ORIGINAL ARTICLE

Comparing monomodality treatments of low-grade intracranial arteriovenous malformation at Hospital Kuala Lumpur between 2008 and 2011: A retrospective study

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ABSTRACT

Introduction: Intracranial arteriovenous malformations (AVMs) of Spetzler-Martin grades (SMGs) I-III are treated using either monomodality treatments of microsurgical excision, embolization or stereotactic radiosurgery (SRS), or a combination of two or more of these treatment options. At Hospital Kuala Lumpur, we still practice monomodality treatments for AVMs of these three grades. In this study, we wanted to achieve an understanding whether monomodality treatments can achieve a satisfactory outcome of AVM nidi for patients, for up to 3 years, and to gather an objective data for AVM treatment for the Malaysian population.

Subjects and Methods: This is a retrospective review of records study. The data are acquired from case notes of patients with intracranial AVM of SMGs I to III who underwent monomodality treatment at Hospital Kuala Lumpur between 2008 and 2011. The patients were followed up with imaging for up to 3 years from the date of treatment. A total of 81 patients were recruited in this study, where 30 underwent microsurgical treatment, 27 underwent embolization, and 24 underwent SRS.

Results: Total obliteration of AVM nidus was achieved in 96.7% of patients who underwent microsurgery, 8.7% of patients who underwent embolization, and 79.2% of patients who underwent SRS. The modified Rankin scale (mRS) for all three groups showed an improving trend, with the microsurgery group showing the best improvement (from 70% at 3 months to 92.3% at 3 years showing favorable mRS scores).

Conclusions: The AVM nidus obliteration for each treatment group is comparable to the meta-analysis published in 2011. Each modality had its own set of complications; however, most of the patients in all three groups had either static or improved mRS at the end of the 3-year follow-up.

Key words: Arteriovenous malformation, embolization, Malaysia, microsurgery, stereotactic radiosurgery

Introduction

Arteriovenous malformation (AVM) is an abnormal connection between arteries and veins, which bypasses the capillary system. Although it can appear in any location, this vascular anomaly is widely known due to its occurrence in the central nervous system.

AVMs are one-tenth as common as saccular aneurysms and about equally frequent in males and females.[1] Bleeding or

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seizures are the main presentations. The rate of hemorrhage in untreated patients is between 2% and 4% per year, with a mortality rate of 5–10% and a 50% risk of serious neurological morbidity with each hemorrhage.[1,2]

AVMs are commonly graded using the Spetzler-Martin grade (SMG) system, which categorizes AVMs based on size (<3 cm, 3–6 cm, more than 6 cm), eloquence of adjacent brain tissue (eloquent areas include the brainstem, thalamus, hypothalamus, cerebellar peduncles, sensorimotor cortex, language cortex, or primary visual cortex), and the presence of deep venous drainage.[3] However, Spetzler and Ponce in 2011 proposed a 3-tiered grading system to simplify the original 5-tiered system as the differences in surgical results between the newly paired grades were small (A: SMG I and II, B: SMG III, C: SMG IV-V).[4]

There are several treatment modalities for AVMs: Microsurgery, endovascular embolization, and stereotactic radiosurgery (SRS). Surgical excision remains the gold standard treatment for accessible, low-grade AVM. In a meta-analysis of 6 journals between January 2000 and March 2011 by van Beijnum *et al*., successful AVM obliteration was achieved in 96% (range: 0–100%) after microsurgery, 38% (range: 0–75%) after SRS, and 13% (range: 0–94%) after embolization.[5]

However, resection of deep-seated AVMs, such as within the thalamus and the brainstem, remains a therapeutic challenge. In a long-term outcome study by Koga *et al*., the annual hemorrhage rate before SRS was 14%, but with treatment, the obliteration rate was 82% at 5 years after treatment, and the annual hemorrhage rate after SRS dropped to 0.36%.[6]

This is a retrospective review of records study to ascertain the efficacy of microsurgery, embolization, and SRS for patients with AVMs of SMG I, II, and III in Hospital Kuala Lumpur between 2008 and 2011 and in determining their outcome up to a period of 3 years posttreatment.

Subjects and Methods

In this retrospective review of records study, the data were acquired from retrospective case review of patients with AVM admitted to Hospital Kuala Lumpur between January 2008 and December 2011. A list of patients was obtained from the medical record office, identified using International Classification of Diseases–Tenth Revision, which is Q28.2.

Several keywords were employed, including intracranial bleed (ICB), intracerebral bleed (ICB) and AVM.

Inclusion criteria

- Intracranial AVM confirmed by imaging (magnetic resonance imaging [MRI]/cerebral angiogram)
- AVMs of SMGs I to III
- AVM patients treated using monomodality treatment of microsurgery, SRS, or embolization
- For patients who underwent embolization, completion of treatment meant the patient either achieved complete obliteration of AVM nidus or was no longer amendable for further embolization treatment
- Patients with continued follow-ups with imaging for up to 3 years from the date of treatment.

Exclusion criteria

- AVMs of SMGs IV, V, and VI
- AVMs of SMGs I, II, or III that has been treated using a combination of the above-mentioned treatment modalities
- For patient who underwent embolization, the patient was scheduled for further embolization sessions beyond the period of the study
- Evidence that the hemorrhage is due to an aneurysm or hemorrhagic stroke
- Hemorrhagic transformation of ischemic stroke
- Intracerebral hemorrhage is secondary to tumor or trauma
- Severe preexisting physical or mental disability or severe comorbidity, which might interfere with the assessment of outcome.

The patient's Glasgow Outcome Scale (GOS) was measured upon discharge, followed by modified Rankin scale (mRS) during outpatient follow-ups with a comparative imaging (angiogram and/or MRI/magnetic resonance angiogram) up to 3 years from the date of treatment.

The statistical software we employed was the IBM SPSS Statistics version 21.0. As most of the variables are categorical, their descriptive analyses are expressed as means, percentages, and frequencies and will be represented as bar charts, pie charts, etc. A $P < 0.05$ is considered statistically significant.

Results

Demographic study

Gender distribution was almost equal, with 51.9% of the patients being female. The ethnic distribution in this study is comparable to the distribution of general Malaysian population, which consists of 50.1% Malays, 22.6% Chinese, 11.8% indigenous races, 6.7% Indians, 0.7% of other ethnic groups, and 8.2% noncitizens (Department of Statistics Malaysia, 2010).

The median age of 27 years old for our patients is younger than that of the meta-analysis done in 2011 (34 years old) and that of a cohort study of 195 patients done between 1998 and 2011 in Prague (42 years old)[5,7] [Table 1].

Clinical and radiological presentation

56.8% of the patients in this study presented with intracranial hemorrhage, similar with that published in textbooks and in a demographic study on 1289 AVM patients done by Hofmeister *et al*. which reported hemorrhage occurring in 53%

Table 1: Comparison of demographic characteristics between treatment modalities

	Treatment modality *n* (%)			Total *n* (%)	*P*
	Microsurgery	Embolization	SRS		
Gender					
Male	15 (50.0)	12 (44.4)	12 (50.0)	39 (48.1)	0.923
Female	15 (50.0)	15 (55.6)	12 (50.0)	42 (51.9)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Race					
Malay	17 (56.7)	16 (59.3)	14 (58.3)	47 (58.0)	0.579
Chinese	11 (36.7)	9 (33.3)	5 (20.8)	25 (30.9)	
Indian	1 (3.3)	2 (7.4)	3 (12.5)	6 (7.4)	
Others	1 (3.3)	0 (0.0)	2 (8.3)	3 (3.7)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Age					
Median (IQR)	27.5 (17)	25.0 (21)	27.5 (14)	27.0 (18)	0.665

Age analyzed using Kruskal-Wallis test; gender analyzed using Chi-square test; race analyzed using Fishers exact test. IQR – Interquartile range; SRS – Stereotactic radiosurgery

(95% confidence interval [CI], 54–59%) of patients.[8] Seizures occurred in 35% of the 81 patients included in this study, also comparable with the same demographic study, which reported 30% (95% CI, 27–33%) of patients presenting with generalized or focal seizures. Unfortunately, in our study, there was no description of type of seizure.

Most of the patients had good Glasgow Coma Score (GCS) of 13–15 on presentation (69%). However, 19.8% ($n = 16$) of our patients presented with poor GCS (3–8). Of those, 14 patients had an intracranial hemorrhage. 7 out of 9 patients in the moderate GCS group (9–12) also presented with intracranial hemorrhages. 30 patients also had intraventricular hemorrhage, with 7 of them belonging to the moderate GCS group and 10 of them belonging to the poor GCS group. Both intracranial hemorrhage and intraventricular hemorrhage occur more in patients who came with moderate and poor GCS as compared to those who came with mild GCS, showing statistical significance ($P = 0.004$ and <0.001, respectively).

Based on angiographic findings, most of the patients had AVMs with a small nidus size of <3 cm in diameter (77.8%, $n = 63$), and none of them had a nidus of more than 6 cm in diameter. Of those, 37 (58.7%) patients had an intracranial hemorrhage, while 26 patients did not have intracranial hemorrhage. This did not show any statistical significance at a $P = 0.593$ using Fisher's exact test. Most of our patients did not have lesions within eloquent areas of the brain (79.0%), while lesions with superficial and deep venous drainages were almost equally distributed (51.9% with superficial-only venous drainage). In this study, 33.3% of our patients were of SMG I, 45.7% were of SMG II, and 21.0% were of SMG III. Only 13.6% of our patients were found to have aneurysms on angiographic studies. As for the lateralization of AVMs, more than half of our patients had left-sided AVMs (53.1%), and a large number had lesions within the frontal lobe (21.0%), the parietal lobe (21.0%), and the temporal lobe (18.5%) [Table 2].

Microsurgery

Of the 81 patients included in this study, 30 patients underwent microsurgical excision of AVM. 15 of them were of SMG I (50.0%), 10 were of SMG II (33.3%), and 5 (16.7%) were of SMG III. 22 (76.3%) of them had a nidus of <3 cm in diameter, and none had a nidus of more than 6 cm in diameter. 7 (23.3%) patients had AVM within eloquent areas of the brain.

4 patients passed away. 2 patients died within 30 days of hospital stay postexcision of AVM; 1 of them died due to acute pulmonary edema, and the other died due to massive hemorrhage postoperatively. 1 patient had a persistent cerebrospinal fluid leak and subsequently developed ventriculitis, and passed away during her second admission. One patient had a complicated surgery with the AVM nidus not fully excised, and subsequently died on the 49th day of admission due to sepsis.

Of the 26 patients who survived, 25 patients had their AVM obliterated (96.2%). 1 patient had minimal residue on the angiographic study. The obliteration rate that we achieved is comparable with the meta-analysis that recorded 96% (range: 0–100%) obliteration rate for microsurgical excision of AVM.[5]

When we compared the obliteration rate for all three modalities, the difference between treatment modality and the obliteration of AVM showed statistical significance ($P < 0.001$). Further analyses revealed that while the comparison between microsurgery and embolization with obliteration of AVM still showed statistical significance ($P < 0.001$), the difference between microsurgery and SRS with obliteration of AVM did not show statistical significance (P 0.093). This is in keeping with the recommendation in various textbooks and journals regarding the use of monomodality treatment of either microsurgery or SRS for AVMs of SMG I and II, and small-sized SMG III[9-11] [Table 3].

Surgery is not without complications. 2 patients bled after surgery, 2 patients had significant residual hematomas, whereas another 2 patients developed a wound infection. 3 patients developed breakthrough seizures within 30 days postsurgery. A total of 15 patients (50%) had complications, higher than those recorded (21%) in a published article on complications from surgery for brain AVMs.[12]

Endovascular embolization

27 patients underwent endovascular embolization of AVM. 2 (7.4%) patients were of SMG I, 17 (63%) were of SMG II, while 8 (29.6%) were of SMG III. With only 7.4% of patients having SMG I AVMs, this shows statistical significance when comparing between the three treatment modalities with SMG (P 0.013) as 50% of the microsurgical group were of SMG

Table 2: Comparison between treatment modalities

	Treatment modality *n* (%)			Total *n* (%)	*P*
	Microsurgery	Embolization	SRS		
GCS on presentation					
Mean (SD)	12.9 (3.6)	11.9 (3.9)	13.3 (3.0)	12.7 (3.6)	0.349
Mild (13-15)	22 (73.3)	16 (59.3)	18 (75.0)	56 (69.1)	0.621
Moderate (9-12)	2 (6.7)	4 (14.8)	3 (12.5)	9 (11.1)	
Severe (3-8)	6 (20.0)	7 (25.9)	3 (12.5)	16 (19.8)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Neurological deficit					
No	16 (53.3)	15 (55.6)	15 (62.5)	46 (56.8)	0.786
Yes	14 (46.7)	12 (44.4)	9 (37.5)	35 (43.2)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Intracranial hemorrhage					
No	11 (36.7)	13 (48.1)	11 (45.8)	35 (43.2)	0.651
Yes	19 (63.3)	14 (51.9)	13 (54.2)	46 (56.8)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Intraventricular hemorrhage					
No	22 (73.3)	16 (59.3)	13 (54.2)	51 (63.0)	0.311
Yes	8 (26.7)	11 (40.7)	11 (45.8)	30 (37.0)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
S					
1	22 (73.3)	17 (63.0)	24 (100.0)	63 (77.8)	0.005*
2	8 (26.7)	10 (37.0)	0 (0.0)	18 (22.2)	
3	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
E					
0	23 (76.7)	21 (77.8)	20 (83.3)	64 (79.0)	0.821
1	7 (23.3)	6 (22.2)	4 (16.7)	17 (21.0)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
D					
0	22 (73.3)	10 (37.0)	10 (41.7)	42 (51.9)	0.008*
1	8 (26.7)	17 (63.0)	14 (58.3)	39 (48.1)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
SMG					
I	15 (50.0)	2 (7.4)	10 (41.7)	27 (33.3)	0.013*
II	10 (33.3)	17 (63.0)	10 (41.7)	37 (45.7)	
III	5 (16.7)	8 (29.6)	4 (16.7)	17 (21.0)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Barrow's classification					
Class A	25 (83.3)	19 (70.4)	20 (83.3)	64 (79.0)	0.402
Class B	5 (16.7)	8 (29.6)	4 (23.5)	17 (21.0)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Aneurysm					
No	25 (83.3)	22 (81.5)	23 (95.8)	70 (86.4)	0.277
Yes	5 (16.7)	5 (18.5)	1 (4.2)	11 (13.6)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	
Hospital stay (days)					
Median (IQR)	9.0 (6)	4.0 (4)	4.0 (1)	4.0 (5)	<0.001**
Symptom control					
Improving	25 (96.2)	20 (87.0)	23 (95.8)	68 (93.2)	0.583
Static	1 (3.8)	2 (8.7)	1 (4.2)	4 (5.5)	
Worsening	0 (0.0)	1 (4.3)	0 (0.0)	1 (1.4)	
Total	26 (100.0)	23 (100.0)	24 (100.0)	73 (100.0)	

Contd...

Table 2: Contd...

	Treatment modality *n* (%)			Total *n* (%)	*P*
	Microsurgery	Embolization	SRS		
New symptoms					
No	20 (76.9)	18 (78.3)	19 (79.2)	57 (78.1)	0.982
Yes	6 (23.1)	5 (21.7)	5 (20.8)	16 (21.9)	
Total	26 (100.0)	23 (100.0)	24 (100.0)	73 (100.0)	
New vascularization					
No	26 (100.0)	22 (95.7)	23 (97.3)	71 (97.3)	0.566
Yes	0 (0.0)	1 (4.3)	1 (4.2)	2 (2.7)	
Total	26 (100.0)	23 (100.0)	24 (100.0)	73 (100.0)	
Hemorrhage					
No	24 (80.0)	24 (88.9)	24 (100.0)	72 (88.9)	0.067
Yes	6 (37.0)	3 (33.3)	0 (0.0)	9 (11.1)	
Total	30 (100.0)	27 (100.0)	24 (100.0)	81 (100.0)	

Categorical data analyzed with Chi-square or Fisher's exact test; continuous data analyzed with one-way ANOVA or Kruskal–Wallis test. *Significant at $P<0.05$; **Significant at $P<0.001$. SD – Standard deviation; SRS – Stereotactic radiosurgery; GCS – Glasgow Coma Score; SMG – Spetzler-Martin grade; S – Size of nidus; E – Eloquent brain; D – Deep draining vein (s); IQR – Interquartile range

Table 3: Comparison between 3 treatment modalities and obliteration of AVM

Obliteration of AVM	Treatment modality *n* (%)			Total *n* (%)	*P*
	Microsurgery	Embolization	SRS		
No	1 (3.8)	21 (91.3)	5 (20.8)	27 (37.0)	<0.001**
Yes	25 (96.2)	2 (8.7)	19 (79.2)	46 (63.0)	
Total	26 (100.0)	23 (100.0)	24 (100.0)	73 (100.0)	

Data analyzed with Chi-square. **Significant at $P<0.001$. AVM – Arteriovenous malformations; SRS – Stereotactic radiosurgery

I and 41.7% of the SRS group were of SMG I. However, using the Barrow's classification of combining SMG I and II into Class A, and SMG III into Class B, the total number of Class A patients in the embolization group were 19 (70.4%) as opposed to 25 (83.3%) in the microsurgical group and 20 (83.3%) in the SRS group, making the comparison between these three groups not statistically significant (*P* 0.402).[4]

There was no statistical difference when comparing all three treatment modalities with the location of the AVM in eloquent areas of the brain (*P* 0.821) with <25% of patients from each group. However, the comparison between the presence of deep venous drainage with the treatment modalities showed statistical difference (*P* 0.008), as only 8 (26.7%) patients from the microsurgery group had deep venous drainage as compared to 17 (63.0%) from the embolization group and 14 (58.3%) from the SRS group.

4 patients passed away, with 3 who died within 30 days postembolization. 1 patient developed intraventricular hemorrhage with uncontrolled seizures, 1 had a ruptured anterior cerebral artery rupture during the procedure, and 1 patient developed hemorrhage from the AVM nidus immediately postprocedure. The fourth patient passed away from ventriculitis and subsequent sepsis 45 days after the procedure. Of the 23 patients who survived, only 2 (8.7%) patients had their AVM obliterated; both patients were of the SMG II group. Using the volume calculation of (length × width × height)/2 described by Malik *et al*., the percentage of residual AVM nidus volume was calculated once endovascular embolization treatment had been exhausted and the patients were no longer suitable for the treatment. 4 (17.4%) patients had minimal residue, and 6 (26.1%) patients had residual nidi of <50% its original volume. 1 patient had a nidus 50% of its original size, while 10 (43.5%) still had an AVM nidus of more than 75% its original size. When comparing the obliteration rate of AVM with all treatment modalities, the result was statistically significant ($P < 0.001$). Detailed analyses comparing microsurgery and embolization, as well as SRS and embolization also showed statistical significance ($P < 0.001$ for both analyses).

As embolization is usually a staged procedure, we also looked into the total number of procedures done and the number of procedure cancellations due to lack of Intensive Care Unit (ICU) backup. We found that 59.3% of the patients underwent a single procedure, while 37.0% had 2 procedures done and 3.7% had 3 procedures done before the AVMs were deemed unsuitable for further endovascular treatment.[7,13,14]

8 (29.6%) patients developed complications, including those who passed away. 2 patients developed breakthrough seizures, 3 patients developed hemorrhage, 1 complained of new-onset paresthesia, and 1 patient was reported to have a premature detachment of microcatheter. 1 patient developed ventriculitis and subsequently died of sepsis, but this was not directly related to the procedure. The patient had presented with both intraparenchymal hematoma and intraventricular hemorrhage, and an external ventricular drain had been inserted.

Stereotactic radiosurgery

A total of 31 patients underwent SRS for intracranial AVM at Hospital Kuala Lumpur between 2008 and 2011, but only 24 of them fit the inclusion and exclusion criteria for this study. Of those 24, 10 (41.7%) were of SMG I, 10 (41.7%) were of SMG II, and 4 (16.7%) were of SMG III. All of them had a nidus of <3 cm in diameter, and only 4 (16.7%) were located in eloquent areas of the brain. More than half of them (58.3%) were found to have AVMs with deep venous drainage.

19 (79.2%) patients showed total obliteration of AVM in angiographic studies done between 2 and 3 years post-SRS, higher than the percentage recorded in the meta-analysis in 2011 (38%, range 0–75%) and in an editorial by Chen and Ding in 2014 involving 444 patients with unruptured AVMs treated using SRS only (62%).[9,5] In this study, the obliteration rate of AVMs using SRS in is comparable with the obliteration rate via microsurgery (*P* 0.093). Of the 5 patients with residual AMs, 2 were of SMG I, 2 were of SMG II, and 1 was of SMG III. Comparison between SMG type and obliteration of AVM within this group showed no statistical significance (*P* 0.975).

There was no death reported in this group. Nevertheless, 5 (20.8%) patients developed complications. 3 patients developed breakthrough seizures within 24 h postprocedure, 1 complained of persistent and worsening headache from 6 months after the procedure, and 1 patient was suspected to have developed radionecrosis.

Outcome

Of the three modalities, patients in the microsurgery group had the longest hospital stay (9 days, interquartile range [IQR] 6), followed by embolization (4 days, IQR 4) and SRS (4 days, IQR 1), which showed statistical significance ($P < 0.001$). Most patients who underwent embolization only required an overnight observation in the ICU, while none of the patients who had SRS needed any ICU backup.

Most of the patients in all three groups were reported to have an improvement in symptom control, with a total of 93.2% out of the patients who survived. 4 patients did not have any improvement, while 1 patient complained of worsening symptoms. Symptom control did now show any statistical significance across the three groups (*P* 0.583).

In this study, the outcome was measured using the GOS upon discharge and using the mRS at 3 months, 6 months, 1 year, 2 years, and 3 years of follow-up.[15-17]

The GOS can be dichotomized into favorable (GOS of 4–5) and nonfavorable (GOS 1–3) outcomes. In total, 77.7% patients were reported to have a favorable outcome; most of them (69.1% of total patients) scored GOS 5 (light damage with minor neurological and psychological deficits). 8 patients passed away as described above, with a total mortality rate from AVM treatment of 9.9%. None of the patients in this study scored GOS 2 (permanent vegetative state).

When broken down into individual groups, the microsurgical group had the least patients with a favorable GOS (70.0%), compared to embolization (77.8%) and SRS (87.5%). However, we noted that the best improvement of clinical condition based on mRS at the end of the study also came from the microsurgery group. Of the patients who survived, 80.7% of patients from the microsurgery group scored favorable mRS (mRS 3–5). 91.3% of patients from the embolization group and 87.5% of patients from the SRS group also recorded favorable mRS. At 3 years, patients in the microsurgery group improved further, with 92.3% of them showing favorable mRS scores. The embolization group remained static at 91.3%, whereas the SRS group improved to 91.7% of them showing favorable mRS scores. In total, 91.7% of the patients in this study were recorded to have favorable mRS scores at the end of their 3-year follow-up, which improved from 86.3% at 3 months.

2 patients were recorded to have neovascularization on angiographic studies, 1 from the embolization group and 1 from the SRS group. Despite the recorded risks of hemorrhage of 2.2% annually and 6.0–6.9% within the 1st year after an AVM rupture, none of the patients in this study developed hemorrhage, other than those directly related to treatment.[18,19] Please note that we did not find any recurrent AVM in this study, possibly due to the short duration of the study (3 years).

Discussion

Although microsurgery is recommended for AVMs of SMG I and II in view of the high immediate cure rate and low risks of complications, monotherapy endovascular embolization and SRS are also offered for patients of SMG I, II, and III with obliteration rates of 96% (range: 0–100%) after microsurgery, 38% (range: 0–75%) after SRS, and 13% (range: 0–94%) after embolization.[5,11]

Hospital Kuala Lumpur offers all three modalities in treating intracranial AVMs. The primary managing team for intracranial AVMs is from the Neurosurgery Department. Angiography and endovascular embolization are done by intervention radiologists from the Radiology Department, while SRS is co-managed with radio-oncologists from the Nuclear Medicine Department.

Monomodality therapies are done for AVMs of SMG I, II, and III. Combined therapies are also done, but in the interest of this dissertation, such cases have been excluded during the case selection process.

The primary end-target of this study is the successful obliteration of AVM nidus for each of the three monomodality treatments, based on the meta-analysis done by van Beijnum *et al*. in 2011 that reported successful AVM obliteration was achieved in 96% (range: 0–100%) after microsurgery, 38% (range: 0–75%) after SRS, and 13% (range: 0–94%) after embolization.[5] Nonetheless, other parameters such as patient demographics, clinical and radiological features of the AVMs, as well as complications and clinical outcomes measured using GOS and mRS were taken into account.

This study was done to evaluate whether there was a difference in the obliteration of AVMs of SMG I, II, and III using a monomodality treatment of either microsurgery, endovascular embolization, or SRS at Hospital Kuala Lumpur as there is no Malaysian data for us to use when managing patients with intracranial AVM, both for the patients' informed benefit and for us to plan a proper management for them. Moreover, we would like to evaluate whether we could achieve a cure rate for intracranial AVMs comparable with international studies.

Our study has shown that between 2008 and 2011, we could achieve 96.2% obliteration of AVMs of SMG I-III with microsurgery, 79.2% with SRS, and 8.7% with embolization. The findings are comparable to the meta-analysis published in 2011, where successful AVM obliteration was achieved in 96% (range: 0–100%) after microsurgery, 38% (range: 0–75%) after SRS, and 13% (range: 0–94%) after embolization. Although we had a lower obliteration rate with endovascular embolization, our cure rate using SRS was comparable with microsurgery. Based on this study, we could conclude that although there were differences in the obliteration of AVMs of SMG I-III, the findings were statistically significant between microsurgery and embolization, as well as between SRS and embolization, but they were not statistically significant between microsurgery and SRS.

We also noted a 9.9% mortality rate from the treatment of AVM, with 4 patients from the microsurgery group and another 4 from the embolization group. Each treatment modality also had its own set of complications; however, surviving patients from all three groups mostly showed an improvement in clinical conditions, from 77.7% of patients showing favorable GOS upon discharge to 86.3% of patients showing favorable mRS at 3 months' follow-up, and finally 91.7% of patients showing favorable mRS at 3 years' follow-up.

As we can achieve good AVM nidus obliteration using microsurgery and SRS, it will be good to explore and develop these treatment options further. Embolization, however, still plays a vital role in complicated cases (eloquent regions, large AVM), as well as an important part in a multimodality approach.

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Conflicts of interest

There are no conflicts of interest.

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