The Role of Preoperative Endovascular Embolization in Surgical Management of Cerebral Arterio-Venous Malformation (AVM)

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ABSTRACT:
Background: Arteriovenous malformations (AVMs) are vascular lesions comprised feeding arteries shunted to draining veins without intervening capillary networks. Preoperative embolization has traditionally been regarded as a safe and effective adjunct to microsurgical treatment of brain arteriovenous malformations.
Aim: The purpose of this study is to determine the impact of preoperative endovascular embolization on the outcome of surgically managed AVMs**.**
Methods: This is a prospective non randomized controlled study of 30 patients with cerebral AVMs that are candidates for surgical resection and or endovascular embolization Patients was divided into two groups. Both groups underwent diagnostic preoperative angiography. In the first group 10 cases had preoperative endovascular embolization followed by microsurgical resection. Materials used for embolization are onyx in low flow AVM and N-butyle cyanoacrylate (NBCA) glue in high flow AVM. In the second group 20 cases had microsurgical excision without preoperative endovascular embolization. We assessed both intraoperative and postoperative variables.
Results: There was no statistically significant difference between the two groups regarding the obliteration rate (P=0.272), estimated blood loss (P=0,286) and morbidity and mortality occurrence (P= 0.148).
Conclusion: In our study, preoperative embolization was associated with higher rate of AVM obliteration and lower amount of intraoperative blood loss. However, the study outcome was statistically insignificant due to the small sample size. Preoperative embolization is to be considered with certain individual cases especially high grade AVMs

1. Introduction

Cerebral Arterio-Venous Malformations (AVMs) are abnormal fistulas between arteries and veins without an intervening capillary bed and eventually resulting in high-flow arteriovenous shunts. Each AVM is unique in location, size, involvement of eloquent areas, angio-architecture, and flow characteristics and so they always represent challenging lesions [1]. These lesions have an estimated prevalence of approximately 50 cases per 100,000 inhabitants [2].

The most well-known classification system to describe them is the Spetzler-Martin grading scale [3]. AVMs are congenital and most often nonfamilial. Clinical onset is usually related to seizures and/or spontaneous cerebral hemorrhage; headache and focal neurological deficits may also be seen [4]. It has been estimated that the yearly risk of hemorrhage related to an untreated AVM ranges between 2 and 4%, with a mortality of 18% [5].

Nowadays, treatment options for AVMs include microsurgical resection, endovascular embolization, and radiosurgery. These modalities may be used alone in smaller lesions or in various types of combinations for high-grade ones. Literature indicates that incomplete treatment of an AVM is not only unhelpful but also increases the risk of bleeding up to four times [6].

Preoperative embolization is established as an advantageous adjunct in multimodality treatment of cerebral AVMs. However, the benefit of preoperative embolization in AVMs with a favorable surgical risk profile is debatable [7].

This study aimed to determine the impact of preoperative endovascular embolization on the outcome of surgically managed AVMs.

Patients and Methods:

This study is a prospective, non-randomized controlled trial conducted on 30 patients diagnosed with cerebral arteriovenous malformations (AVMs) who were candidates for surgical resection and/or endovascular embolization. The study was carried out at Cairo University Hospitals between November 2022 and July 2024. The patients were divided into two parallel groups. The first group consisted of 10 patients who underwent preoperative endovascular embolization followed by microsurgical resection. The embolization materials used were Onyx for low-flow AVMs and N-butyl cyanoacrylate (NBCA) glue for high-flow AVMs. The second group comprised 20 patients who underwent microsurgical excision without preoperative embolization.

To analyze outcomes, intraoperative and postoperative variables were assessed. The study compared the obliteration rate, estimated blood loss during surgical resection, postoperative complications, and mortality rate between the two groups.

Patient Population

The study was conducted on patients with cerebral AVMs who were deemed suitable candidates for surgical resection or endovascular embolization. Patients of all age groups were included as long as they met the eligibility criteria. However, those with recurrent AVMs, prior exposure to radiation therapy, electrothrombosis, or cryosurgery were excluded. Additionally, patients with AVMs supplied by tiny branches, perforators, or en passant feeders that could not be embolized were not considered for the study.

Methods

All patients underwent a comprehensive preoperative evaluation, including history taking, clinical examination, and radiological investigations. The medical history focused on age, sex, chronic illnesses, particularly those associated with coagulopathy such as liver disease, and medications, especially anticoagulants, antiplatelet agents, and antiepileptic drugs. A detailed symptom assessment was conducted, including headache, progressive weakness, altered consciousness, cognitive impairment, sphincteric dysfunction, speech difficulties, and seizure history.

A thorough clinical assessment was performed, evaluating the patient's general condition and surgical fitness. The neurological examination included an assessment of the level of consciousness using the Glasgow Coma Scale (GCS), as well as motor function, speech ability, cranial nerve function, sensory function, and gait. The modified Rankin Scale (mRS) was recorded for each patient prior to intervention to determine their baseline neurological status.

Table (1): Modified Rankin Scale.

Score	Description
0	No symptoms at all
1	No significant disability despite symptoms; able to carry out all usual duties and activities
2	Slight disability; unable to carry out all prestroke activities , but able to look after own affairs without assistance.
3	Moderate disability; requiring some help, but able to walk without assistance.
4	Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance,
5	Severe disability; bedridden, incontinent and requiring constant nursing care.

Radiological investigations were conducted for all patients. A CT scan of the brain was performed to evaluate the location, size, and density of hematomas, as well as the presence of midline shifts or other complications. In some patients, MRI was performed to provide a more detailed assessment of the nidus, best visualized on T2-weighted images as a tangle of signal voids, along with the enlarged feeding arteries and draining veins. Digital subtraction angiography (DSA) was performed in most cases as the gold standard for AVM evaluation. The angiographic study included six vessels—two internal carotid arteries, two external carotid arteries, and two vertebral arteries—to assess the angioarchitecture of the AVM and identify any dural blood supply or multiple arterial feeders. In cases where DSA was unavailable, CTA was utilized as an alternative imaging modality.

Preoperative Optimization

Prior to surgery, patients with multiple comorbidities or those on anticoagulant or antiplatelet therapy underwent a comprehensive anesthetic evaluation. This assessment included a detailed cardiorespiratory examination, routine laboratory tests such as complete blood count, coagulation profile, prothrombin time, INR, urea, and electrolytes, as well as an electrocardiogram. In selected cases, additional tests such as chest radiographs and echocardiography were performed. The purpose of this evaluation was to determine the patient's suitability for general anesthesia and guide perioperative management strategies.

Preoperative Embolization

The primary objectives of preoperative embolization were to occlude deep components of the AVM that were surgically inaccessible, infiltrate as much of the nidus as possible, and close the arterial feeders when feasible. Most embolization procedures were performed under general anesthesia with endotracheal intubation. A bladder catheter was inserted for fluid management and postoperative comfort. Coagulation parameters were closely monitored to minimize the risk of thromboembolic complications.

The embolization procedure began with vascular access, where a femoral puncture was performed using the Seldinger technique. A 6F femoral sheath was inserted into the femoral artery and continuously flushed with saline to prevent clot formation. Diagnostic angiography was then performed using a 4F or 5F catheter with a hydrophilic guidewire to evaluate the AVM's angioarchitecture and hemodynamics. Selective catheterization of the feeding artery was performed using a guiding catheter, with a hemostatic valve to allow continuous flushing with heparinized saline. Under fluoroscopic roadmap guidance, a microcatheter was navigated to the distal aspect of the chosen arterial feeder.

During embolization, the choice of material depended on the AVM flow characteristics. NBCA glue was used to occlude the nidus and draining veins, ensuring that arterial occlusion occurred only at the level of distal arterioles. Onyx was prepared by vigorous shaking for 20 minutes before injection to ensure adequate radiopacity. After embolization was complete, the catheters were removed, and hemostasis was achieved manually or with a closure device.

Post-embolization care included strict bed rest for at least six hours, neurological monitoring in the neuro-intensive care unit for 24 hours, and discharge on the second post-embolization day. Neurological examinations and groin site checks were conducted hourly. In cases where large, high-flow AVMs were embolized, mild hypotension was induced for 24 hours. For complex AVMs requiring staged embolization, additional sessions were scheduled every three to four weeks.

Surgical Resection

Surgical resection of AVMs was performed in a well-equipped operating theater with microsurgical instruments, a nonstick bipolar coagulation device, and a surgical microscope. The procedure involved a wide craniotomy based on the AVM's location and size. Sharp dissection of the sulci, fissures, and subarachnoid cisterns was performed to secure the proximal portions of the feeding arteries. A stepwise temporary-clip application technique was employed, reducing the pressure in the feeding arteries and nidus while preserving adjacent normal brain tissue. The nidus was dissected using blunt techniques, and feeding arteries were coagulated and divided at their entry points. The draining veins were coagulated and divided last to prevent premature AVM rupture.

Intraoperative blood loss was estimated from the anesthesia records or operative notes. The duration of surgery was calculated from the time of dural incision to closure.

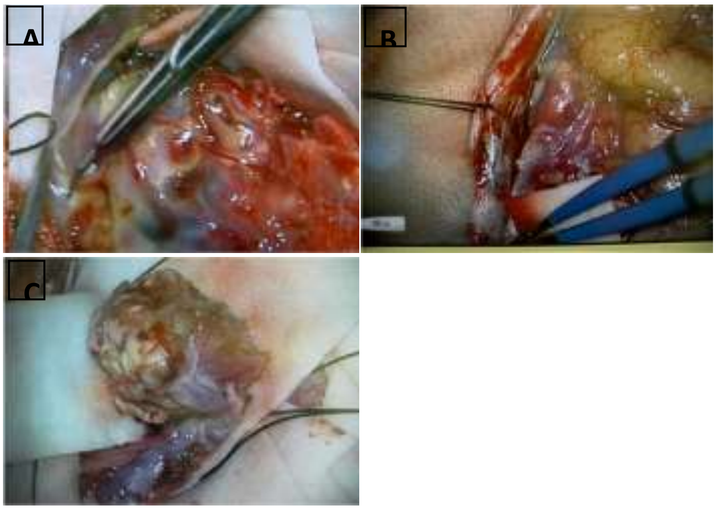

Figure (1): sharp dissection of the arachnoid, sulci and feeding vessels. B. blunt dissection of the nidus. C. Blunt dissection of the whole nidus keeping the draining vein till the end of the surgery.

Postoperative Care

Following surgery, patients were admitted to the intensive care unit for close monitoring of their general and neurological status. A follow-up CT scan was performed, and in some cases, CTA or DSA was conducted to assess the success of resection. Patients were transferred to the ward after two days and were typically discharged home within five days if no complications arose.

Outcome Assessment

The clinical outcomes of the procedure were assessed based on symptom control, including hemorrhage, seizures, headaches, and neurological deficits, as well as procedure-related complications. Postoperative neurological status was evaluated using the modified Rankin Scale (mRS). Patients were classified into two categories based on their postoperative progress. A favorable outcome included cases with improvement or no significant deterioration, while an unfavorable outcome included those with moderate or major deterioration or death.

Surgical parameters such as estimated blood loss and operative time were recorded. The final angioarchitectural outcome was determined using follow-up DSA or CTA conducted two to five days postoperatively. The AVM obliteration rate was classified as complete or residual, guiding decisions on further management if necessary.

Statistical analysis

Microsoft Excel 2013 was used for data entry, while data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 24 (SPSS, Armonk, New York: International Business Machines Corporation). Descriptive statistics were applied to summarize the collected data. Quantitative data were expressed using arithmetic means and standard deviations, while medians and ranges were used for data that did not follow a normal distribution. Qualitative data were presented as frequencies and percentages. To assess bivariate relationships, cross-tabulations were used for categorical variables. Comparisons of proportions between groups were conducted using the chi-square test, and Fisher's exact test was applied when appropriate for smaller sample sizes. For the comparison of abnormally distributed quantitative data, the Mann-Whitney test was performed to determine statistical significance. The threshold for statistical significance was set at a probability (P) value of less than 0.05. Any results with a P-value below this threshold were considered statistically significant, indicating a meaningful difference between the compared groups.

Results

After applying the exclusion criteria, a total of 30 patients who underwent surgical resection for AVM were included in the study. Among these, 10 patients had preoperative embolization, while the remaining 20 did not. The average age at diagnosis was 26 years, and just over half of the patients (56.7%) were male.

Headache was the most common presenting symptom, occurring in 30% of cases, followed by seizures in 16.6%. Other symptoms included unilateral weakness, decreased consciousness level (DCL), ataxia, and syncopal attacks.

Regarding AVM characteristics, most lesions were classified as Spetzler-Martin grades 2 and 3, accounting for 33.3% each, corresponding to Spetzler-Ponce class A and B. Grade 1 lesions represented 20% of cases, while grade 4 accounted for 13.3%. The average maximum AVM diameter was 3 cm, with patients who received preoperative embolization having slightly larger AVMs on average (3.08 cm vs. 2.9 cm in the non-embolized group).

More than half of the AVMs (53.3%) were located in the right hemisphere, while 46.7% were in the left. A total of 26.7% of cases were found in eloquent brain regions, with six of these cases belonging to the non-embolized group. The majority of AVMs were located in the frontal, temporal, and parietal lobes, with fewer cases in other lobes.

Most arterial feeders originated from the anterior circulation, with the middle cerebral artery (MCA) being the most common feeder. Regarding venous drainage, the majority of niduses drained into the superficial venous system alone, followed by those with both superficial and deep venous drainage, and finally those draining into the deep venous system alone. A higher proportion of cases in the non-embolized group exhibited deep venous drainage.

Arterial feeder aneurysms, nidus aneurysms, and venous aneurysms were each observed in 3.3% of cases. Less than half of the patients (36.7%) presented with intracerebral hemorrhage. Among the preoperatively embolized group, AVMs were less likely to be ruptured at the time of presentation.

Table (2): Descriptive data of patients' characteristics.

		Count	%
Procedure data	Surgical excision	20	66.7%
	E + surgical excision	10	33.3%
	Total	30	100.0%
Gender	Male	17	56.7%
	Female	13	43.3%
	Total	30	100.0%
Eloquence	Yes	8	26.7%
	No	22	73.3%
	Total	30	100.0%
S-P	A	14	46.7%
	B	12	40.0%
	C	4	13.3%
	Total	30	100.0%
SMG	1	6	20.0%
	2	10	33.3%
	3	10	33.3%
	4	4	13.3%
	Total	30	100.0%
Rate of obliteration	Residual	4	13.3%
	Total excision	26	86.7%
	Total	30	100.0%
Presentation	Fits	8	26.7%
	Headache	10	33.3%
	Ataxia	2	6.7%
	DCL	1	3.3%
	lt side weakness	5	16.7%
	rt side weakness	1	3.3%
	lt side numbness	1	3.3%
	syncopal attack	2	6.7%
	Total	30	100.0%
Rupture on presentation	lt cerebellar AVM	2	6.7%
	lt frontal AVM	3	10%
	lt frontal ICH	1	3.3%
	lt fronto parietal ICH	1	3.3%
	lt occipital and IVH	1	3.3%
	lt parietal AVM	3	10%
	lt temporal	2	6.7%
	lt temproparietal ICH	1	3.3%
	rt frontal AVM	2	6.7%
	rt frontal ICH	1	3.3%
	rt fronto parietal ICH	1	3.3%
	rt occipital AVM	1	3.3%

		Count	%
	rt parietal ICH	1	3.3%
	rt parietal and intraventricular ICH	2	6.7%
	rt parietal AVM	2	6.7%
	rt temporal AVM	4	13.3%
	rt temproparietal ICH	2	6.7%
	Total	30	100.0%
AVM loction	lt cerebellar	2	6.7%
	lt frontal	4	13.3%
	lt fronto parietal	1	3.3%
	lt occipital	1	3.3%
	lt parietal	3	10.0%
	lt temporal	2	6.7%
	lt temproparietal	1	3.3%
	rt frontal	3	10.0%
	rt fronto parietal	1	3.3%
	rt occipital	1	3.3%
	rt parietal	3	10.0%
	rt parietal and intraventricular	2	6.7%
	rt temporal	4	13.3%
	rt tempropariental	2	6.7%
	Total	30	100.0%
Feeding arteries	lt ACA	2	6.7%
	lt ICA and anterior choroidal A	1	3.3%
	lt MCA	4	13.3%
	lt MCA and ACA	1	3.3%
	lt MCA and PCA	2	6.7%
	lt PCA	1	3.3%
	lt superior cerebellar and PICA	2	6.7%
	rt ACA	2	6.7%
	rt MCA	7	23.3%
	rt MCA and ACA	4	13.3%
	rt PCA	4	13.3%
	Total	30	100.0%
Venous drainage	deep to VOG	1	3.3%
	deep veins to straight sinus	2	6.7%
	internal cerebral V into straight sinus	1	3.3%
	rt transverse and sigmoid sinus	2	6.7%
	straight sinus	1	3.3%
	superficial to cortical veins to rt transverse sinus	1	3.3%
	superficial to SSS	10	33.3%
	superficial to SSS and deep into internal cerebral vein	5	16.7%

		Count	%
	superficial to SSS and deep into vein of Galen	1	3.3%
	superficial to SSS and tansverse sinus	2	6.7%
	superficial to transverse sinus	2	6.7%
	tiny branches to vein of Labe	1	3.3%
	vein of gallen	1	3.3%
	Total	30	100.0%
Associated aneurysms	1 feeder	1	3.3%
	2 nidal	1	3.3%
	No	26	86.7%
	venous aneurysm	1	3.3%
	Yes	1	3.3%
	Total	30	100.0%
Morbidity and mortality	Died	2	6.7%
	no deficit	23	76.7%
	post E fits	1	3.3%
	Weakness	4	13.3%
	Total	30	100.0%

Outcomes Analysis

Obliteration Rate

The obliteration rate in the group that underwent embolization followed by microsurgery was 100%, with no residual nidus detected postoperatively. In comparison, the microsurgery-only group had an obliteration rate of 80%, with four cases (20%) showing residual nidus. However, despite the higher obliteration rate in the embolized group, the difference between both groups was not statistically significant (P-value = 0.272).

Estimated Blood Loss

The average blood loss among all patients was 373 mL. The maximum recorded blood loss in the embolization plus microsurgery group was 500 mL, whereas in the microsurgery-only group, the highest recorded loss was 4 liters. Although there was a trend toward lower blood loss in the embolized group, the difference between the two groups was not statistically significant (P-value = 0.286).

Morbidity and Mortality

Postoperative morbidity was assessed using the modified Rankin Score (mRS). A worse postoperative mRS was observed in seven patients, while 23 patients had no significant postoperative deficits. In the microsurgery-only group, four patients (20%) developed postoperative weakness, which showed improvement within three months with physiotherapy. Additionally, two patients in this group (10%) succumbed to complications. In the embolization plus microsurgery group, one patient experienced post-embolization seizures, which were successfully managed. Despite these differences in morbidity and mortality between the two groups, the statistical analysis revealed no significant difference (P-value = 0.148).

Table (3): Relations between both procedures

		Procedure data				P value
		Surgical excision		E + surgical excision		
		N	%	N	%	
Rate of obliteration	**Residual**	4	20.0%	0	0.0%	0.272
	Total excision	16	80.0%	10	100.0%	
Morbidity and mortality	**Died**	2	10.0%	0	0.0%	0.148
	no deficit	14	70.0%	9	90.0%	
	post E fits	0	0.0%	1	10.0%	
	weakness	4	20.0%	0	0.0%	

*Chi-square test

Table (4): Relations between both procedures

Procedure data			Age	Blood loss amount
Surgical excision	**N**	**Valid**	20	20
		Missing	0	0
	Median		26.00	200.00
	Minimum		7	100
	Maximum		55	4000
	Percentiles	**25**	17.50	200.00
		75	34.50	300.00
E + surgical excision	**N**	**Valid**	10	10
		Missing	0	0
	Median		24.50	200.00
	Minimum		12	100
	Maximum		40	500
	Percentiles	**25**	18.25	100.00
		75	34.00	300.00
P value			0.741	0.286

*Mann-Whtiney test

Discussion:

Arteriovenous malformations (AVMs) are vascular lesions comprised feeding arteries shunted to draining veins without intervening capillary networks. The prevalence of AVM is 10 to 18 patients per 100,000 persons, and the annual incidence is 1.1 to 1.3 cases per 100,000 individuals [8]. Symptomatic AVMs may present with intracranial hemorrhage, seizure, headache, and ischemic deficits. The annual rupture risk ranges from 2.1% to 4.3%, leading to devastating ICHs, which are associated with morbidity and mortality of 25% to 60% and 10% to 30%, respectively. The risk factors of hemorrhage are prior AVM rupture, aging, exclusively deep venous drainage, deep-seated AVM, venous outflow stenosis, and feeding artery aneurysm [9].

Provided intracranial hemorrhage as the most common debilitating manifestation, the AVM treatment goal is total obliteration. Treatments include conservative management, microsurgical resection, stereotactic radiosurgery, endovascular embolization, and multimodality approaches. Given that interventions are not risk-free, surgeons should weigh interventions against the natural history on an individualized approach [10].

Surgery is an option when the risk is acceptable. Preoperative embolization has traditionally been regarded as a safe and effective adjunct to microsurgical treatment of brain arteriovenous malformations. However, there is currently no high-level evidence to ascertain this presumption. To date, no randomized controlled trial has compared the safety and efficacy of microsurgery with preoperative embolization (E + MS) vs. microsurgery (MS) alone. This study seeks to assess whether there is a significant difference in AVM obliteration, intraoperative blood loss, morbidities, and mortalities in patients who underwent MS vs. patients who underwent E + MS.

In a retrospective review of a collected clinical database of brain AVMs treated from January 2005 to March 2021, a total of 38 consecutive patients underwent AVM resection after preoperative embolization. Based on preoperative embolization materials, the patients were divided into the pre-Onyx group (n=16), in which NBCA or coils were used for embolization, and the Onyx group (n=22). Patient characteristics and treatment results were compared between the two groups. They concluded that preoperative embolization with Onyx can significantly reduce the amount of intraoperative bleeding in AVM resection and may contribute to safe AVM surgery [11].

In a recent cohort study of 88 patients (median age 40 years [IQR 19–53], 55% male) who underwent AVM resection, 34/88 (39%) patients underwent preoperative embolization, and complete resection was achieved at first surgery in 74/88 (84%). Preoperative embolization was associated with increased adjusted odds of complete AVM resection (adjusted odds ratio [aOR] 8.6 [95% confidence interval (95% CI) 1.7–67.7]; p=0.017). The presence of deep venous drainage was associated with a reduced chance of complete AVM resection (aOR 0.18 [95% CI 0.04–0.63]; p=0.009). Preoperative embolization is associated with improved chances of complete AVM resection following adjustment for Spetzler-Martin grade and should therefore be considered when planning surgical resection of AVMs [12].

Luksik et al. collected a database of retrospective and prospective cases between 1990 and 2015. Patients with complete clinical data who underwent surgical resection for AVMs were included. Forty-eight patients without preoperative embolization were matched to 48 with embolization, with no significant differences in baseline variables or AVM characteristics between the two groups. They found no significant differences in AVM obliteration and postoperative modified Rankin Scale (mRS) scores between embolized and nonembolized patients, respectively. Secondary outcome measures, including duration of surgery (P=0.172), intraoperative bleeding (P=0.280), duration of hospitalization (P=0.368), and postoperative symptoms, were also similar between both groups. Their data do not support the substantial benefit of preoperative embolization for patients with a favorable surgical risk profile. Because of the risks and costs associated with this intervention, the prudent use of preoperative embolization should be individually considered [13].

In a systematic review and meta-analysis, data were collected from thirty-six studies with 2,108 patients included in this analysis. Most patients (90.6%) who underwent embolization had at least a 50% obliteration of AVMs on post-treatment preoperative angiography, with a mean rate of obliteration of approximately 80% (range 28.8–100%). Among patients who had combined treatment, 3.4% (95% confidence interval [CI] 2.1–4.6%) experienced embolization-related hemorrhagic complications before surgery. Both treatment groups achieved excellent postsurgical complete resection rates (odds ratio [OR] 1.05; 95% CI 0.60–1.85). Neither the clinical outcome (OR 1.42; 95% CI 0.84–2.40) nor the total number of hemorrhagic complications (OR 1.84; 95% CI 0.88–3.85) was significantly different between the treatment groups. Anecdotally, preoperative embolization facilitates safe and efficient resection; however, differences in outcomes were not significant. The decision to pursue preoperative embolization remains nuanced based on individual lesion anatomy and treatment team experience [14].

Our study is a prospective non-randomized study conducted on 30 patients with cerebral AVM who were treated with microsurgical resection.

Twenty cases had microsurgical resection without preoperative embolization, with an obliteration rate of 80% proven at the postsurgical angiography. Four cases showed postoperative residual (three cases were followed up, and one case required a second session). Postoperatively, two cases died (one due to massive blood loss and transfusion). Two cases had associated nidal aneurysms, and both showed postoperative residuals. Four cases developed immediate postoperative weakness on one side, which improved with physiotherapy and antiplatelet drugs. Fourteen cases had no deficit (70%). Most cases included in this group were of Spetzler-Martin grade 2 and 3 and located close to an eloquent area.

Ten cases had preoperative endovascular embolization, with an obliteration rate of 100% proven at the postsurgical angiography. There was a decrease in intraoperative blood loss in these cases (maximum 500 ml), and the rate of postoperative morbidity and mortality also decreased (only one case developed fits and dysphasia, 10%). Most cases included in this group were high-grade AVMs (Spetzler-Martin grade 3 and 4). One case had a feeder-associated aneurysm that was easily closed during embolization. Preoperative embolization downgraded the AVM, decreased the nidal size, and made it more compact, which helped in microsurgical resection. Also, in low-grade and small AVMs, the compact nidus and the solid mass obtained after embolization had a significant effect on localization, dissection, and excision of the AVM.

There was no statistically significant difference between the two groups regarding obliteration rate ($P=0.272$), estimated blood loss ($P=0.286$), and morbidity and mortality occurrence ($P=0.148$), probably due to the small sample size and the short duration of the study.

Limitations

One of the primary limitations of this study is the relatively small sample size compared to similar studies. A larger cohort would have provided more robust statistical power and potentially more conclusive results. Additionally, the study was conducted in a non-randomized manner, which may introduce selection bias and affect the comparability of outcomes between the two groups.

Despite a high number of patients being admitted with cerebral AVMs, only 30 met the inclusion criteria, while the rest were excluded due to one or more exclusion criteria. This further limited the sample size and may have influenced the generalizability of the findings. Expanding the study over a longer duration may allow for a larger sample size, which could yield more definitive conclusions.

Another significant limitation was the availability of embolization supplies and materials. Limited resources restricted the ability to perform preoperative embolization for all eligible patients, which may have influenced the observed outcomes. Addressing these limitations in future research could improve the study's applicability and provide a more comprehensive understanding of the optimal management of cerebral AVMs.

Conclusion

Preoperative embolization is a safe and effective adjunct to microsurgical treatment of brain arteriovenous malformations. In our study, it was associated with higher rate of AVM obliteration and lower amount of intraoperative blood loss. However, the study outcome was statistically insignificant due to the small sample size. Preoperative embolization is to be considered with certain individual cases especially high grade AVMs.

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