Original Article

Free full text available from
www.cancerjournal.net

Analysis of X-knife and surgery in treatment of arteriovenous malformation of brain

ABSTRACT

Background: The goal of treatment in arteriovenous malformation (AVM) is total obliteration of the AVM, restoration of normal cerebral function, and preservation of life and neurological function.

Aim: To analyze the results of X-knife and surgery for AVM of the brain. The endpoints for success or failure were as follows: success was defined as angiographic obliteration and failure as residual lesion, requiring retreatment, or death due to hemorrhage from the AVM.

Materials and Methods: From May 2002 to May 2007, 54 patients were enrolled for this study. Grade I AVM was seen in 9%, grade II in 43%, grade III in 26%, grade IV in 9%, and grade V in 13%. Thirty-eight patients were treated by microsurgical resection out of which Grade I was seen in 5 patients, Grade II was seen in 17 patients, Grade III was seen in 9 patients and Grade V was seen in 7 patients. Rest of the sixteen patients were treated by linear accelerator radiosurgery out of which Grade II was seen in 6 patients, Grade III was seen in 5 patients and Grade IV was seen in 5 patients. The follow up was in range of 3-63 months. In follow up, digital subtraction angiography/ magnetic resonance angiography (DSA/MRA) was performed 3 months after surgery and 1 year and 2 years after stereotactic radiosurgery (SRS).

Results: Among the patients treated with X-knife, 12/16 (75%) had proven angiographic obliteration. Complications were seen in 4/16 (25%) patients. Among the patients treated with microsurgical resection, 23/38 (61%) had proven angiographic obliteration. Complications (both intraoperative and postoperative) were seen in 19/38 (50%) patients.

Conclusions: Sixty-one percent of patients were candidates for surgical resection. X-knife is a good modality of treatment for a low-grade AVM situated in eloquent areas of the brain and also for high-grade AVMs, when the surgical risk and morbidity is high.

Pooja Nandwani Patel,
Rakesh K Vyas,
Devang C Bhavsar,
UK Suryanarayan,
Satish Pelagade,
Dipak Patel[1]

Departments of Radiation Oncology, [1]Neurosurgery, Gujarat Cancer and Research Institute, Ahmedabad, India

For correspondence:
Dr. Pooja K. Nandwani, Junior Lecturer, N-3, Government Officers' Colony, Meghani Nagar, Ahmedabad - 380 016, Gujarat, India. E-mail: drpoojanandwanipatel@yahoo.co.in

KEY WORDS: X- knife, surgery, arteriovenous malformation

INTRODUCTION

Arteriovenous malformation (AVM) is a vascular anomaly consisting of a fistulous connection of arteries and veins without the normal intervening capillary beds. It is present in 0.2–0.8% of the general population and accounts for 2% of all strokes and 38% of intracranial hemorrhage (ICH) in patients between 15–45 years. Natural studies have indicated that the yearly rate of first hemorrhage is 2–3%, with a mortality of 10–30% and a 6% risk of recurrent bleeding in the first year and 21% risk thereafter. Fortunately, development and refinement of microsurgical, interventional, neuroradiological, and radiosurgical techniques now provide multiple options for AVM management.[1–4]

The goal of all these modalities is total obliteration of the AVM, restoration of normal cerebral function, and preservation of life and neurological function. Success with any of these modalities is defined as complete obliteration of the AVM which, according to Lindquist and Steiner, is an angiographic appearance with 'normal circulation time, complete absence of pathological vessels in the former nidus of malformation, and the disappearance or normalization of draining veins from the area.' Steinberg *et al.* defined obliteration as the absence of any angiographically visible arteriovenous shunt. Radiosurgery is believed to result in AVM obliteration via endothelial cell proliferation, progressive vessel wall thickening, and eventual luminal closure.

Aim

To analyze and compare the results of X-knife and surgery in the treatment of AVM of the brain. Successful treatment was defined as angiographic obliteration and failure as residual lesion, requiring retreatment, or death due to AVM hemorrhage.

MATERIALS AND METHODS

From May 2002 to May 2007, 54 patients were enrolled for this study. Out of the 54 patients, 43 were male and 11 were female. The age of patients ranged from 12-70 years. The patients had varied clinical presentations: seizures in twenty four patients, ICH or intraventricular hemorrhage in twenty patients, headache in eight patients, focal neurological deficit in two patients, and altered higher mental functions in four patients.

Commonly done investigations were CT brain, MRI brain, MRA, CT angiography, and four-vessel DSA. These investigations were also repeated as necessary at follow-up before categorizing the end result as 'success' or 'failure.'

The different sites involved, as identified by radiological investigations, were parietal in thirteen patients, frontal in twelve patients, temporal in ten patients, cerebellar in eight patients, parietooccipital in seven patients, and the basal ganglia and thalamic region in two patients each.

All these lesions were then graded according to the Spetzler and Martin grading system as shown in Table 1. Out of 54 patients, 38 underwent surgery and 16 had linear accelerator stereotactic radiosurgery (SRS). Majority of the patients were taken for surgery as these patients were initially approached by neurosurgeon for their symptoms.

Briefly, the steps in surgery are as follows: With the help of an operating microscope the most commonly used technique is marginal resection. At their point of entrance into the AVM the feeding arteries are interrupted. One draining vein is preserved until resection is nearly complete. The major feeding arteries supplying distal cortical tissue are also preserved. Meticulous hemostasis is maintained. The procedure is terminated if significant edema appears. Larger lesions in frontal and temporal poles and the cerebellar hemisphere may be removed by en block resection. AVMs associated with ICH are preferably treated 3 weeks after the bleed.

The steps of the stereotactic procedure in brief are as follows: With the help of the neurosurgeon the stereotactic frame is applied. The patient is then shifted to the CT simulator where, after proper positioning of the patient, the depth helmet is applied. At least two persons should take readings with the depth helmet. The CT localizer frame is then applied, after which patient undergoes thin-sliced high-resolution CT imaging. This is shown in Figure 1.

The localizer gives rise to the appearance of fiducial points (white dots) on the images. Images are transferred to the treatment planning computer through network (PACS), after which the images are aligned and the structures reconstructed

Table 1: Spetzler-Martin grading system.

Grade	I	II	III	IV	V
Surgery	5	17	9	-	7
SRS	-	6	5	5	-

Figure 1: Patient with stereotactic frame

using the fiducial points. Target contouring is done by the radiotherapists and then the physicists generate an adequate plan by selecting a proper isocentre in the target volume center. The collimator size that can cover the target volume is decided. Arcs selection is done, which is mostly non-coplanar. The isodoses are seen and the dose is prescribed at the satisfactory isodose line, which is generally the 90% isodose line. The dose is usually in the range of 15–17 Gy. The number of isocenters was two in three cases and one in the rest of the cases. Most commonly, the numbers of arcs used were 4–8. This is shown in Figure 2.

Observation and analysis

After the procedure, patients were kept on regular follow-up. The follow-up period was 3–63 months. All patients were asked

Figure 2: Patient on treatment table

Table 2: Results of surgical treatment

AVM grade	No. of cases	Operative results	
		Morbidity	Mortality
I	05	0	0
II	17	0	0
III	09	5	0
IV	-	-	-
V	07	2	5

AVM: Arteriovenous malformation

Table 3: Results of X-knife

AVM grade	No. of cases	SRS results	
		Morbidity	Mortality
I	-	-	
II	06	-	-
III	05	1	1
IV	05	1	1
V	-	-	-

AVM: Arteriovenous malformation

Table 4: Comparison of series using X-knife

Study	Patients	Dose	2-Year obliteration rate (%)
Friedman *et al*.	158	15–18 Gy	78
Colombo *et al*.	97	18–40 Gy	75
Betli *et al*.	66	Up to 40 Gy	66
Souhami *et al*.	33	50–55Gy	62
Loeffler *et al*.	16	15–25 Gy	73
Our study	16	15–17 Gy	75

to have clinical and radiological (CT/MRI) assessment every 6 months. DSA/MRA was performed 3 months after surgery and at 1 and 2 years after SRS.

Results of surgery

Angiographic control was possible in 23 out of 38 patients [Table 2]. The complications met with in the surgical setup can be divided broadly into intraoperative and postoperative complications. The most commonly seen intraoperative complications were AVM rupture (seen in seven patients) and resection of functional brain (leading to neurological deficits) in six patients. The most commonly seen postoperative complications were arterial-capillary-venous hypertensive syndrome in two patients and CSF leak in four patients.

RESULTS OF X-KNIFE

For patients treated with X-knife, 12 out of 16 (75%) had angiographic obliteration [Table 3]. The complications seen with the X-knife treatment were acute morbidity in two patients: hemorrhage and radiation necrosis in one patient each.

DISCUSSION

An AVM is a complex network of vascular channels consisting of arterial feeders, an AVM nidus, and enlarged venous outflow channels, all of which are demonstrable at angiography. Successful AVM management is dependent upon the lesion and location, the hemodynamics and morphology, the patient's clinical condition,[5] and the treatment modalities selected. The goal of all these modalities is total obliteration of the AVM, restoration of normal cerebral function, and preservation of life and neurological function.

The results obtained by microsurgery and interventional neuroradiology have progressively improved over the past 20 years. Radiosurgery is a very good alternative treatment in certain AVMs because of its low incidence of treatment-related morbidity, especially in eloquent brain locations. The basic idea of obtaining a progressive obliterating process in nidus vessels by focusing a high radiation dose has proved to be safe and effective irrespective of the device used; these devices include gamma knife, cyclothrone, and modified linear accelerators.[6–14]

Using gamma knife technology, researchers at the University of Pittsburgh have demonstrated 2-year obliteration rates of 100% for lesions smaller than 1 cm in diameter, 85% for those 1–4 cm in diameter, and 58% for lesions larger than 4 cm. SRS using modified linear accelerators yield 2-year complete obliteration rates in the range of 29.4–84%.

The LINAC system has Cerro-bend collimators ranging from 5 to 40 mm in diameter, with 2-mm increments. This wide range in collimator size makes it possible to treat any AVM in that size range with a homogeneous dose of radiation, and larger AVMs with one, as opposed to multiple, isocenters.

Accelerated charged particles such as protons and helium ions have quite distinctive properties that are used for stereotactic irradiation but because of the cost of installation they are not widely available.

The recent advances in the field of intravascular embolization have also been of help. Embolization prior to surgical procedures made inoperable large lesions more amenable to surgery or SRS. In many institutes where facilities for embolization are available, combined modalities including embolization, microsurgical resection and Linear Accelerator Radiosurgery have also been tried.

In the large majority of the cases, the decision on the treatment modality to be adopted is often open to discussion. Success with any modality means complete obliteration of the AVM; Lindquist and Steiner define complete obliteration as: an angiographic appearance with 'normal circulation time, complete absence of pathological vessels in the former nidus of malformation, and the disappearance or normalization of draining veins from area.' Steinberg *et al.* defined obliteration as the absence of any angiographically visible arteriovenous shunt. Table 4 shows a comparison of our results with the series of studies made so far in the treatment of AVM. The doses we used were in the range of 15–17 Gy and the 2-year obliteration rate was 75%.

CONCLUSIONS

Sixty-one percent patients with grade I and II lesions, in whom the surgical risks were low or nil, were candidates for surgical resection. X-knife is a good treatment modality for low-grade AVM that are in eloquent areas and also in high-grade AVMs where the surgical risk and morbidity is relatively high.

REFERENCES

1. Florio F, Lauriola W, Nardella M, Strizzi V, Vallone S, Trossello MP. Endovascular treatment of intracranial arterio-venous malformations with Onyx embolization: Preliminary experience. Radiol Med (Torino) 2003;106:512–20.
2. Huang YC, Tseng CK, Chang CN, Wei KC, Liao CC, Hsu PW. LINAC radiosurgery for intracranial cavernous malformation: 10-year experience. Clin Neurol Neurosurg 2006;108:750–6.
3. Pollock BE, Garces YI, Stafford SL, Foote RL, Schomberg PJ, Link MJ. Stereotactic radiosurgery for cavernous malformations. J Neurosurg 2000;93:987–91.
4. Szeifert GT, Massager N, DeVriendt D, David P, De Smedt F, Rorive S, *et al*. Observations of intracranial neoplasms treated with gamma knife radiosurgery. J Neurosurg 2002;97:623–6.
5. Kupersmith MJ, Kalish H, Epstein F, Yu G, Berenstein A, Woo H, *et al*. Natural history of brainstem cavernous malformations. Neurosurgery 2001;48:47–53.
6. Maruyama K, Kawahara N, Shin M, Tago M, Kishimoto J, Kurita H, *et al*. The risk of hemorrhage after radiosurgery for cerebral arteriovenous malformations. N Engl J Med 2005;352:146–53.
7. Maesawa S, Flickinger JC, Kondziolka D, Lunsford LD. Repeated radiosurgery for incompletely obliterated arteriovenous malformations. J Neurosurg 2000;92:961–70.
8. Sirin S, Kondziolka D, Niranjan A, Flickinger JC, Maitz AH, Lunsford LD. Prospective staged volume radiosurgery for large arteriovenous malformations: Indications and outcomes in otherwise untreatable patients. Neurosurgery 2006;58:17–27.
9. Kondziolka D, Nathoo N, Flickinger JC, Niranjan A, Maitz AH, Lunsford LD. Long-term results after radiosurgery for benign intracranial tumors. Neurosurgery 2003;53:815–21.
10. Hasegawa T, McInerney J, Kondziolka D, Lee JY, Flickinger JC, Lunsford LD. Long-term results after stereotactic radiosurgery for patients with cavernous malformations. Neurosurgery 2002;50:1190–7.
11. Flickinger JC, Kondziolka D, Lunsford LD. Radiobiological analysis of tissue responses following radiosurgery. Technol Cancer Res Treat 2003;2:87–92.
12. Flickinger JC, Kondziolka D, Maitz AH, Lunsford LD. An analysis of the dose-response for arteriovenous malformation radiosurgery and other factors affecting obliteration. Radiother Oncol 2002;63:347–54.
13. Flickinger JC, Kondziolka D, Lunsford LD, Kassam A, Phuong LK, Liscak R, *et al*. Development of a model to predict permanent symptomatic postradiosurgery injury for arteriovenous malformation patients: Arteriovenous Malformation Radiosurgery Study Group. Int J Radiat Oncol Biol Phys 2000;46:1143–8.
14. Stafford SL, Pollock BE, Leavitt JA, Foote RL, Brown PD, Link MJ, *et al*. A study on the radiation tolerance of the optic nerves and chiasm after stereotactic radiosurgery. Int J Radiat Oncol Biol Phys 2003;55:1177–81.

Source of Support: Nil**, Conflict of Interest:** None declared.