Section: Radiation Oncology

Original Research Article

BRAIN ARTERIOVENOUS MALFORMATION: STEREOTACTIC RADIOSURGERY ON CYBERKNIFE; AN EARLY INSTITUTIONAL EXPERIENCE

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ABSTRACT

Background: Arteriovenous malformation (AVM) is developmental anomaly comprised of tangle of dysplastic blood vessels with abnormal connection between arteries and veins. Most common cause of spontaneous intracerebral hemorrhage in young is vascular malformation. Rupture of AVM associated with mortality of 10-15% and morbidity of up to 50%. Annual rate of bleeding from AVM rupture is 2-4%. At present available treatment modality options for intracranial AVM are close observation with anti-epileptics, surgical/microsurgical resection, endovascular embolization and stereotactic radiosurgery (SRS). SRS can be delivered via conventional LINAC, Gamma knife or robotic frameless cyberknife. Cyberknife is a robotic SRS system consists of compact linear accelerator of 6-MV beam energy mounted on computer controlled, industrial robot which has capability of manipulation in 6 axis. This robotic LINAC, 5 axis freedom of movement of couch with orthogonally positioned x ray sources and their image detector allows very accurate positioning of patient in align to treatment simulation position which in turn provide precise treatment delivery which is comparable to published frame based SRS system. In this case series we have evaluated cases of arteriovenous malformation in brain treated with SRS on cyberknife and its preliminary results.

INTRODUCTION

Arteriovenous malformation (AVM) is developmental anomaly comprised of tangle of dysplastic blood vessels with abnormal connection between arteries and veins.[1] They lack in high resistance system of capillaries which leads to high flow of blood running directly from artery to vein so venous dilation, engorgement and ultimately vessel rupture occurs. Most common cause of spontaneous intracerebral hemorrhage in young is vascular malformation.[2] Rupture of AVM associated with mortality of 10-15% and morbidity of up to 50%.[3] Annual rate of bleeding from AVM rupture is 2-4%.[4-6] At present available treatment modality options for intracranial AVM are close observation with anti-epileptics, surgical/microsurgical resection, endovascular embolization and stereotactic radiosurgery (SRS).[7,8]

SRS can be delivered via conventional LINAC, Gamma knife or robotic frameless cyberknife. In this case series we have shown our early experience of using cyberknife to treat AVM and priliminary outcome.

MATERIALS AND METHODS

From period of January 2022 to December 2024 at our institute treated 11 patients diagnosed with AVM in brain for stereotactic radiotherapy on cyberknife included in this retrospective analysis. [Table 1] shows patient's characteristics. All patients were diagnosed outside at private hospital due to presenting symptoms were either seizure or headache or any neurological deficit. Spetzler martin grade were assessed before SRS [Table 2].

Pre-treatment workup

All patients were assessed by Radiation oncologist and Neurosurgeon at our institute and decision to treat with SRS was taken. Patients were underwent pre radiotherapy workup including Magnetic Resonance Imaging (MRI) of brain with angiography (if not done at time of diagnosis), Digital subtraction angiography (DSA), pituitary hormone profile in selected cases as and when required.

Planning scan

At our institute a dedicated Computed Tomography (CT) scan machine available for Radiation oncology

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department to simulate radiation treatment. All patients were simulated in treatment position with appropriate immobilization devices compatible with cyberknife system. Cyberknife is a frameless non-invasive stereotactic radiotherapy machine; we used a simple thermoplastic mask with head rest for head and neck fixation. There is no need for putting external reference fiducial marker over thermoplastic mask and non-contrast ct scan is taken with volume covering 15-20cm superior and inferior to the region of interest.

Planning CT scan requiremnets: Gantry tilt 0 degree, pitch 1, slice thickness 1mm, kv 120, mAs 350-400.

With same immobilization device in same treatment position but on MR compatible baseplate, MRI sequences were acquired. Minimum T1 post gadolinium and T2 sequence were required for planning and other sequences were acquired according to need.

Target & OAR delineation

After these MRI sequences were co registered with planning CT scan, organ at risk (OAR) and target volume that is AVM nidus were delineated.[9] Although DSA was acquired before treatment, couldn't be used directly to co-register with planning CT scan as it was not acquired with stereotactic frame or in treatment position. So DSA was only used as adjunct information to delineate nidus.

Planning was done on accuracy precision system by medical physicists.

Target dose

For single fraction SRS we have prescribed 18Gy for one case which had previous history of radiation was prescribed 15Gy. One patient with very large volume were treated with hypofractionation stereotactic radiotherapy.

Treatment on Cyberknife

Cyberknife is a robotic SRS system consists of compact linear accelerator of 6-MV beam energy mounted on computer controlled, industrial robot which has capability of manipulation in 6 axis.[10] This robotic LINAC, 5 axis freedom of movement of couch with orthogonally positioned x ray sources and their image detector allows very accurate positioning of patient in align to treatment simulation position which in turn provide precise treatment delivery which is comparable to published frame based SRS system.[11]

Table 1: Patient's characteristics

Case No.	Age	Sex	Presenting symptom	Pre SRS bleed	Neurological deficit at diagnosis	Neurological deficit pre SRS	Pre SRS emboli-zation	Previous radiation therapy
1	8	M	seizure	yes	yes	yes	Yes	yes
2	32	M	seizure	No	No	No	No	No
3	28	M	seizure	yes	No	No	No	No
4	36	M	Slurring speech	yes	yes	No	No	No
5	21	F	seizure	yes	No	No	No	No
6	17	M	seizure	No	No	No	No	No
7	22	F	seizure	yes	No	yes	No	No
8	31	M	Headache	Yes	yes	yes	No	No
9	21	M	Headache	yes	Yes	No	No	No
10	19	M	Headache	No	No	No	No	No
11	57	M	Headache	yes	yes	yes	Yes	No

Table 2: Spetzler-Martin Grading system

Case No.	Spetzler-Martin grade (points)			
	Size (cm)	Location	venous drainage	grade
1	4.5	Eloquent	deep	4
2	4	Eloquent	deep	4
3	0.9	Non eloquent	deep	2
4	< 3	Eloquent	deep	3
5	4.2	Eloquent	deep	4
6	1.9	Non eloquent	deep	2
7	4.4	Eloquent	deep	4
8	2.1	Eloquent	deep	3
9	2.5	Eloquent	deep	3
10	3	Eloquent	Superficial	3
11	4.6	Eloquent	deep	4

RESULTS

Patient demographics: Out of 11 patients nine (81.8%) were male, two (18.2%) were female. Median age was 22 years (minimum 8- maximum 57 years). Only two patient had AVM in non-eloquent location. Most common presenting complaint was seizure (n=6) followed by headache (n=4) and slurring of speech (n=1). Seven had history of hemorrhage due to AVM rupture before presenting to us for SRS. Of these seven patients five had neurological deficit in the form of hemiparesis after bleeding, two patients recovered before SRS while one patient had recurrent bleed and developed de novo hemiparesis after second bleeding episode before SRS. [Table 1]

Five patients (45%) had Spetzler Martin grade 4, four (36%) had grade 3, two (18%) had grade 2. [Table 2]

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Two patients had prior embolization before SRS while one patient underwent both embolization and stereotactic radiotherapy at other center before presenting to our institute for further management.
Mean, median size of AVM was 3.2cm and 3.5cm respectively.

Treatment details: All patients had single target volume. Median volume of AVM nidus was 22.45 cm3 while it's range 0.45-52.3 cm3. All except two patients were treated with 18Gy of marginal dose in single fraction for nidus. One patient was treated with SRT 25Gy in 5 fractions two years before, so it was prescribed 15Gy in single fraction. One patient was treated with hypofractionation 35Gy in 4 fractions due to large volume and neurological deficit. The median prescription isodose line was 75.8%. Median homogeneity index, conformity index and coverage were 1.32 (range 1.13-1.61), 1.15 (range 1.06-1.18), and 98% (range 95-99.2%) respectively [Table 3]. [Figure 1] shows one of patient's nidus GTV in red colour and prescribed isodose of 18Gy in blue colour.

Follow up: Median follow up period is 1.7 years. The follow up period ranges from 0.6 years to 3 years. Every patient was followed up with MRI yearly post SRS.

Toxicity: There was no acute toxicity was reported. And it's early for late toxicity to be reported. One patient had developed symptomatic post radiation T2 and FLAIR hyperintensity in white matter of region adjacent to irradiated target. While all patients with neurological deficit were improved post SRS. There was no reported incident of hemorrhage post SRS.

Figure 1: GTV-nidus (red colour), and 18 Gy prescription isodose (blue colour).

Table 3: Treatment and follow up details

Case No.	Nidus volume (cm3)	P-F score	K-index	SRS dose	fraction	Homogenity Index	Conformity Index	Coverage (%)	Follow up(year)
1	3.55	0.81	0.24	15	1	1.31	1.06	98	3
2	12.67	2.21	0.70	18	1	1.55	1.11	95	2.3
3	0.82	0.64	0.05	18	1	1.28	1.2	99	2
4	1.16	1.14	0.06	18	1	1.18	1.16	99.2	1.8
5	1.67	0.89	0.09	18	1	1.13	1.18	99	1.8
6	2.05	0.55	0.11	18	1	1.21	1.15	96.9	1.7
7	17.2	2.46	0.49	35	4	1.61	1.17	95	1.6
8	0.66	0.99	0.04	18	1	1.61	1.3	96	1.4
9	3.73	1.09	0.21	18	1	1.56	1.11	98	1.3
10	9.04	1.58	0.50	18	1	1.38	1.13	99	1
11	9.87	2.43	0.55	18	1	1.32	1.14	98.1	0.6

DISCUSSION

In this case series we have retrospectively evaluated 11 cases of AVM in brain treated with SRS treatment on cyberknife. Although there is no data for incidence in India, but it is rare in indian population. Second there are many oncology centers providing LINAC based SRS treatment in the city, so very less number of cases referred to our institute for treatment of cyberknife.

Although minimum three years period of follow up is necessary for obliteration rate, we have shown obliteration % of total AVM volume. One patient had near complete obliteration while rest has partial and one had no obliteration on MRI on median follow up of 1.7 years. The range of obliteration was 0%-80%. Lower rates of obliteration were explained by high number of Spetzler Martin grade 4 patients in this case series.

On the time of data collection, retrospectively we have calculated Pollock Flickinger score (P-F score) and K-index.[12,13] Both are used to predict outcomes after SRS for brain AVM. (Table 3). Median P-F score was 1.09 (range 0.55-2.46). Median K-index was 0.21 (range 0.05-0.7). P-F score is radiosurgery based grading system for AVM; according to Pollock BE et al score 1 or lower has excellent outcome compare to more than 1. K-index is used for determining radiation treatment dose for SRS. Lower the K-index; higher the radiation dose or small volume of nidus results in higher obliteration rate.[14] In this case series we have presented very early outcomes and in future we will discuss the long term outcome and toxicities with large number of study population.

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CONCLUSION

AVM can safely and efficiently be treated on cyberknife with SRS and available scoring and grading system can guide for selection of cases who will be benefited most from SRS and predict who can develop radiation induced toxicities.

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