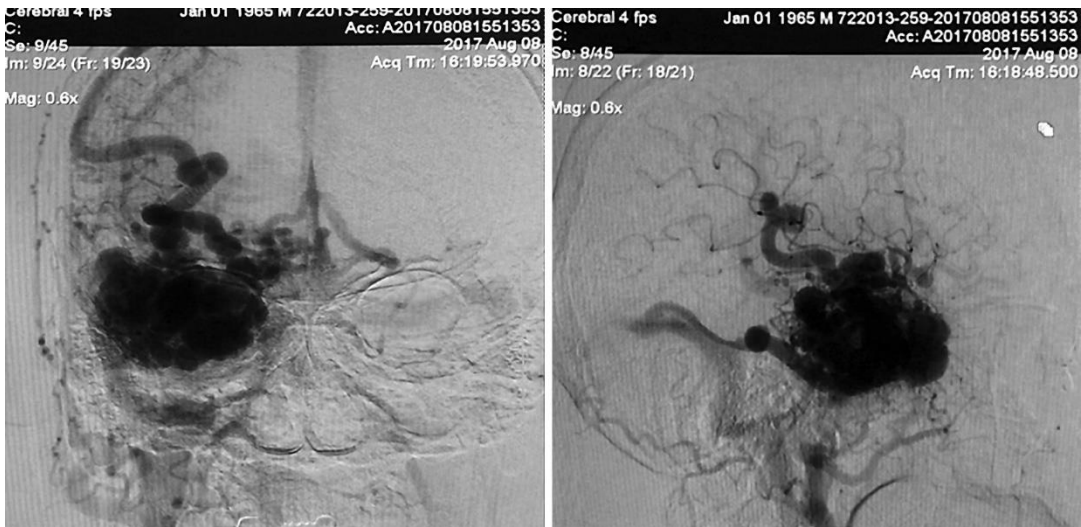


Fig. 3. Pre-treatment DSA.

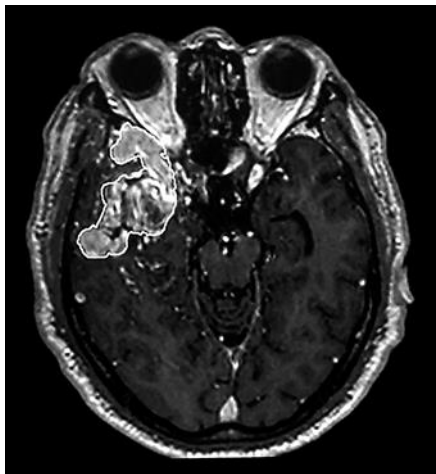


Fig. 4. Whole AVM nidus contouring.

Structure	Volume (cc)	Min. Dose (Gy)	Max. Dose (Gy)	Mean Dose (Gy)	Gold Ref. (cc)	Volume < 100% (cc)	Volume < 90% (cc)	Hct Ref. (cc)	Volume > 100% (cc)	Volume > 90% (cc)	% in Vol.	Is in ...	Heterogeneity Ind.	Conformity Index
GT V T 1ST	30.544	1335.2	2020.6	1760.8				1500.0	30.495	99.84	100.00	yes	1.16	0.61
PTV15A	46.888	988.7	2020.6	1704.4				1500.0	44.988	95.95	100.00	yes	1.24	0.85
R.OPTIC	0.600	410.7	988.7	657.9				800.0	0.120	20.00	100.00	yes	2.07	0.00
CHASMA	0.584	218.0	976.3	509.2				800.0	0.048	8.22	100.00	yes	3.41	0.00
Skull (Unop. Tiss.)	3539.416	2.3	634.8	99.3							100.00	no	15.29	
BRUN	2447.832	8.7	2015.2	221.9							100.00	yes	25.89	
BRUN STEM	27.132	67.5	415.4	155.5							100.00	yes	2.96	
L.COCHLEA	0.344	124.6	216.1	166.0							100.00	yes	1.51	
L.EYE	6.864	58.8	195.7	119.5							100.00	yes	2.16	
L.LEN	0.144	94.0	143.5	117.7							100.00	yes	1.48	
L.OPTIC	0.592	80.5	215.6	136.4							100.00	yes	2.02	
R.COCHLEA	0.328	175.7	387.9	269.7							100.00	yes	1.97	
R.EYE	7.184	90.8	618.7	265.8							100.00	yes	3.41	
R.LEN	0.208	131.2	208.3	171.9							100.00	yes	1.40	

Fig. 5. Dose volume histogram.

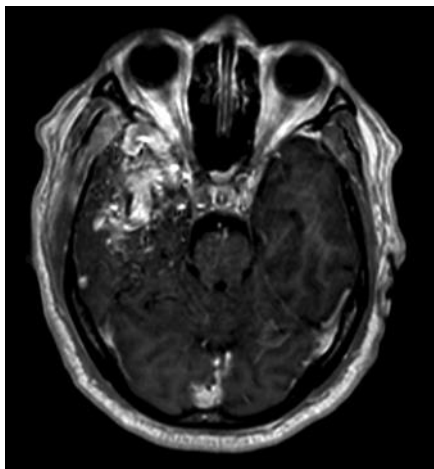


Fig. 6. MRI before second stage.

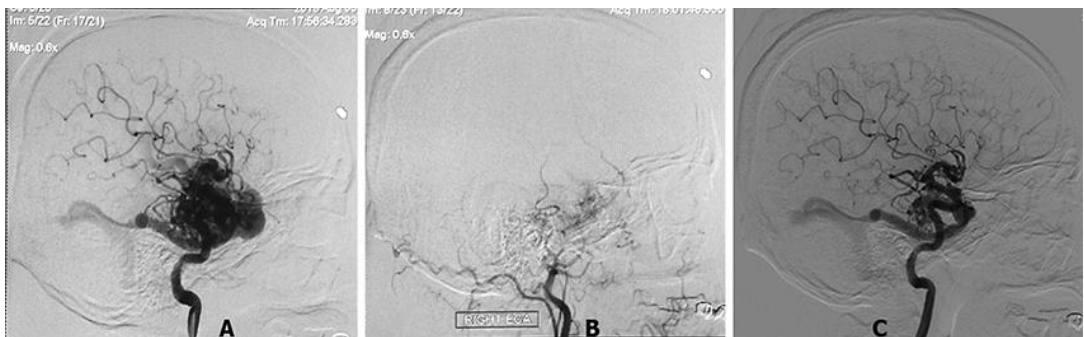


Fig. 7. A Remaining shunts for right internal carotid artery. B Complete obliteration for right external carotid artery. C Complete obliteration for right internal carotid artery.

Table 1. Spetzler-Martin AVM grading scale

	Points
Size	
0–3 cm	1
3.1–6.0 cm	2
>6 cm	3
Location	
Noneloquent	0
Eloquent*	1
Deep venous drainage	
Not present	0
Present	1
AVM total score	1–5

* Eloquent locations: areas of sensorimotor, language, visual, thalamus, hypothalamus, internal capsule, brain stem.