



# Linear Accelerator Radiosurgery for Arteriovenous Malformations: A 10 year experience

Mobbs RJ, Stoodley MA, Vonau M, Kwok BCT, Kwok BCM, Smee RI  
*The Prince of Wales Hospital and the University of New South Wales  
Sydney, Australia*



## Abstract

**Purpose:** In comparison to other radiosurgery modalities, there are few publications regarding the efficacy of LINAC radiosurgery for arteriovenous malformations (AVMs). A series of AVMs treated at a single institution is presented.

**Methods:** LINAC radiosurgery was used to treat 124 AVMs in 119 patients (age 7 - 72 yrs, mean 32.5). 12 months follow-up or more was possible for 113 patients and 117 AVMs. Presentation was with hemorrhage in 72 patients, epilepsy in 18, and neurological deficit in 11. Radiosurgery was the sole treatment in 87 cases; 7 patients had embolization and 18 had surgery prior to radiosurgery. Spetzler grades were: I, 4 cases; II, 53; III, 44; IV, 16. AVM diameters were 4 - 46 mm (mean 23 mm) and volumes were 1.5 - 51 cc (mean 6.4 cc). One hundred and seven (102) AVM's were supratentorial. Peripheral isodoses ranged from 90 - 110% (median 100%). Treatment doses ranged from 12 to 25 Gy (mean 20 Gy). Average clinical follow-up was 52 months.

**Results:** Obliteration was achieved in 81 of 102 patients followed with angiography. A further 10 patients were judged to have obliteration based on MRI, with an overall obliteration rate (OR) of 78%. Mean time to obliteration was 21 months. The OR was 33% at 12 months and 69% at 24 months. Factors associated with obliteration included small AVM volume, young age, and hemispheric location. Recurrent hemorrhage occurred in 9 cases (7.6%). There were 4 deaths due to hemorrhage (3%). Other complications included brain necrosis (2.9%), epilepsy (3.8%), hemiparesis (4.8%) and cranial nerve deficits (2%).

**Conclusion:** LINAC is a viable alternative to other forms of radiosurgery and should be considered for surgically unsuitable cases .

## Introduction

Stereotactic radiosurgery is an important treatment modality for cerebral arteriovenous malformations (1-6). For small AVMs (volumes less than 4 cc) obliteration rates of 64 to 96% have been reported. For larger AVMs (volumes greater than 14 cc), obliteration rates of as low as 23% have been reported (2-3,5-7). The hemorrhage rate from treatment to obliteration is probably no different to the natural history, although higher and lower rates have been reported (7). The morbidity following radiosurgery also has a widely reported range of 1-11%, including a permanent neurological deficit rate of 1-5% (3-7) . Despite the effectiveness and relative safety of radiosurgery in the management of many AVMs, its precise role in the overall management of the condition remains unclear. In addition, there are few large published series of AVMs treated with LINAC radiosurgery. The aim of this report is to present the 10 year results of LINAC radiosurgery for AVMs at Australia's largest radiosurgical center.

Table 1. Patient characteristics

	Number	Percent
Patients total	119 patients (124 AVMs)	
Patients with > 1 yr F/U	113 patients (117 AVMs)	95%
Gender: M/F	62/51	55%/45%
Prior treatments:		
Embolization	7	6%
Surgery	18	16%
Radiosurgery elsewhere	2	2%
Location:		
Supratentorial	102	87%
Infratentorial	15	13%
Spetzler-Martin grades		
I	4	3%
II	53	45%
III	44	38%
IV	16	14%

## Methods & Materials

### Patient population

From November 1990 to January 2001, 124 AVM's (119 patients, Table 1) were treated at the one institution under the guidance of the senior author (RIS). Adequate follow-up of more than 12 months was possible for 113 patients (117 AVMs). The mean patient age was 32.5 years. The gender ratio of male: female was 55%:45%. There was a total of 102 supratentorial AVMs (87%) and 15 infratentorial (13%); 13 brainstem and 2 cerebellar.

### Dosimetry

Lesion dimensions were 4 - 46 mm (mean 23 mm). A median radiation dose to the AVM margin was 20 Gy. Treatment doses ranged from 12 - 25 Gy. Target volume margins were enclosed by isodoses from 90 - 110%. Two or more isodoses were used in 21% of cases (22/105, Graph 1).

### Follow-up

Patients are followed up in a combined clinic every 6 months, or earlier on appropriate clinic grounds. Follow-up angiography (or MRA for patients refusing angiography) is performed at 12, 24 and 36 months. The patient population is geographically diverse (many from New Zealand and Asia) and long term follow-up is therefore difficult. Many follow-up imaging studies are not done at the referring centers. If obliteration was not achieved at an end point of 24 - 36 months, repeat radiosurgery or alternative treatment was recommended.

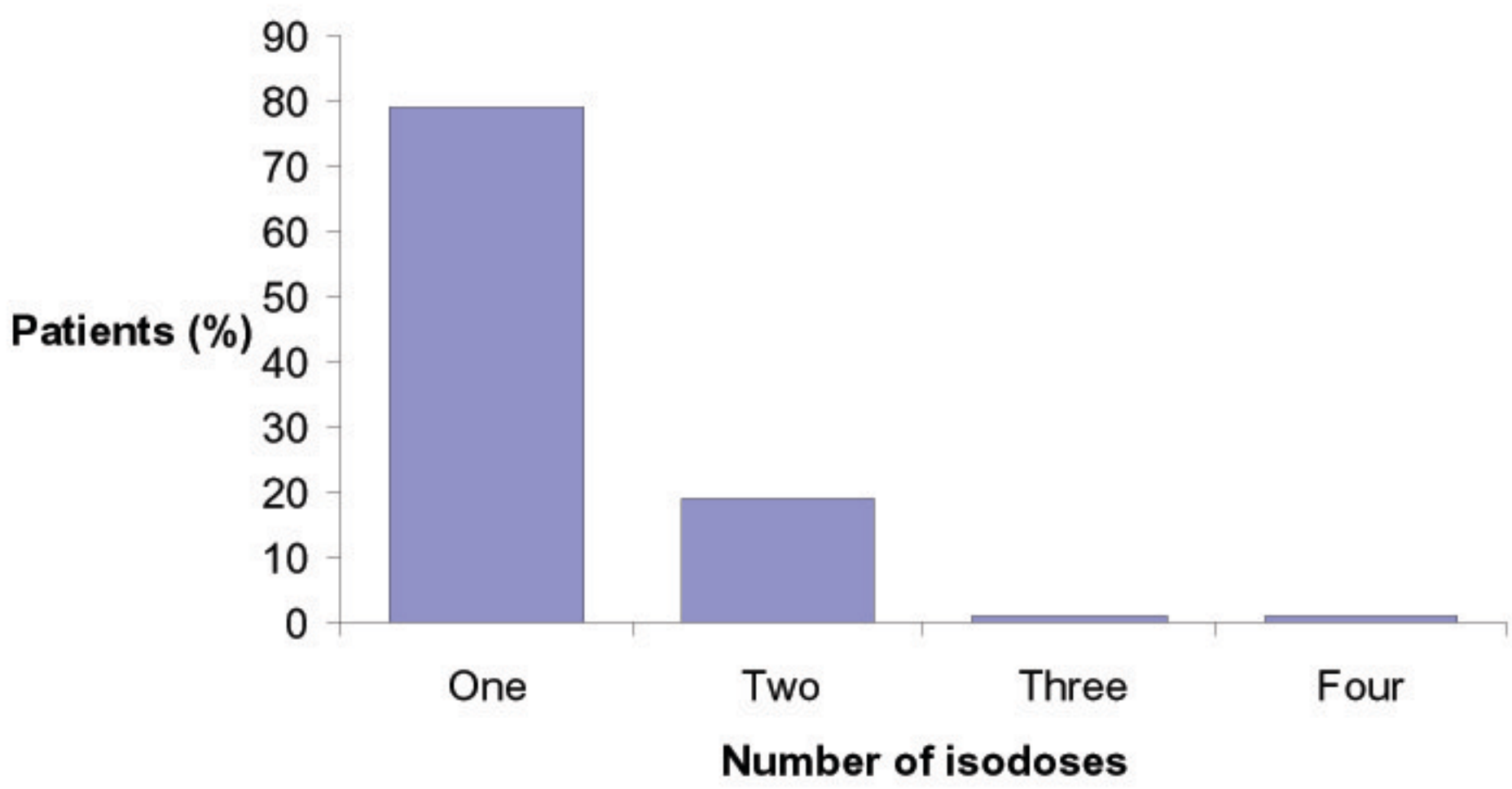


Figure 1. Distribution of isodoses used to treat AVMs.

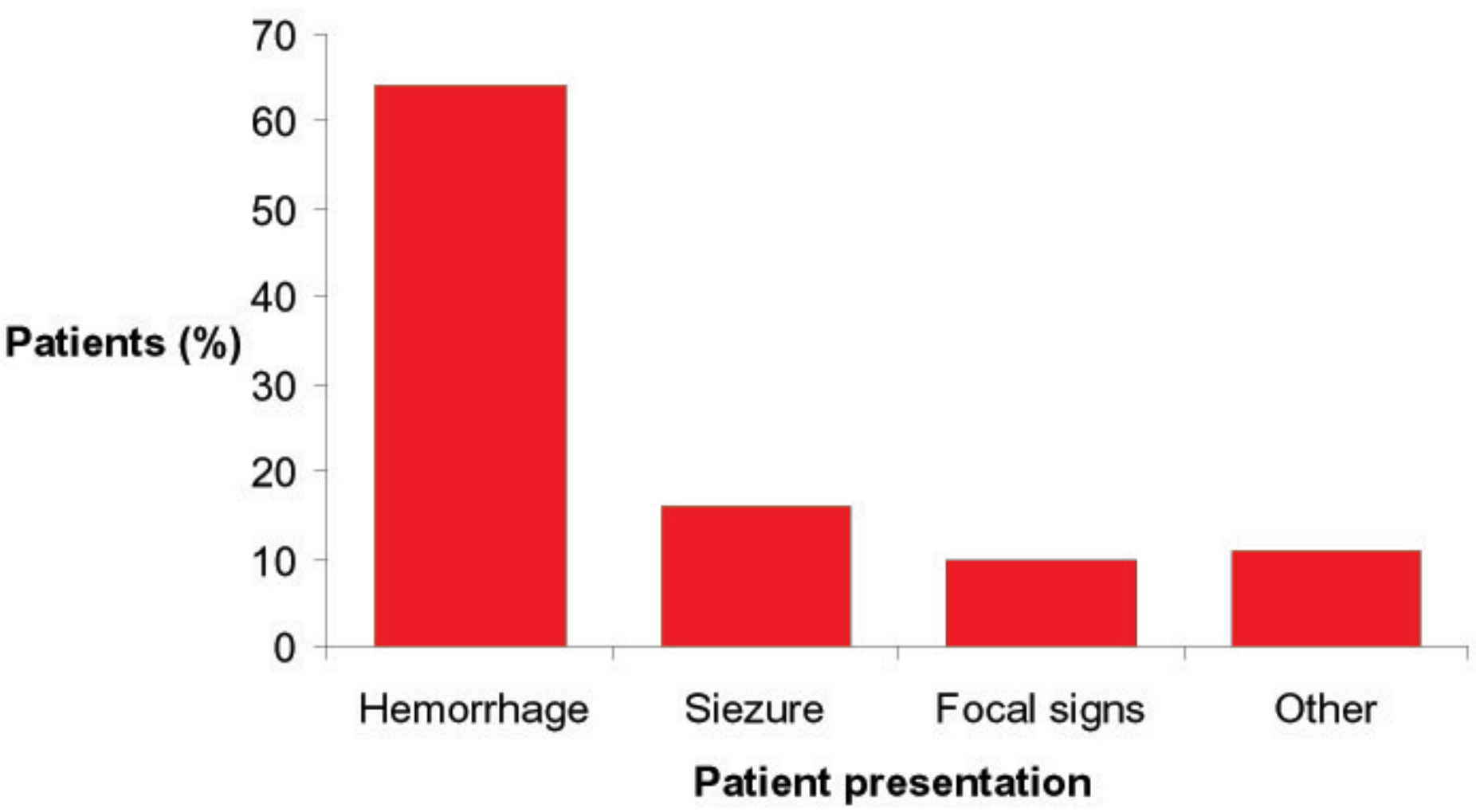


Figure 2. Initial clinical presentation for AVMs.

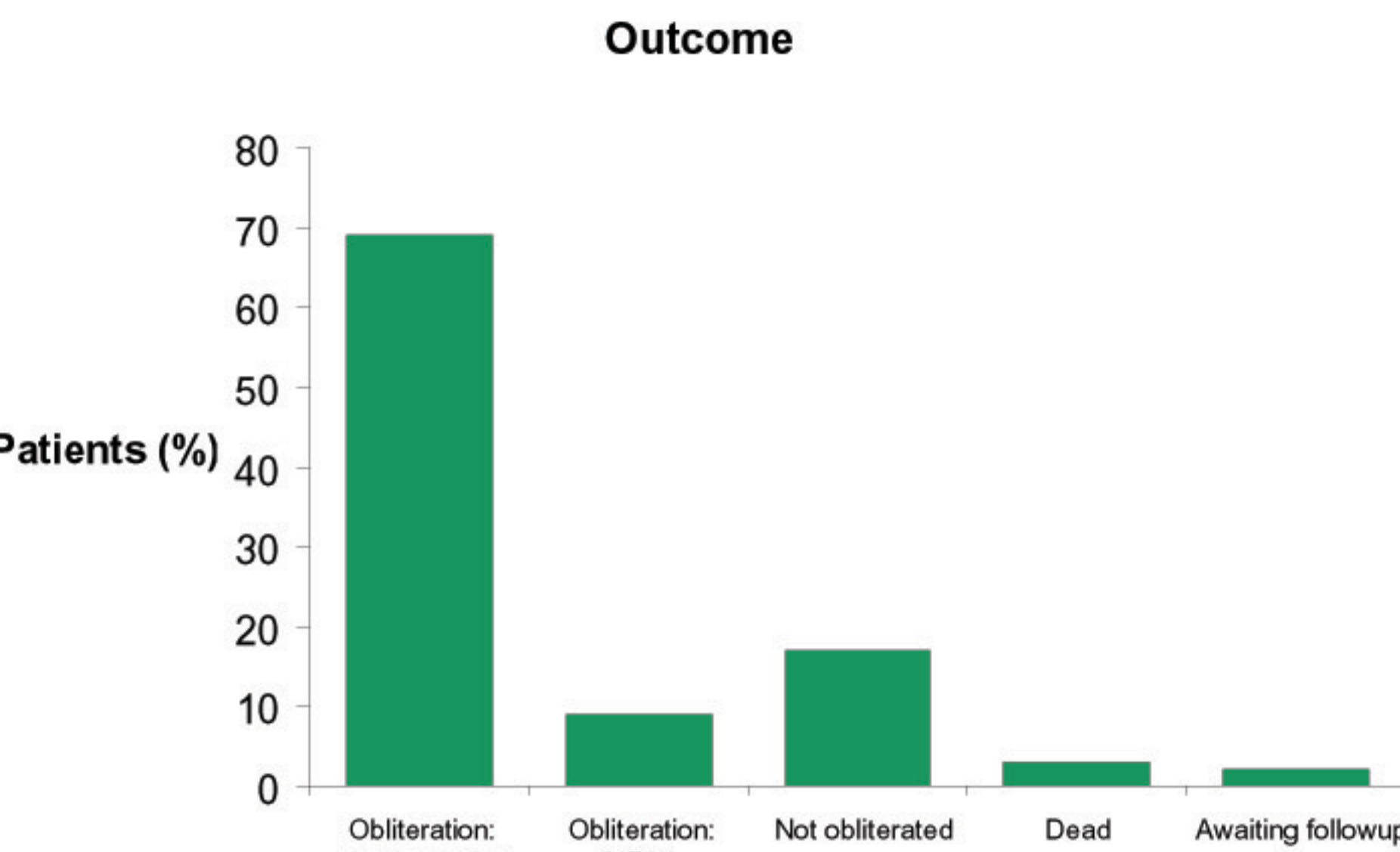


Figure 3. Outcome after radiosurgery for 113 patients with 119 AVMs.

## Results

Hemorrhage was the presenting feature in 64% of cases (Figure 2) and 25 patients had received prior for their AVMs (Table 1).

### Obliteration

Obliteration was achieved in 81 of 102 patients followed with catheter angiography. A further 10 patients were judged to have obliteration based on MRI, with an overall obliteration rate of 78% (Figure 3). The mean time to obliteration was 21 months. The obliteration rate was 33% at 12 months and 69% at 24 months (Figure 4). Factors positively associated with obliteration included small AVM volume (less than 35 mm diameter), young age, and hemispheric location. The mean diameter for the non-obliterated group in this series was 26 mm, compared with the obliterated group at 20 mm.

### Complications

Hemorrhage occurred after treatment in 9 cases (7.6%), with 4 deaths (3%). Other complications included brain necrosis (2.9%), epilepsy (3.8%), hemiparesis (4.8%) and cranial nerve deficits (2%). There was a new permanent neurological deficit rate of 7% (8/113).

### Retreatment

Four patients had retreatment for non obliterated AVMs during the study period with 12 months or more follow-up. Three patients had obliteration of their AVMs following retreatment.

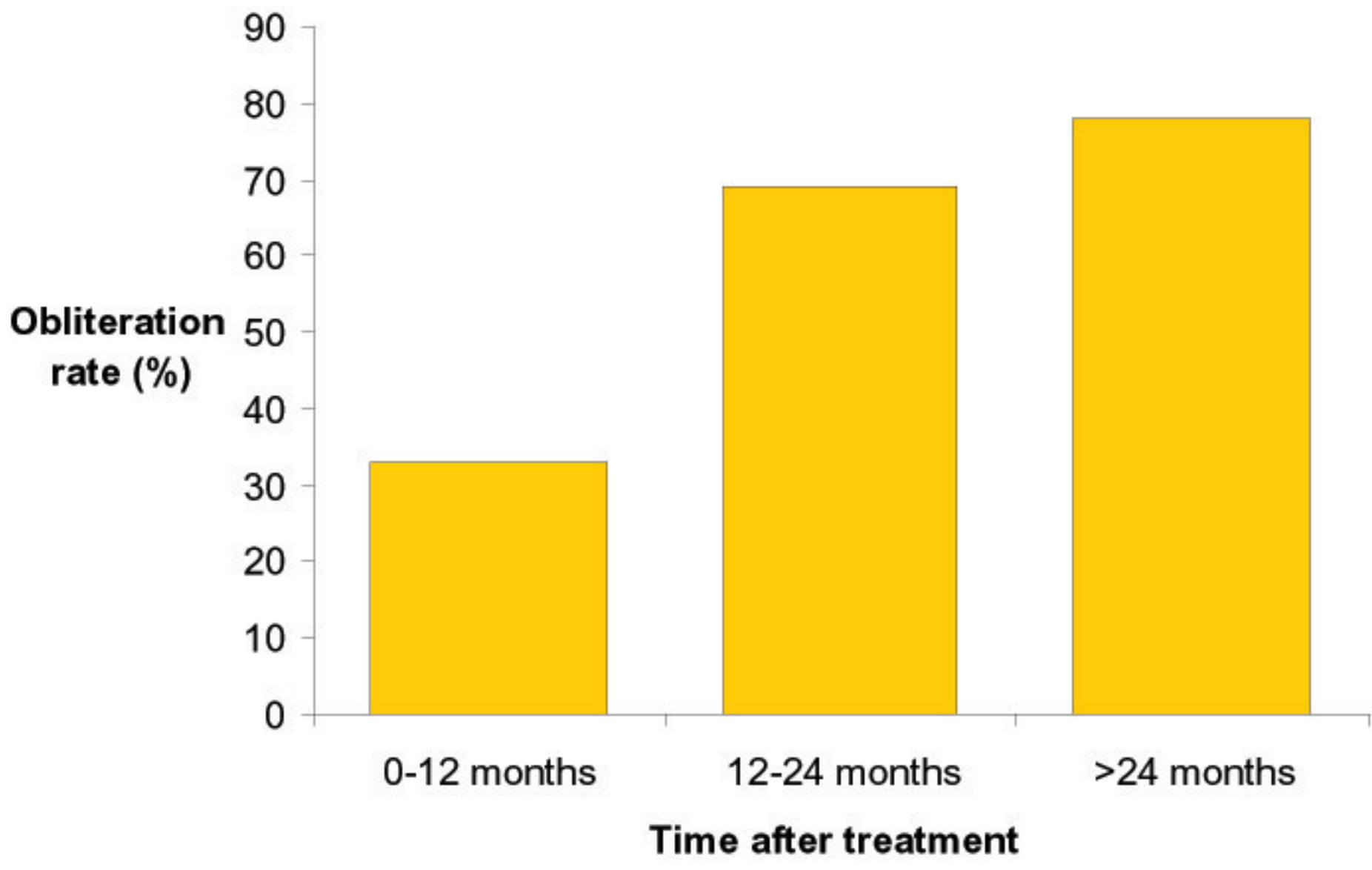


Figure 4. Obliteration rate of AVMs at various times after treatment with radiosurgery.

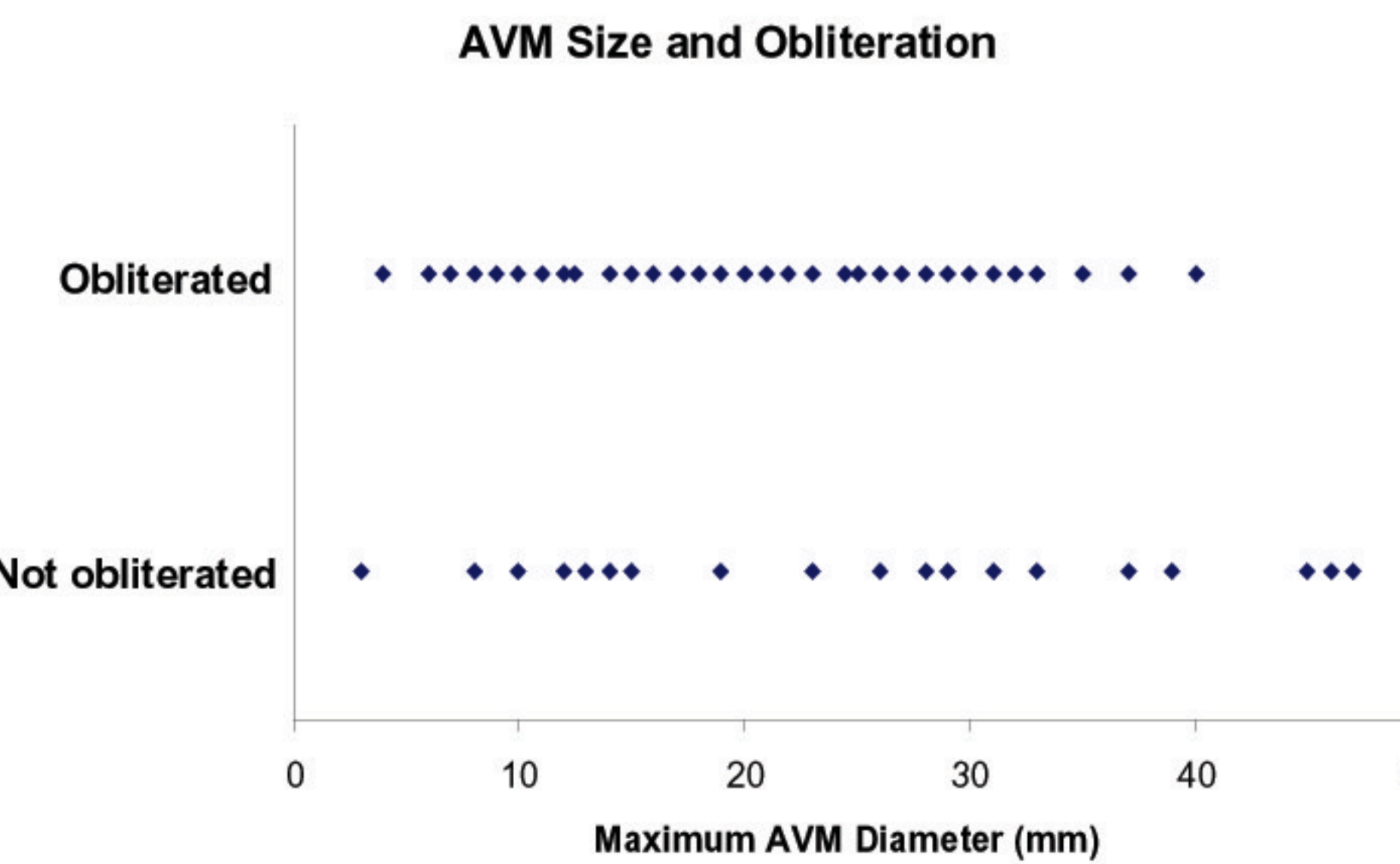


Figure 5. Scatter plot demonstrating the relationship between maximum AVM diameter and obliteration after radiosurgery.

## Conclusions

The overall obliteration rate of 78% in this study is comparable to other large studies of LINAC and gamma knife treatment for AVM's. An AVM size of less than 35 mm diameter correlates well with obliteration. However, our data do not support the linear relationship of size to obliteration rate as described by many articles in the literature (Figure 5).

LINAC is a viable alternative to other forms of radiosurgery and should be considered for surgically unsuitable cases.

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