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RESEARCH

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Assessment of endovascular embolization of cerebral arterio-venous malformations in vertebrobasilar domain

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Abstract

Background Endovascular approaches have been widely applied in patients with brain arterio-venous malformations (AVM). However, little is known regarding the risk factors for complications or predictors of procedure success. Herein, we report our experience regarding the outcomes of endovascular embolization of posterior fossa AVM, focusing on how angioarchitectural and hemodynamic characteristics of the AVM affect the post-intervention outcomes. 17 patients diagnosed with posterior cranial fossa AVM were enrolled and scheduled for endovascular interventions by Onyx or Histoacryl.

Results Most patients had a single session (58.8%), while 29.4% had two sessions, 11.7% had three sessions. Total nidus obliteration was achieved in 52.9% of cases, while 35.3% and 11.8% of them had subtotal and partial occlusion, respectively. Postprocedural hematoma was encountered in 17.6% of cases. All preprocedural demographic characteristics did not have a significant impact on occlusion outcomes. However, some angioarchitecture criteria were associated with partial occlusion including large size, superficial or mixed drainage. No significant association was noted between patients criteria and the incidence of complications.

Conclusion Endovascular interventions could be curative for brain AVM, with an accepted periprocedural morbidity rate. Proper knowledge of the angioarchitectural characteristics of these lesions could help us to predict lesions that carry high risk for complications or high chance for cure.

Keywords Brain AVM, Endovascular, Outcomes, Predictors, Complications

Background

Arterio-venous malformations (AVM) of the human brain represent a rare clinical entity. The presence of abnormal tortuous vascular channels, rather than normal intervening capillary network, connecting between the feeding artery and draining veins, which is called a "nidus", is characteristic for such lesions [1, 2].

Intracranial AVM are dangerous pathologies as they carry a greater risk for rupture and subsequent intracranial hemorrhage[3]. They may elicit epilepsy in many cases [4]. Some neurologists consider them as the most dangerous cerebrovascular malformations[5]. Therefore, more attention have been given to these pathologies resulting in good management outcomes even for high-flow lesions[6]. Multiple approaches exist for the management of brain AVM including surgery[7], radiosurgery[8], and endovascular intervention approaches [9].

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In the recent past, endovascular approaches were only used as adjunctive therapy for devascularization and volume reduction before surgery and radiosurgery, respectively [10]. Nonetheless, technological medical advances in the field of endovascular therapy, especially regarding the development of liquid embolic materials and flow-directed microcatheters, made it possible to cure brain AVMs, even in a single setting [11, 12].

The literature is poor with Egyptian studies handling the outcomes after endovascular embolization of brain AVMs. Thus, we conducted the present study to report our experience regarding the outcomes of endovascular embolization of posterior fossa AVM, focusing on how angioarchitectural and hemodynamic characteristics of the AVM affect the post-intervention outcomes.

Methods

The current prospective interventional study was conducted after gaining approval from the ethical scientific board of our medical school. The study was designed for patients diagnosed with posterior fossa intracranial AVM, having a nidus accessible for the microcatheter tip, whether they presented with neurological manifestations (including intracranial hemorrhage) or accidentally discovered. On the other hand, we excluded patients with dural AVM, cavernous malformations, or known allergy to the injected dye. We also excluded the comatose patients till stabilization of their clinical condition.

We enrolled a total of 17 patients managed by endovascular embolization using Onyx or N-butyl cyanoacrylate. These patients were performed during the period between October 2018 and October 2021. All of them signed informed consent explaining the benefits and possible complications of the endovascular intervention. Before the intervention, all patients received the standard preprocedural care including proper history taking, detailed neurological examination, routine laboratory investigations (coagulation profile, viral hepatitis markers, liver and renal function tests), in addition to radiological investigations.

Brain computed tomography (with or without contrast) helped to locate the lesion site, associated hydrocephalus, infraction, or hemorrhage. Brain magnetic resonance imaging with angiography also helped to reveal the anatomy, associated edema and gliosis. Moreover, intraarterial digital subtraction angiography (DSA) was done for all patients to assess the morphological and hemodynamic criteria of the AVM. The collected parameters included size, borders (diffuse or compact), morphology (plexiform or fistulous), type of feeders (terminal perforator or en passage), type of venous drainage (superficial, deep, or mixed), number of draining veins (single or multiple), the presence of aneurysm, the presence of venous ectasia, rupture, Spetzler and Martin grade [13], location, and the feeding artery.

Computed tomography (CT) and computed tomography angiography (CTA) were carried out on a 64-channel multidetector CT scanner (Aquilion; Toshiba Medical Systems, Tokyo, Japan). DSA was performed on three-dimensional (3D) digital subtraction angiography machine (GE Innova IGS 520, GE Healthcare, Chicago, Illinois, USA).Magnetic resonance imaging (MRI) was carried out on a 1.5 Tesla MRI system (Achieva, Philips Medical Systems, Netherlands).

Regarding the endovascular procedure, it was conducted under general anesthesia under the guidance of biplane angiographic unit. A six-Fr arterial sheath was inserted through the right femoral artery, and a cerebral angiography was done, followed by inserting the sheath into the vertebral artery via the standard co-axial technique. Angiography was initially done to ensure that the feeding pedicle was amenable to occlusion up to 2 mm in a retrograde fashion (by the Onyx reflux). A dimethylsulphoxide (DMSO) compatible catheter was navigated till reaching the AVM nidus. The catheter was flushed with normal saline, followed by DMSO till it filled the dead space of the microcatheter.

The Onyx was vigorously shaken for 20 min till the time of injection, then drawn into a syringe containing 1 ml of DMSO. The syringe was connected to the microcatheter, and the onyx was injected slowly till it replaced the DMSO in the dead space of the catheter and under fluoroscopic guidance, the onyx was injected into the nidus of the AVM till reflux of early embolization of the draining vein occurred, we stopped the injection to be resumed later. Finally, the microcatheter was removed using one technique of gradual increase in traction. If partial occlusion was performed, staged sessions were scheduled.

After the intervention, patients were followed up for six months. During these visits, clinical assessment was done, and DSA was repeated six months after the procedure. Nidus obliteration was classified as total, subtotal, or partial.

Our primary objective was the post-procedural outcomes following endovascular management of posterior fossa AVM. The secondary objective was to assess if the morphological or clinical criteria of the AVM affect that outcome.

Our data were tabulated and analyzed via the SPSS software (IBM, 2009, New York, USA). Categorical data were expressed as numbers and percent, whereas numerical data were expressed as mean and standard deviation. Categorical data were compared between two or more groups using the Chi square test (or Fischer exact or Monte Carlo tests). For comparing numerical variables, the Student's t test or Anova tests were used when two or three groups were compared. For all tests, a p-value less than 0.05 was considered significant.

Results

The included 17 patients had a mean age of 34.47 years (range, 1 – 52). Twelve of them were men (70.6%), whereas the remaining patients were women. Family history of AVM was positive in two patients (11.8%). Smokers represented 35.3% of the included population. Regarding the clinical presentation of the included cases, intracerebral hemorrhage was present in 52.9% of patients, while seizures were present in 17.6% of them. Other manifestations included subarachnoid hemorrhage (11.8%), headache (17.6%), and hydrocephalus (11.8%). Regarding angioarchitectural features, Five AVM nidi sized from 3-6cms (29.4%), with five nidi sizing less than 3cms (29.4%) and seven nidisizing more than 6 cms (41.2%). Five AVMs showed the presence of intranidal aneurysm (29.4%), 9 AVMs showed rupture (52.9%). Regarding the arterial feeders 16 AVMs (94.1%) had terminal feeders, while only one with en-passage feeder (5.9%). Three AVMs had single venous drainage (17.6%), while 14 AVMs (82.4%) had multiple venous drainage. Those draining veins were deep in 11 AVMs (64.4%), superficial in one AVM (5.9%) and mixed in 5 AVMs (29.4%). Venous ectasia was present in 6 AVMs (35.3%) (Table 1).

Both Age and gender did not have a significant effect on the occlusion outcomes among the studied cases, as well as family history and clinical presentation (Table 2).

There was statistical significance between size of AVM and nidus obliteration (P= 0.004), as well as venous drainage (P= 0.012). Totalocclusion was done in patients with occipital, occipito-parietal, occipito-temporal and pericallosal regions, while partial occlusion was performed in patients with cerebellar, brainstem and occipito-temporal regions. While the presence of intra-nidal aneurysms or presence of rupture have no impact on occlusion outcome (Table 3).

Most patients had a single session (58.8%), while 29.4% and 11.8% had two and three sessions, respectively. Onyx was injected in 76.5% of patients, histoacryl was used in 11.8% of patients, while combined histoacryl and coils was utilized in 11.88% of patients. Two patients required additional gamma knife intervention, while another one required surgery. Total nidus obliteration was achieved in 52.9% of cases, while 35.3% and 11.8% of them had subtotal and partial occlusion, respectively. No complications were encountered in 14 cases (82.4%). However, hematoma occurred in three patients (17.6%) (Table 4), (Fig. 1).

All preprocedural demographic characteristics including age, gender, smoking, cardiovascular comorbidity,

Table 1 Angioarchitecture characteristics of the studied cases

	n **= 17**	**%**
Size		
< 3 cm	5	29.4
From 3to 6 cm	5	29.4
> 6 cm	7	41.2
Feeders		
Terminal perforator	16	94.1
En passage	1	5.9
Number of draining veins		
Single	3	17.6
Multiple	14	82.4
Venous drainage		
Superficial	1	5.9
Deep	11	64.7
Mixed	5	29.4
Aneurysm		
−ve	12	70.6
+ve	5	29.4
Fistulous		
Mixed	2	11.8
Plexiform	15	88.2
Borders		
Diffuse	7	41.2
Compact	10	58.8
Venous ectasia		
No	11	64.7
Yes	6	35.3
Bleeding		
Non-ruptured	8	47.1
Ruptured	9	52.9
Spetzler and Martin		
2	5	29.4
3	5	29.4
4	7	41.2
Eloquence		
Non-eloquent	7	41.2
Eloquent	10	58.8
Location		
Occipital	4	23.5
Cerebellar	3	17.6
Brainstem	1	5.9
Occipito-parietal	3	17.6
Occipito-temporal	3	17.6
Brainstem + cerebellar	1	5.9
Pericallosal	2	11.8
Feeding artery		
SCA	3	17.6
PCA	10	58.8
Basilar	1	5.9
PICA	1	5.9
Pericallosal, PCA	2	11.8

PCA posterior cerebral artery, *SCA* superior cerebellar artery, *PICA* posterior inferior cerebellar artery and clinical presentation did not have a significant impact on occlusion outcomes ($p > 0.05$).

Discussion

The current study was conducted to report our outcomes of endovascular embolization in brain posterior fossa AVMs, focusing on how the angioarchitectural and hemodynamic parameters of AVMs affect the post-endovascular embolization results.

Our patients had a mean age of 34.47 years which was near to Baharvahdat and colleagues (33.3 ± 14.1 years) [14], Ovalle et al. also confirmed the previous findings [15]. While Sato and colleagues reported that the mean age was 41.3 years [2].

Our findings showed that gender did not have a significant impact on the development of post-procedural complications ($p = 0.515$) which is consistent with Pan and colleagues who noted no significant impact of gender on the development of post-procedural complications ($p = 0.75$) [20]. Contrarily, Kim and colleagues reported that the rate of complication was significantly higher in women than in men, but more branches were embolized in the females than in the males [21].

In the current study, post-procedural complications were encountered in three patients (17.6%) in the form of hematoma, which is consistent with previous morbidity range reported by multiple reports (0 – 22%) [16–18].

In the current investigation, venous drainage was significantly different according to the occlusion outcomes ($p = 0.012$). Nonetheless, another study negated that finding, as deep venous drainage was associated with 12% occlusion rate, compared to 21.7% in patients without deep drainage [23].

Our findings showed that the presence of intracerebral hemorrhage at presentation was not a risk factor for complications after endovascular management of AVM ($p = 1.0$). Nonetheless, subarachnoid was not a risk factor for complications in our study. This agrees with another study where the presence of hemorrhagic presentation was not a risk factor for complications, as hemorrhagic presentation was noted in 38% and 43% of complicated and non-complicated cases, respectively ($p = 0.419$) [14].

In our study, the size of AVM was not significantly associated with post-intervention complications ($p = 0.435$) which agrees with Hartmann and his colleagues [19] and Baharvahdat and his colleagues [14].

Our findings showed that the location of the AVM did not have a significant impact on the incidence of post-procedural complications ($p = 0.850$) which is consistent with Kim and his associates reports [21]. Contrarily, another study reported that infratentorial location including the cerebellum and brain stem were significantly associated with complications on the univariate

Table 2 Relation between sociodemographic characteristics and nidus obliteration among the studied cases

	Partial (< 80%) ***n* = 2 (%)**	**Subtotal (80–99%)** ***n* = 6 (%)**	**Total (100%)** ***n* = 9 (%)**	**Test of significance**
Age/years	39.0 ± 12.72	41.17 ± 11.89	29.0 ± 18.77	*F = 1.09* *P = 0.360*
Sex				
Male	2 (100)	5 (83.3)	5 (55.6)	MC = 2.28
Female	0	1 (16.7)	4 (44.4)	*P* = 0.319
Family history				
−ve	2 (100)	6 (100)	7 (77.8)	MC = 2.02
+ve	0	0	2 (22.2)	*P* = 0.385
Hypertension				
−ve	1 (50)	3 (50)	9 (100)	MC = 5.88
+ve	1 (50)	3 (50)	0	*P* = 0.053
Smoking				
Non-smokers	0	4 (66.7)	7 (77.8)	MC = 4.35
Smokers	2 (100)	2 (33.3)	2 (22.2)	*P* = 0.114
Clinical picture				
Headache	0	0	3 (33.3)	MC = 3.24, *P* = 0.198
Seizures	1 (50)	1 (16.7)	1 (11.1)	MC = 1.71, *P* = 0.425
SAH	1 (50)	1 (16.7)	0 (0.0)	MC = 4.16, *P* = 0.125
ICH	1 (50)	5 (83.3)	3 (33.3)	MC = 3.62, *P* = 0.164
Hydrocephalus	0	0	2 (22.2)	MC = 2.02, *P* = 0.365

ICH intracerebral hemorrhage, *SAH* subarachnoid hemorrhage

Table 3 Relation between angioarchitecture characters and nidus obliteration among the studied cases

	Partial (< 80%) n = 2 (%)	Subtotal (80–99%) n = 6 (%)	Total (100%) n = 9 (%)	Test of significance
Size				
< 3 cm	0	1 (16.7)	4 (44.4)	MC = 15.38
From 3to 6 cm	0	5(83.3)	0	P = 0.004*
> 6 cm	2 (100)	0	5 (55.6)	
Feeders				
Terminal perforator	2 (100)	6 (100)	8 (88.9)	MC = 0.944
En passage	0	0	1 (11.1)	P = 0.624
Number of draining veins				
Single	0	0	3 (33.3)	MC = 3.24
Multiple	2 (100)	6 (100)	6 (66.7)	P = 0.198
Venous drainage				
Superficial	1 (50)	0	0	
Deep	0	6 (100)	5 (55.6)	MC = 12.81
Mixed	1 (50)	0	4 (44.4)	P = 0.012*
Aneurysm				
−ve	1 (50)	3 (50)	8 (88.9)	MC = 3.09
+ve	1 (50)	3 (50)	1 (11.1)	P = 0.214
Fistulous				
Plexiform	2(100)	6(100)	7(77.8)	MC = 2.02
Mixed	0	0	2(22.2)	p = 0.365
Borders				
Diffuse	2 (100)	2 (100)	3 (33.3)	MC = 3.24
Compact	0	4 (66.7)	6 (66.7)	P = 0.198
Venous ectasia				
No	1 (50)	3 (50)	7 (77.8)	MC = 1.43
Yes	1 (50)	3 (50)	2 (22.2)	P = 0.489
Non-ruptured	1 (50)	1 (16.7)	6 (66.7)	MC = 3.62
Ruptured	1 (50)	5 (83.3)	3 (33.3)	P = 0.164
Spetzler and Martin				
2	0	0	5 (55.6)	
3	0	3 (50)	2 (22.2)	MC = 8.64
4	2 (100)	3 (50)	2 (22.2)	P = 0.07
Eloquence				
Non-eloquent	1 (50)	1 (16.7)	5 (55.6)	MC = 2.32
Eloquent	1 (50)	5 (83.3)	4 (44.4)	P = 0.313
Location				
Occipital	0	1 (16.7)	3 (33.3)	
Cerebellar	1 (50)	2 (33.3)	0	MC = 12.83
Brain stem	0	1 (16.7)	0	P = 0.382
Occipito-parietal	1 (50)	0	2 (22.2)	
Occipito-temporal	0	1 (16.7)	2 (22.2)	
Brainstem + cerebellar	0	1 (16.7)	0	
Pericallosal	0	0	2 (22.2)	
Feeding artery				
SCA	1 (50)	2 (33.3)	0	
PCA	1 (50)	2 (33.3)	7 (77.8)	MC = 10.29
Basilar	0	1 (16.7)	0	P = 0.245
PICA	0	1 (16.7)	0	
Pericallosal, PCA	0	0	2 (22.2)	

Table 3 (continued)

PCA posterior cerebral artery, *SCA* superior cerebellar artery, *PICA* posterior inferior cerebellar artery

*statistically significant

analysis. These variables maintained its significance on the multivariate one [2].

In our study, venous ectasia was present in 33.3% and 35.7% of patients in the complicated and non-complicated groups, respectively, with no significant difference between the two groups ($p = 1$). In a previous similar study, venous ectasia was encountered in 52.08% and 51% of complicated and non-complicated patients, respectively, with no significant difference on statistical analysis ($p = 0.596$) [14]. Pan and colleagues confirmed these findings [20].

Our findings showed that the pattern of venous drainage did not have a significant impact on the incidence of post-procedural complications ($p = 0.073$). This is in accordance with Baharvahdat and colleagues who noticed that deep venous drainage was present in 44% and 43% of patients in the complicated and non-complicated groups, respectively [14]. However, a previous similar study noted that the presence of deep venous drainage was a significant risk factor for complications after endovascular management of brain AVM ($p < 0.01$) [2].

In the current study, we noted no significant difference in the prevalence of aneurysms between the complicated and non-complicated patients ($p = 0.191$) which is similar to Baharvahdat and colleagues findings ($p = 0.513$) [14]. On the other hand, Sato and his colleagues reported that the presence of flow related aneurysms was a significant risk factor for post-procedural complications on the univariate analysis ($p = 0.01$) [2].

Our findings showed that Spetzler and Martin grading was statistically comparable between the complicated and non-complicated cases ($p = 0.435$). In another analysis, neither the total score of the Spetzler–Martin grading system nor any of its 3 components predicted treatment complications [19].

In our study, the type of feeding vessel did not have a significant impact on the incidence of post-procedural complications ($p = 1.0$). In the same context, Kim and his associates reported that the type of vascular territory was not associated with a significant difference regarding post-intervention complications [21].

Our findings showed no significant impact of the number of draining veins on post-procedural complications ($p = 0.465$). Pan and colleagues also noted the same findings; even when the draining veins were increased, this has nothing to do with the post-operative complications ($p > 0.05$) [20].

Our findings showed that total nidus obliteration was achieved in nine patients (52.9%), followed by subtotal occlusion in six patients (40%), whereas partial occlusion occurred in two cases (13.3%). Sato and colleagues noted that complete and partial AVM obliteration were achieved in 37% and 60.3% of their cases, respectively. No morphological changes were noticed in the remaining 1.6% of cases [2].

In our study, both age and gender did not have a significant impact on the occlusion outcomes after endovascular embolization, and that was also confirmed by a recent study conducted in 2022, which noted that both parameters were statistically comparable between cases with complete and incomplete closure ($p = 0.367$ and 0.389, respectively) [22]. This is in line with our findings.

In our study, the size of the AVM had a direct impact on technical outcomes ($p = 0.004$). Lesions > 6 cm increased the chance of only partial not total occlusion. In the same context, Jordan and his associates also reported that occlusion was achieved in 75% of patients with AVM < three cm, compared to only 8.2% of patients with AVM > six cm [23]. It appears that an increased AVM diameter is associated with an increased risk of technical failure.

Our findings showed that the number of draining veins did not have a significant impact on the occlusion outcomes ($p = 0.198$), and this was also confirmed by Rodriguez-Calienes and his coworkers who reported that multiple veins were detected in 48.3% and 51.7% of cases in the incomplete and complete occlusion groups, respectively, with no significant between them ($p = 0.371$) [22].

Our study showed that the presence of aneurysms did not have a significant impact on occlusion outcomes, and that was also noted by Jordan and his colleagues (CI 0.22–16.9–p = 0.556) [23].

In the current study, the presence of rupture was not associated with a significant impact on occlusion outcomes ($p = 0.164$). Pierot and colleagues noticed that ruptured AVM had twofold chance to be totally occluded compared to non-ruptured ones [24].

Our findings showed that the decreased Spetzler and Martin grade was associated with an increased chance of complete occlusion ($p = 0.07$). Likewise, another study noted that occlusion was performed in 100% of patients with grade I, compared to only 46.2% and 11.9% occlusion rates in patients with grades 2 and 3, respectively [23].

Table 4 Relation between angioarchitecture characters and incidence of complications (hematoma) among the studied cases

	No complications $n = 14$ (%)	Complications (hematoma) $n = 3$ (%)	Test of significance
Size			
< 3 cm	4 (28.6)	1(33.3)	MC = 1.67
From 3to 6 cm	5 (35.7)	0	$P = 0.435$
> 6 cm	5(35.7)	2 (66.70)	
Feeders			
Terminal perforator	13 (92.9)	3 (100)	FET = 0.228
En passage	1 (7.1)	0	$P = 1.0$
Number of draining veins			
Single	2(14.3)	1 (33.3)	FET = 0.617
Multiple	12 (85.7)	2 (66.7)	$P = 0.465$
Venous drainage			
Superficial	0	1 (33.3)	
Deep	10 (71.4)	1 (33.3)	MC = 5.24
Mixed	4 (28.6)	1 (33.3)	$P = 0.073$
Aneurysm			
−ve	11 (78.3)	1 (33.3)	FET = 2.44
+ve	3 (21.4)	2 (66.7)	$P = 0.191$
Fistulous			
Plexiform	12 (85.7)	3 (100)	FET = 0.486
Mixed	2 (14.3)	0	$P = 1.0$
Borders			
Diffuse	5 (35.7)	2 (66.7)	FET = 0.977
Compact	9 (64.3)	1 (33.3)	$P = 0.537$
Venous ectasia			
No	9 (64.3)	2 (66.7)	FET = 0.006
Yes	5 (35.7)	1(33.3)	$P = 1.0$
Non-ruptured	7 (50)	1 (33.3)	FET = 0.275
Ruptured	7 (50)	2 (66.7)	$P = 1.0$
Spetzler and Martin			
2	4 (28.6)	1 (33.3)	
3	5 (35.7)	0	MC = 1.67
4	5 (35.7)	2 (66.7)	$P = 0.435$
Eloquence			
Non-eloquent	5 (35.7)	2 (66.7)	FET = 0.977
Eloquent	9 (64.3)	1 (33.3)	$P = 0.537$
Location			
Occipital	3 (21.4)	1 (33.3)	
Cerebellar	2 (14.3)	1 (33.3)	
Brain stem	1 (7.1)	0	MC = 2.67
Occipito-parietal	2 (14.3)	1 (33.3)	$P = 0.850$
Occipito-temporal	3 (21.4)	0	
Brainstem + cerebellar	1 (7.1)	0	
Pericallosal	2 (14.3)	0	
Feeding artery			
SCA	2 (14.3)	1 (33.3)	MC = 1.40
PCA	8 (57.1)	2 (66.7)	$P = 0.844$
Basilar	1 (7.1)	0	
PICA	1 (7.1)	0	
Pericallosal + PCA	2 (14.3)	0	

PCA posterior cerebral artery, *SCA* superior cerebellar artery, *PICA* posterior inferior cerebellar artery

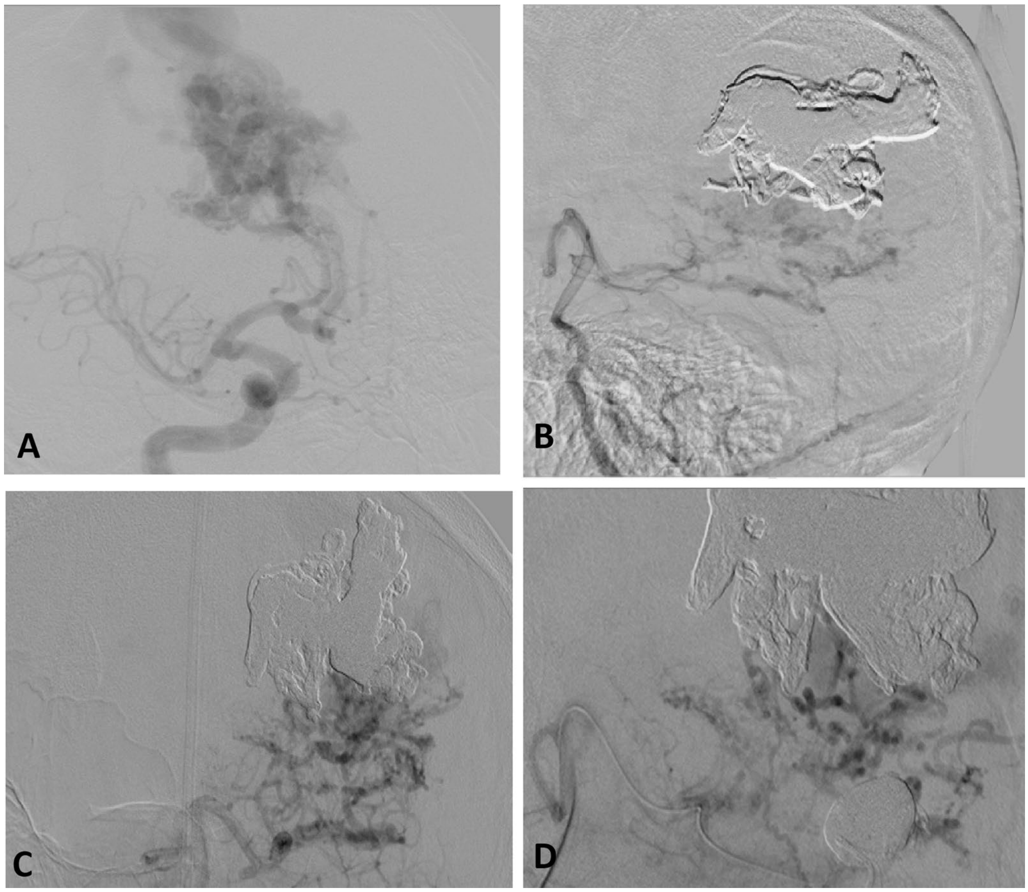

Figure 1 **A**, **B** Left parieto-occipital AVM first session of embolization, hemorrhage occurred on the second day after injection due to increased systolic blood pressure over 140 mmHg with minor neurological complications in the form of right homonymous hemianopia that improved with conservative treatment after 1 month. **C** Second session of embolization after six months, despite injection of large amounts of ONYX, hemorrhage occurred due to rapid change in the hemodynamics within the nidus. **D** Intraprocedural complication in the form of hematoma due to perforation of the nidus by the wire

Our study has some limitations. First of all, it is a single center study that included a small sample of patients. Also, it lacks long-term follow-up of the included cases. Thus, more studies including more cases from different neurological centers should be conducted in the near future.

Conclusion

Endovascular interventions could be curative for brain AVM, with an accepted periprocedural morbidity rate. Proper knowledge of the angioarchitectural characteristics of these lesions could help predict lesions that carry high risk for complications or high chance for cure.

Abbreviations

AVM	Arterio-venous malformation
ANOVA	Analysis of variance
CT	Computed tomography
CTA	Computed tomography angiography
DMSO	Dimethylsulphoxide
DSA	Digital subtraction angiography
ICH	Intracerebral hemorrhage
MRI	Magnetic resonance imaging
PCA	Posterior cerebral artery
PICA	Posterior inferior cerebellar artery
SAH	Subarachnoid hemorrhage
SCA	Superior cerebellar artery
SPSS	Statistical Package for the Social Sciences

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Author contributions

MAE, MAM and KMS have participated in study conception and design. MAE, ANY and MGA have analyzed and interpreted data. All authors read and approved the manuscript.

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Availability of data and materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by Al-Azhar University, Faculty of Medicine, Ethical committee on 7-8-2018, Registration number: Neur-Med._23Med.Research_Endovascular.Embolization.AVM.0000023.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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