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Clinical Study

Clinical outcome and complications of gamma knife radiosurgery for intracranial arteriovenous malformations

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ABSTRACT

We sought to evaluate the outcome of intracranial arteriovenous malformation (AVM) treated with gamma knife radiosurgery (GKRS) (Elekta, Stockholm, Sweden) as a primary treatment as well as an adjunct therapy. GKRS has emerged as an important treatment option for intracranial AVM. However, the long term outcome of GKRS on AVM is not well understood. We performed a retrospective review of 85 patients with AVM from 2000–2012 who received GKRS. Out of 85 patients, 13 had undergone prior embolization. The study population was monitored clinically and radiographically after GKRS treatment. Outcome following GKRS for intracranial AVM showed significant variations in nidus obliteration (obliteration in 67 [79%] patients and increase of nidus size on MRI in 18 [21%] patients). The median time to nidus obliteration was 31 months. Overall two (2.3%) patients had intracranial bleeding and the annual bleeding risk was 1.6% after GKRS. Predictive factors for obliteration of the nidus in patients with AVM were low AVM score, Spetzler–Martin grade I–III and female sex. Seventeen (20%) and one (1.17%) patients underwent repeat GKRS and resection, respectively, after initial GKRS, due to increased size of the nidus and GKRS related cyst formation. Thus, GKRS offers a high obliteration rate of AVM, low risk of intracranial bleeding and neurological morbidity, both as primary modality and as an adjunctive treatment. Therefore, GKRS is an effective treatment option for new patients with AVM as well as an adjuvant therapy in patients with recurrent AVM.

1. Introduction

Over the last decades the management options for arteriovenous malformations (AVM) have been expanding. Although microsurgical resection has been used as the primary treatment option, stereotactic radiosurgery and embolization have been established as effective treatment options for AVM. Moreover, recent advances in imaging technology and computerized radiation dose planning have improved the outcome of radiosurgery [1]. Gamma knife radiosurgery (GKRS) (Elekta, Stockholm, Sweden) is widely used in many centers in the world for management of AVM [2–4]. GKRS is usually applied as a single treatment for small AVM (<3 cm) as well as part of multimodal therapy in combination with microsurgical resection and embolization for large AVM [1]. Evidence from the literature revealed that GKRS has a significant impact on obliteration of the AVM nidus in 65–94% patients over a 5 year observation interval [5–9]. GKRS has been associated with a low risk of radiation related complications, even for lesions located in areas that are difficult to access via microsurgery [10]. However, little information is available regarding intermediate or long term outcomes of GKRS on AVM. In the present study, we retrospectively evaluated our experience in the management and long term outcomes of GKRS on AVM, focused particularly on the obliteration of nidus and radiation complications after GKRS. We have also determined the predictive factors related to successful obliteration of the nidus.

2. Materials and methods

This study was done after approval by the Institutional Review Board at our institution. Information related to clinical history, surgery, neuroimaging, including MRI, and outcomes of patients with AVM between 2000 and 2013 were collected retrospectively by review of case notes and follow-up charts.

2.1. Patients and tumor characteristics

The characteristics of the patients and lesions are listed in Table 1 and 2. Briefly, the median age was 41 years (range:

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Table 1
Characteristics (age, sex and ethnicity), clinical features and treatment of intracranial arteriovenous malformation patients who underwent Gamma Knife (Elekta, Stockholm, Sweden) radiosurgery (GKRS)

Variables	Value
Age (years)	
Median	41
Range	17–76
Sex, n (%)	
Male,	43 (50.6)
Female	42 (49.5)
Ethnicity, n (%)	
Caucasians	61 (71.8)
African Americans	24 (28.2)
Clinical features, n (%)	
Neurological deficit	35 (41)
Prior hemorrhage	26 (31)
Prior embolization	8 (9.4)
Time between presentation and GKRS (months)	
Mean	17
Median	2.3

Table 2
Characteristics of arteriovenous malformations in patient series including size, location and Spetzler–Martin grade of nidus

Variables	Value
Nidus size (cm)	
Median	3
Range	0.4–9.5
Spetzler–Martin grade	
I	8
II	29
III	25
IV	21
V	2
Location of nidus	
Frontal	19
Parietal	29
Temporal	20
Occipital	25
Cerebellum	9
Thalamus	4
Brain stem	3
Basal ganglia	2
Corpus callosum	2

17–76). Out of the 85 patients, 43 (50.6%) were men and 42 (49.4%) were women, 61 (71.8%) were Caucasians and 24 (28.2%) were African Americans. Twenty-six (30.5%) patients had a history of prior hemorrhage, eight (9.4%) had undergone prior embolization and 35 (41%) had neurological deficits including numbness, hemiparesis and altered mental status.

2.2. Radiosurgical technique

GKRS was performed using the Leksell stereotactic unit (model C with automatic positioning system (Elekta, Stockholm, Sweden). The Leksell head frame was applied to the head under intravenous sedation and local anesthesia. The patient was then transferred to the MRI suite. High resolution contrast enhanced axial images of the brain were taken in the 3D spoiled gradient recalled echo sequence. The imaging data was then transferred to the Gamma Knife planning computer. The Leksell Gamma Plan software (version 5.34) was used to perform the dose planning. A management team including neurosurgeon, radiation oncologist and medical physicist performed dose selection and planning. The mean marginal dose to the AVM was 18 Gy (range: 14–25), maximum dose to the AVM was 36 Gy (range: 28–50), and mean 50% isodose line was 50% (range: 50–60). Mean radiation exposure time was 32 min (range: 12–82; Table 3).

Table 3
Summary of marginal dose, maximum dose and isodose line and radiation time used during treatment of arteriovenous malformation with Gamma Knife (Elekta, Stockholm, Sweden) radiosurgery

Parameter	Value
Mean marginal dose, Gy (range)	18 (14–25)
Mean maximum dose, Gy (range)	36 (28–50)
Mean isodose line, % (range)	50 (50–60)
Radiation time, min (range)	34 (12–82)

Table 4
Follow-up data with changes in nidus and complications after Gamma Knife (Elekta, Stockholm, Sweden) radiosurgery for arteriovenous malformation

Follow-up	Value
Nidus, n (%)	
Obliteration of the nidus	67 (79)
Increased nidus size	18 (21)
Time to control or enlargement, months (range)	
Obliteration of the nidus	35 (5–89)
Increased nidus size	23 (3–68)
Complications, n (%)	
Hemorrhage	2 (2.3)
Hydrocephalus	2 (2.3)
Cyst formation	1 (1.17)
Intervention required, n (%)	
Gamma knife radiosurgery	17 (20)
Resection	1 (1.17)

2.3. Follow-up

Preoperative and follow-up data were collected from the patients in this study. Neuroimaging studies were performed at 3 month intervals in the first year of the GKRS treatment, at 6 month intervals for the following 2 years and annually thereafter. Angiography was also done if MRI showed an interval increase in the size of the AVM or complete obliteration of the AVM. The median duration of follow-up was 32.65 months (range: 6–133).

2.4. Statistical analyses

Commercially available software SPSS Statistics (version 21.0; IBM Corporation, Armonk, NY, USA) was used for statistical analyses. Univariate analysis was performed to identify predictive factors for obliteration of the AVM. A chi-squared test was also used when applicable. A p value <0.05 was considered significant.

3. Results

3.1. Nidus growth control

The nidus obliteration rate after GKRS is listed in Table 4. The median volume of AVM nidus was 3 cm (range: 0.5–9.5). The most recent follow-up showed obliteration of the nidus in 67 (79%) of the patients and an increase of AVM size in 18 (21%). All patients with obliteration of the nidus were assessed using MRI and of them, 30 patients proceeded to digital subtraction angiogram (DSA). On average it took 35 months (range: 6–89) for obliteration of the nidus and 23 months (range: 3–68) for an increase in size of the AVM after GKRS. Median time for obliteration and increasing size of the AVM was 31 months and 15 months, respectively (Fig. 1–3).