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Efficacy and safety of endovascular embolization of cerebral AVM

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ORIGINAL ARTICLE

Efficacy and Safety of Endovascular Embolization of Cerebral Arteriovenous Malformation

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Abstract

Background: **Endovascular embolization of cerebral arteriovenous malformations (AVMs) has several benefits including AVM occlusion and flow reduction in preparation for other treatment techniques.**

Aim and objectives: **The aim was to assess the efficacy and safety of endovascular embolization of cerebral AVM with different techniques and materials.**

Patients and methods: **In a prospective and retrospective study, 22 patients diagnosed as having AVM or arteriovenous fistula who underwent endovascular embolization at Neurosurgical Intervention Unit et al. Hussein University Hospital were recruited in the period from the beginning of January 2020 to the end of May 2022.**

The authors included patients aged above 1 month, diagnosed to have cerebral AVM or arteriovenous fistula. Patients with recent cerebral hemorrhage were delayed for at least 2 weeks.

The authors excluded patients with vein of Galen malformation, neonatal AVM, patients who underwent surgical excision, patients with contraindication to radiation or dye injection, and inaccessible endovascular techniques such as severely tortuous vessels.

Results: **In the current study, the mean age was 24.5 ± 14.7 years. Most cases were male (68.2%). Most cases (86.4%) manifested headache, 40.9% had hemorrhage, 31.8% had side weakness, and 27.3% had fits. Spetzler and Martin grade of the cerebral AVMs was significantly improved after embolization compared with the initial grading score ($P = 0.002$). Eight patients showed complete occlusion of nidus and 14 had partial occlusion according to Spetzler and Martin grade. After 3 months of follow-up, modified Rankin scale, epilepsy, and headache were improved. No patient had procedure-related complications.**

Conclusion: **Endovascular embolization is safe and effective in patients with cerebral AVM.**

Keywords: AVM, Embolization, Modified rankin scale (mRS), Spetzler and martin score

1. Introduction

Cerebral arteriovenous malformation (AVMs) are developmental anomalies. These lesions are complex shaped consisting of a feeding artery, a drainage vein, and a vascular network (nidus) that consists of dysplastic capillaries and connect structures. They can arise anywhere in the body but are most frequently detected in the intracranial region.[1]

Of every 100 000 people, 10 experience an AVM, and every year, 0.42 out of every 100 000 people experience an AVM hemorrhage.[2] AVMs are thought to be a major cause of spontaneous intracerebral hemorrhage in those under 40 years of age.[3]

The vast majority of all AVMs are found in the cerebral hemispheres (85% supratentorial). Only 10% are found deep within the cerebral hemisphere, including basal ganglia, ventricles, and corpus callosum. Only 15% are found in the posterior fossa, and cerebellar hemisphere is a more common site than brainstem.[4]

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Patients with AVMs present with hemorrhage in 50% of the cases, which is considered the most common presentation; seizures in 30%; headaches in 10%, and neurological deficit in 10%. Any one of these symptoms may occur alone.[5]

Conventional angiography is the gold standard for diagnosing AVMs. Three therapy modalities are frequently used, either separately or in conjunction: embolization, stereotactic radiosurgery, and surgical removal.[6]

Endovascular embolization can be applied for a curative embolization, nidus reduction before surgery or radiosurgery, and palliative embolization. The purpose of curative embolization is to completely and permanently obliterate the AVM's nidus while preserving venous drainage and restoring normal arterial blood flow.[7]

This study aimed to assess the efficacy and safety of endovascular embolization of cerebral AVM with different techniques and materials.

2. Patients and methods

The study was approved by the Ethics Committee of the Al-Azhar Faculty of Medicine. We obtained written informed consent from parents/guardians before enrollment in this study.

In a prospective and retrospective study, 22 patients diagnosed clinically and radiologically as AVM or arteriovenous fistula who underwent endovascular embolization at the Neurosurgical Intervention Unit et al. Hussein University Hospital were recruited in the period from the beginning of January 2020 to the end of May 2022.

We included patients aged above one month, diagnosed to have cerebral AVM or arteriovenous fistula [either ruptured or not, symptomatic or accidently discovered, with high risk of bleeding because of small size (<3 cm), deep venous drainage, and/or associated aneurysm], and subjected to endovascular embolization with different techniques. Patients with recent cerebral hemorrhage were delayed for at least 2 weeks.

We excluded patients with vein of Galen malformation, patients who underwent surgical excision, patients with contraindication to radiation (e.g. pregnancy) or dye injection, inaccessible endovascular techniques such as severely tortuous vessels, and neonatal AVM.

All patients involved in this study were subjected to complete medical history, general and neurological examination, brain imaging studies, endovascular intervention, and postoperative clinical and radiological assessment.

Three different sized (transarterial) sheaths were used (4, 5, and 6 French). A guiding catheter was used followed by insertion of three types of selective catheters [Echelon, Apollo (SL10), and Marathon]. The embolizing materials used were Onyx, Histoacryl, and coils according to AVM size and availability of materials in our unit.

Outcome measures were immediate angiographic AVM occlusion rate using Spetzler and Martin grading (SMG), which detects size reduction. Modified Rankin scale (mRS) was used to evaluate clinical outcome (side weakness) immediately and 30 days after.

2.1. Statistical analysis

SPSS (Statistical Package for the Social Science) program version 25.0 (IBM Inc., Chicago, Illinois, USA) and Microsoft Office Excel 2016 software were used to calculate the statistical significance. Improvement was measured by mean change.

We used Kolmogorov–Smirnov test to validate normal distribution of data. Percentages and numbers represented qualitative data. Range (minimum and maximum), mean, and SD represented quantitative parametric data. Difference between qualitative variables was calculated using χ^2-test. The obtained findings were evaluated at 5% significance level.

3. Results

In the current study, 22 patients with cerebral AVM underwent embolization. The mean age was 24.5 ± 14.7 years. The majority of cases were male (68.2%). Seven (31.8%) patients were hypertensive, six (27.3%) were smoker, two (9%) had positive family history, and one (4.5%) had diabetes.

The majority of clinical cases manifested headache (86.4%; $n = 19$), nine (40.9%) had hemorrhage, seven (31.8%) had side weakness, and six (27.3%) had fits (Table 1).

AVMs were located in the right hemisphere in 12 patients (54.5%) and in left hemisphere in 10 (45.5%). The location of the AVMs in order of decreasing

Table 1. Clinical presentation of the studied group.

Clinical presentation	*N* (%)
Headache	19 (86.4)
Hemorrhage	9 (40.9)
Side weakness	7 (mRS >2) (31.8)
Fits	6 (27.3)
A symptomatic	1 (4.5)
Left eye proptosis	1 (4.5)
Bleeding from eye	1 (4.5)
cerebellar manifestation	1 (4.5)

Table 2. Distribution of studied sample according to Spetzler and Martin grading before and after embolization.

Spetzler and Martin grading (SMG)	Before embolization [*N* (%)]	After embolization [*N* (%)]	χ^2	*P* value
Grade I	0	0		
Grade II	2 (9.1)	0		
Grade III	1 (4.5)	5 (22.7)	17.04	0.002*
Grade IV	9 (40.9)	6 (27.3)		
Grade V	10 (45.5)	3 (13.6)		
Complete occlusion	0	8 (36.4)		
Total	22 (100)	22 (100)		

frequency was parieto-occipital in six (27.3%) patients, parietal in five (22.7%), temporoparietal in four (18.18%), temporal in four (18.18%), frontal in two (9%), and cerebellar in one (4.5%).

The number of arterial feeders in our study was multiple in 15 patients (68.2%) and single in seven patients (31.8%). The venous drainage of the AVMs was multiple in 19 patients (86.4%) and single in three patients (13.6%). The dural supply of the AVMs was positive in 18 patients (81.8%) and negative in four patients (18.2%). Nidus diameter before embolization of the AVMs was less than 3 cm in three patients (13.6%), 3–6 cm in nine patients (40.9%), and greater than 6 cm in 10 patients (45.5%). Echelon catheter was used in eight (36.4%) patients, Echelon + Apollo (SL10) catheters were used in two (9.1%), and in 12 (54.5%), Marathon catheters were used. The embolizing materials used were Onyx (68.2%; $n = 15$), Histoacryl (31.8%; $n = 7$), and coils (4.5%; $n = 1$) according to AVM size and availability of materials in our unit.

SMG of the cerebral AVMs was significantly improved after embolization compared with the initial grading score ($P = 0.002$). Eight patients (36.4%) showed complete occlusion of nidus and 14 (63.6%) had partial occlusion according to SMG (Table 2).

Regarding the modified Rankin scale, there was statistically significant improvement immediately and 30 days after embolization compared with the initial grading score ($P < 0.001$) in seven patients presented with weakness (Table 3).

Regarding the epilepsy outcome after 6 months, 83.3% of patients were well controlled, and the remaining patients had infrequent fits.

Regarding the headache outcome after 6 months, 94.7% of patients were improved.

No patient had procedure-related complications. No deaths related to the operation occurred. No bleeding or recurrence was observed in the follow-up (Table 4 and Figs. 1–3).

4. Discussion

Embolization of high-grade intracranial AVMs before surgical resection is an accepted treatment technique to improve the outcome. The goal of embolization before surgery or radiosurgery is to reduce the AVM volume and to occlude critical feeders.[8]

In this study, we aimed to assess the efficacy and safety of endovascular embolization of cerebral AVM with different techniques and materials.

Regarding the distribution of age of diagnosis, the mean age of the patients in our study was 24.55 years with range from 4 to 45 years and the standard deviation was 14.7 years. In our study, the age distribution showed incidence peaks in the second and third decade, as the mean age of the patients was 24.55 years.

This comes in agreement with some studies[9–11] in which the mean age of diagnosis of cerebral AVM was 38.3 and 31.2, years respectively, whereas the peak age range at diagnosis was 20–30 years.

Table 3. Distribution of studied sample according to modified Rankin scale before and after embolization.

Modified Rankin scale	Before embolization [*N* (%)]	After embolization [*N* (%)]	After 3 months [*N* (%)]	χ^2	*P* value
Grade 0	0	0	2 (28.6)		
Grade I	0	0	5 (71.4)		
Grade II	0	2 (28.6)	0	32.40	<0.001*
Grade III	1 (14.3)	4 (57.1)	0		
Grade IV	4 (57.1)	1 (14.3)	0		
Grade V	2 (28.6)	0	0		
Total	7 (100)	7 (100)	7 (100)		

Table 4. Outcome of headache and epilepsy in headache and epileptic patients of our study after 3 months of follow-up.

Outcome	*N* (%)
Epilepsy outcome	
Controlled	5 (83.3)
Infrequent	1 (16.4)
Unchanged	0
Increased	0
Total	6 (100)
Headache	
Improved	18 (94.7)
Unchanged	1 (5.3)
Total	19 (100)

Regarding sex distribution, our study showed a higher incidence in males (68.2%) than in females (31.8%).

This comes in agreement with some studies[9,12,13] in which male preponderance appeared to exist. The male distribution was 63 and 80%, respectively.

In contrast to our results, one study[4] revealed that cAVMs are equally distributed between sexes.

In the current study, hypertension was present in seven (31.8%) patients, followed by smoking, being present in six (27.3%) patients. Two (9%) patients had a positive family history and one (4.5%) had diabetes.

This comes in agreement with some studies,[14,15] in which smoking was present in most cases (15%), followed by hypertension (6%), hypercholesterolemia (3% of cases), diabetes (3% of cases), and lastly, cardiac disease, being the lest factor (only 2%).

The burden of hypertension and diabetes in Egypt was 29.2 and 15.6%, respectively, according to WHO 2017.[16] This is similar to our findings, which concluded that hypertension and diabetes are not clear risk factors for cerebral AVM.

In our study, headache was the most common recorded type of AVM presentation, accounting for 86.4% ($n = 19$) of total patients. Hemorrhage was the second most common presentation in our data, accounting for 40.9% ($n = 9$) of total patients. Side weakness was the third most common presentation, accounting for 31.8% ($n = 7$). Seizure was the fourth most common presentation, accounting for ~27.3% ($n = 6$).

This comes in agreement with some studies.[14,17] In one of these studies,[17] 53.1% of patients presented with hemorrhage, 32.3% with seizure, and 7.7% with headache. In the other one, 15 patients (71.4%) had a history of intracranial hemorrhage, 10 patients (47.6%) had a history of seizures, and four patients (19.0%) were complaining of chronic headache.

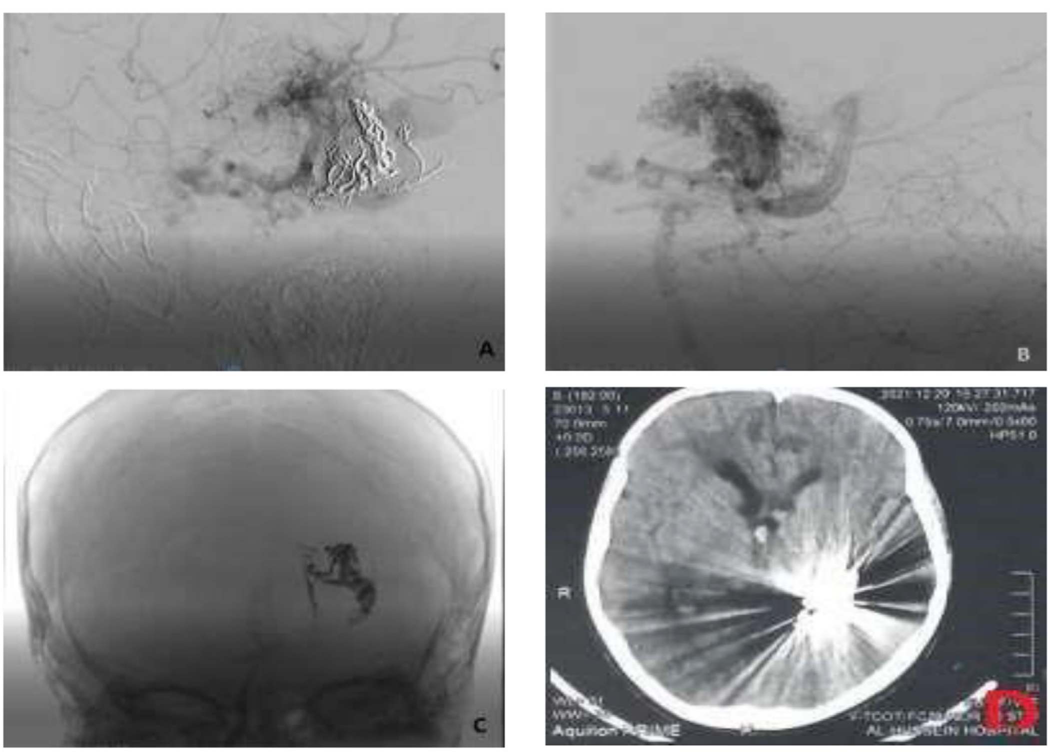

Fig. 1. (a) DSA of a 10-year-old female patient presented with headache and right-side weakness showing left parietal partially occluded medium-sized arteriovenous malformation. (b) DSA of arteriovenous malformation before embolization. (c) Onyx cast. (d) Computed tomography post-operatively showing cast.

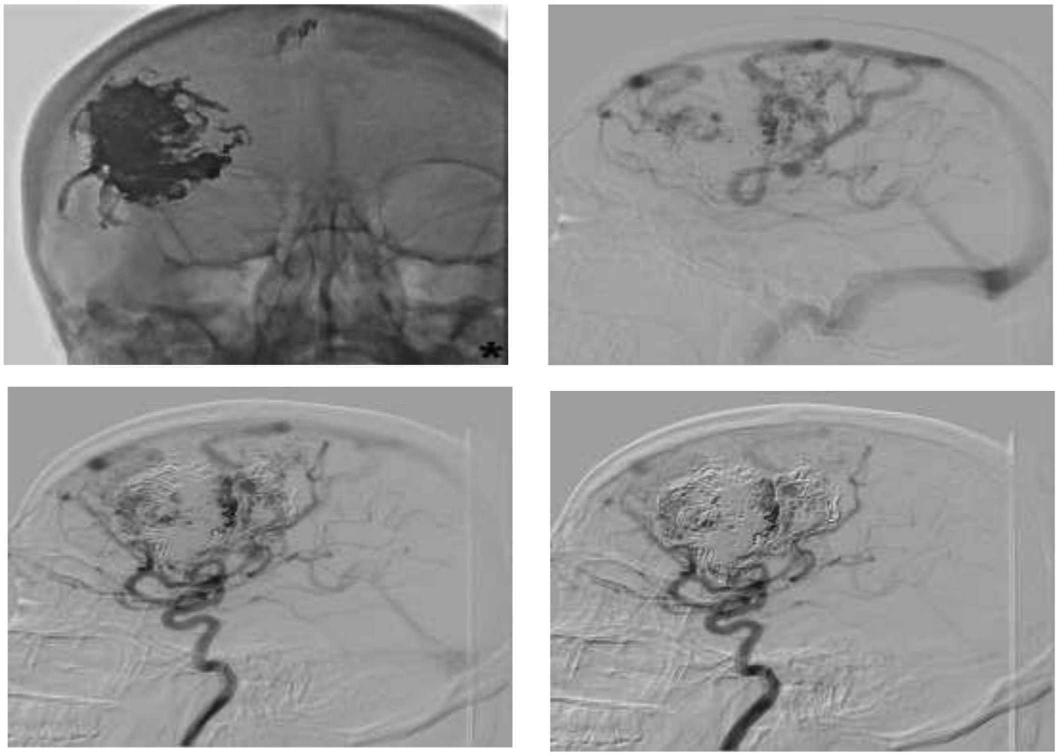

*Fig. 2. DSA of a 35-year-old female patient not having diabetes mellitus or hypertension who presented with headache and seizures showing partial occlusion of large-sized right frontal arteriovenous malformation. *Nonsubtracted postoperative onyx cast.*

In contrast, other study[18] revealed that headache was the second common presentation following intracranial hemorrhage. Seizure was the third common presentation, accounting for approximately 17.3%.

Regarding the hemispheric location and site of AVMs, our study proved that the AVMs were located in the right hemisphere more than left hemisphere. The location of the AVMs in order of decreasing frequency was parieto-occipital, parietal,

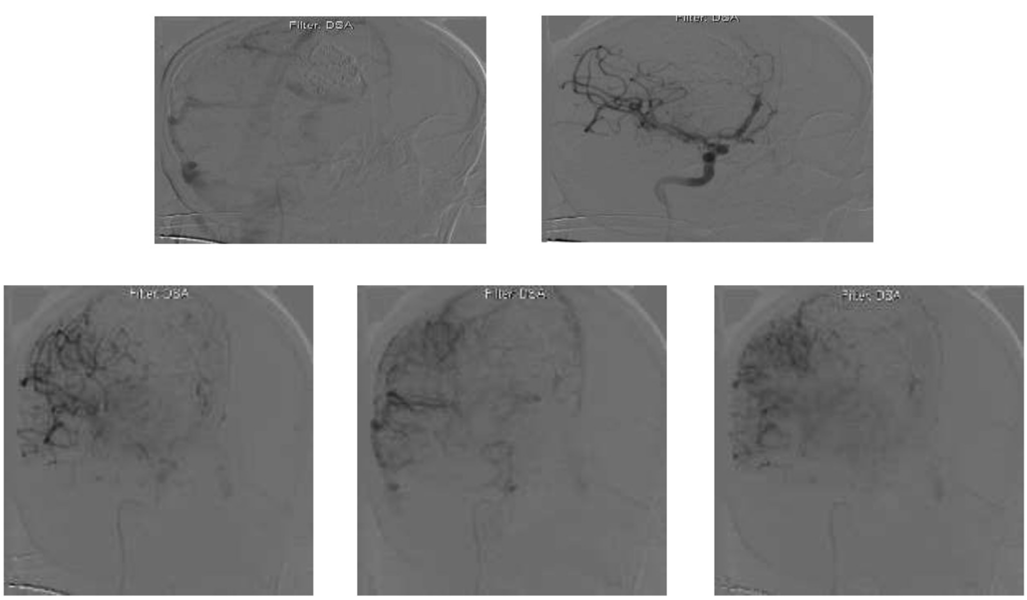

Fig. 3. DSA of a 24-year-old female patient not having diabetes mellitus or hypertension who presented with headache and side weakness showing postoperative complete occlusion of medium-sized right parietal AVM.

temproparietal, temporal, frontal, and cerebellar hemisphere. This comes in agreement with a study by Weber et al.,[8] which revealed the same results.

The number of arterial feeders in our study was multiple in 15 patients (68.2%) and single in seven patients (31.8%). The venous drainage of the AVMs was multiple in 19 patients (86.4%) and single in three patients (13.6%). The dural supply of the AVMs was positive in 18 patients (81.8%) and negative in four patients (18.2%). Nidus diameter before embolization of the AVMs was less than 3 cm in three patients (13.6%), 3–6 cm in nine patients (40.9%), and greater than 6 cm in 10 patients (45.5%). Echelon catheter was used in eight (36.4%) patients, Echelon + Apollo (SL10) catheters were used in two (9.1%), and in 12 (54.5%), Marathon catheters were used. The embolizing materials used were Onyx (68.2%; $n = 15$), Histoacryl (31.8%; $n = 7$), and coils (4.5%; $n = 1$) according to AVM size and availability of materials in our unit. These results agree to some extent and differ in some characteristics with some studies.[14,19]

A commonly used grading scale for brain AVMs is SMG scale. It gives a score that predicts the morbidity/mortality risk of surgery.[20] In our study, SMG of the cerebral AVMs was significantly improved after embolization compared with the initial grading score ($P = 0.002$). Eight patients (36.4%) showed complete occlusion of nidus and 14 (63.6%) had partial occlusion according to SMG.

This comes in agreement with some studies,[21,22] in which a complete occlusion rate of 20% has been reported with the use of cyanoacrylate-based liquid embolic agents. The advent of detachable-tip microcatheters, which facilitate prolonged Onyx infusion, may improve the rate of curative embolization. Intuitively, smaller bAVMs with fewer arterial feeders are most amenable to complete obliteration with embolization.

Regarding the modified Rankin scale, there was a statistically significant improvement immediately and 30 days after embolization compared with the initial grading score ($P < 0.001$) in seven patients presented with weakness. Before embolization, all seven patients were disabled (mRS $\geq$ grade III). During hospitalization, only two patients (28.6%) were improved with mRS grade II. After 3 months of intervention, all patients were improved.

This comes in agreement with some studies.[15,23] In one study,[15] before the first embolization, 91% of patients had no significant disability mRS (0–2), and after the embolization, 86% of patients had no significant disability. On long-term follow-up at 43.4 ± 34.6 months on average, 94% of patients had no significant disability. The other study[23] revealed that mean mRS before treatment, at 30 days, and 12 months after embolization was 1.5, 1.5, and 1.3, respectively.

Regarding the epilepsy outcome after 3 months, we found that five of the six patients who had epilepsy (83.3%) were controlled, whereas in the remaining patient (16.7%), the fits became infrequent. Epilepsy was arbitrarily defined as 'well controlled' if the patient had no seizures in the last 3 months and was defined as 'poorly controlled' if he or she had had at least one seizure in the last 3 months.[24] This could be explained by the presence of edema and inflammation surrounding the nidus.

In one study,[25] among 30 patients presented with seizure due to brain AVMs, seizure control in a limited follow-up period was excellent in 21 patients, good in four, fair in two, and poor in three. In another study,[22] complete obliteration of the brain AVM nidus probably reduced the subsequent occurrence of epilepsy.

Regarding the headache outcome after 3 months, we found that 18 of the 19 patients (94.7%) were improved and the remaining one patient (5.3%) was not improved.

This comes in agreement with a study by Jin et al.,[26] which revealed that embolization via dural blood supply branches may be more efficient for headache alleviation.

4.1. Conclusion

The endovascular treatment of the cerebral AVMs is safe and efficient and can achieve high rates of total and near-total occlusion. Good selection of patients with indications for endovascular treatment of the cerebral AVMs and good selection of material used help in decreasing the complications.

Conflict of interest

None declared.

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