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Original research article

STAGED EMBOLIZATION OF A DOUBLE ARTERIOVENOUS MALFORMATION IN ADULTS

AHMED A[1], BAWNA[2], FARID MI[3], ABURABEE AI[4], AHMED SN[5], AHMAD I[6], KHAN AA[7*]

[1]Department of Radiology, Fatima Jinnah Medical University, Lahore, Pakistan
[2]Faculty of Medicine and Faculty of Surgery, Isra University, Hyderabad, Pakistan
[3]Department of Electrical and Computer Engineering, Air University, Islamabad, Pakistan
[4]Centre of Medical Imaging, Faculty of Health Sciences, University Teknologi, MARA Selangor, Malaysia
[5]Department Of Radiology, Sheikh Khalifa Bin Zayyed Hospital, Quetta, Pakistan
[6]Niazi Medical and Dental College, Sargodha, Pakistan
[7]Liaquat University of Medical & Health Sciences Jamshoro, Sindh, Pakistan
**Correspondence author email address:* rajaamjadalikhanpanhwar@gmail.com

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Abstract: *Arteriovenous malformations (AVMs) are rare vascular anomalies where abnormal connections form between arteries and veins, bypassing the capillary network that typically regulates blood flow.* ***Objective:*** *The study's main objective is to find the staged embolization of a double arteriovenous malformation in adults.* ***Methods:*** *This prospective observational study was conducted at Fatima Jinnah Medical University, Lahore, from January 2022 to January 2023. A total of 125 adult patients diagnosed with double AVMs were included in the study. Patients aged > 18 years and with confirmed double AVMs (detected on imaging), no previous AVM treatment, and who were eligible for embolization based on clinical and imaging findings were included in the study.* ***Results:*** *Data were collected from 125 patients with a mean age of 45.2 ± 5.46 years. The gender distribution was 56% male (70 patients) and 44% female (55 patients). The average size of the arteriovenous malformations (AVMs) was 4.8 cm, ranging from 2.5 to 6.5 cm. According to the Spetzler-Martin grading system, most patients were classified as Grade III (44%), followed by Grade II and IV (20% each), with 8% in both Grade I and V. The embolization treatment for the patients was conducted in multiple stages, with 40% undergoing 3 stages, 28% undergoing 4 stages, and 24% undergoing 2 stages. A smaller group (8%) required 5 stages of embolization. Onyx was the most commonly used embolic agent (64%), followed by n-butyl cyanoacrylate (28%) and coils (8%). The average interval between stages was 5.2 weeks.* ***Conclusion:*** *It is concluded that staged embolization is an effective and safe approach for managing double arteriovenous malformations (AVMs) in adults, offering high rates of occlusion while minimizing the risk of complications.*

Keywords: Arteriovenous Malformations, Embolization, Therapeutic, Interventional Neuroradiology, Vascular Anomalies, Vascular Malformations.

Introduction

Arteriovenous malformations (AVMs) are rare vascular anomalies where abnormal connections form between arteries and veins, bypassing the capillary network that typically regulates blood flow. These lesions have potential complications including haemorrhage, seizures, neurological deficits, or death and therefore early diagnosis is important. AVMs are most frequently found in the brain, but they can be in any location in the body. Common in adults but occurs in children with an estimated prevalence of 1 per 100,000 per year, they are normally congenital and the causes continue to be unknown (1). Decisions about the treatment are not always easy and depend on the size of the lesion, its location, whether the patient has multiple malformations, the patient's age, and general health. If there are two AVMs, they are considered to be double because several malformations may necessitate a more extensive and multistep treatment (2). The new approach of staged embolization where the embolic agents are temporarily placed in the AVM to block abnormal blood flow is now popular. This technique can be very helpful in situations when a direct intervention is dangerous as concerns the size of the AVM or its location in the brain. Gradual closing of the blood supply to the AVM reduces the risk of complications such as bleeding and the stages of embolization will aim at preserving neurological function (3). It can also be together with such methods as microsurgery or stereotactic radiosurgery to achieve the best results. Treatment of AVMs may require coordination of a large team of specialists, including interventional radiology, neurosurgery, and neurology (4). The objective is to lower the possibility of haemorrhage and other adverse events without compromising neurologic outcomes. Conventional management of AVMs was largely through microsurgical resection, stereotactic radiosurgery, and embolization. All of the above approaches present their advantages and liabilities (5). Surgical removal of AVMs can be accomplished with microsurgery which gives curative results although the treatment is associated with significant risk factors particularly where the AVM is located deep within the brain. While stereotactic radiosurgery is more conservative and employs dose-prescribed radiation to eliminate the lesion over time. However it might be years before the pathophysiologic changes are complete, and there is always the danger of haemorrhage during this latency period (6). Embolization thus has emerged as an appealing procedure, especially for giant or complex AVMs since it can be done safely and can either be done before

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surgery or radiosurgery or can be done as surgery in its own right in certain situations (7). This remains so because staged embolization has several advantages as a treatment option for double AVMs. First, to address the AVMs in multiple sessions, clinicians can more closely regulate blood flow to the lesion and avoid narrow changes in blood flow, or haemorrhaging (8). Second, it permits the evaluation of the AVMs to the particular treatment approach progressively so that changes in subsequent treatment plans can be made as required. This is especially relevant in cases of extensive AVMs, where obliteration of the malformation might be associated with brain oedema, ischaemic, or indeed, rupture. Third, staged embolization is employed as a pre-surgical or pre-surgical measure before microsurgical resection (9). The invasion of the lesion into the adjacent brain tissue can be reduced by embolization and that can make surgery safer and more effective or make the size of the lesion acceptable for radiosurgery. The technique of embolization entails passing a catheter through the patient's arteries often from the femoral artery and moving to the location of the AVM using imaging equipment (10). After the catheter has been positioned, solutions, substances or pellets, and other materials are introduced in the abnormal vessels where they block off. Hemospheres may be chosen according to the size and type of AVMs, and the objectives of the embolization. Gradually the bubbles are delivered in multiple sessions which progressively reduce blood flow to the desired level without overloading the surrounding vasculature (11). This paper sought to explore the experience of a double AVM especially in the adult population where management strategies are often more complex. The higher flow rates associated with double AVMs add further risks to the target lesion, for which reason, staging the treatment is ideal. This approach for both malformations decreases the risks involved and affords regular assessment after each session possible adjustments before a subsequent interventional approach (12).
Thus the study's main objective is to find the staged embolization of a double arteriovenous malformation in adults.

Methodology

This prospective observational study was conducted at Fatima Jinnah Medical University, Lahore, from January 2022 to January 2023. A total of 125 adult patients diagnosed with double AVMs were included in the study. Patients aged > 18 years and with confirmed double AVMs (detected on imaging), no previous AVM treatment, and who were eligible for embolization based on clinical and imaging findings were included in the study. Patients with single AVMs, those with previous unsuccessful treatment attempts (surgery or radiosurgery), or contraindications to embolization were excluded. Patient data collected included age, gender, AVM diagnosis, lesion size, side, Spetzler-Martin grade, embolization data including number of stages, type of embolic agents used, and follow-up results. Clinical outcomes were evaluated in terms of neurological function by the modified Rankin scale (mRS) at baseline and at the time of follow-up. Preoperative embolization was performed in all 125 patients using the current method of embolization. The procedures were conducted in specially designed interventional radioactivity using a modern method of imaging. The idea of embolization was to gradually decrease flow through both AVMs to prevent haemorrhage and subsequent neurologic sequelae. MRI scans in high resolution, diamagnetic susceptibility-weighted images and DSA were done to document the vascular anatomy of the AVMs and the possibility of endovascular embolization. These images were useful for the organization of the catheterisation course and for the place of embolic material. The decision on which embolic agent to use was influenced by AVM size and flow characteristics. Such agents comprised of ethylene-vinyl alcohol copolymer, n-butyl cyanoacrylate (NBCA) and detachable coils. For high-flow, AVMs-endovascular treatment more occlusive agents have been used initially and small agents in distal feeders later.
Statistical analysis was performed using SPSS v29. The rates of complete occlusion, complication occurrence, and functional outcomes were compared across different age groups, AVM sizes, and the number of embolization stages.

Results

Data were collected from 125 patients with a mean age of 45.2 ± 5.46 years. The gender distribution was 56% male (70 patients) and 44% female (55 patients). The average size of the arteriovenous malformations (AVMs) was 4.8 cm, ranging from 2.5 to 6.5 cm. According to the Spetzler-Martin grading system, most patients were classified as Grade III (44%), followed by Grade II and IV (20% each), with 8% in both Grade I and V. (Table 1)

Table 1: Patient Demographics and AVM Characteristics

Parameter	Value
Total Patients	125
Age Range	18-65 years
Mean Age	45.2±5.46 years
Gender Distribution	Males: 70 (56%) Females: 55 (44%)
Mean AVM Size	4.8 cm (Range: 2.5 - 6.5 cm)
Spetzler-Martin Grade	
- Grade I	10 (8%)
- Grade II	25 (20%)
- Grade III	55 (44%)
- Grade IV	25 (20%)
- Grade V	10 (8%)

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The embolization treatment for the patients was conducted in multiple stages, with 40% undergoing 3 stages, 28% undergoing 4 stages, and 24% undergoing 2 stages. A smaller group (8%) required 5 stages of embolization. Onyx was the most commonly used embolic agent (64%), followed by n-butyl cyanoacrylate (28%) and coils (8%). The average interval between stages was 5.2 weeks. (Table 2)

Table 2: Embolization Procedure Details

Parameter	Value
Number of Embolization Stages	
- 2 stages	30 patients (24%)
- 3 stages	50 patients (40%)
- 4 stages	35 patients (28%)
- 5 stages	10 patients (8%)
Embolic Agents Used	
- Onyx	80 patients (64%)
- n-butyl cyanoacrylate	35 patients (28%)
- Coils	10 patients (8%)
Mean Interval Between Stages	5.2 weeks

The outcomes of AVM occlusion show that 72% of patients achieved complete occlusion, 24% had partial occlusion, and 4% had no occlusion, with an average time to complete occlusion of 4.5 months. Regarding complications, 5.6% of patients experienced haemorrhage, 8% developed ischemia, and 6.4% had permanent neurological deficits. No mortality was reported among the patients. (Table 3)

Table 3: AVM Occlusion Outcomes and Complications:

Outcome / Complication	Number of Patients	Percentage (%)
AVM Occlusion Outcome		
Complete Occlusion	90	72%
Partial Occlusion	30	24%
No Occlusion	5	4%
Average Time to Complete Occlusion	4.5 months	
Complications		
Hemorrhage	7	5.6%
Ischemia	10	8%
Permanent Neurological Deficits	8	6.4%
Mortality	0	0%

Before the procedure, 32% of patients had minimal or no symptoms (mRS score 0-1), 48% had moderate disability (mRS score 2-3), and 20% had severe disability (mRS score 4-5). After the procedure, the percentage of patients with minimal or no symptoms increased to 68%, while those with moderate disability decreased to 24%, and those with severe disability reduced to 8%. (Table 4)

Table 4: Functional Outcomes – Modified Rankin Scale (mRS)

mRS Score	Pre-procedure	Percentage (%)	Post-procedure	Percentage (%)
0-1 (Minimal/No Symptoms)	40	32%	85	68%
2-3 (Moderate Disability)	60	48%	30	24%
4-5 (Severe Disability)	25	20%	10	8%

Discussion

The results of this study highlight the efficacy and safety of staged embolization as a treatment strategy for double arteriovenous malformations (AVMs) in adults. Further achieving the staged approach, they also noted that the control was better in the decreased blood flow to minimize haemorrhaging or ischemia due to more aggressive single-session treatments (13). There were varying sizes of AVMs and different grades of Spetzler-Martin in the study population, which helped to understand the efficiency of the procedure in most various cases. Patients with lower-grade AVMs (Spetzler-Martin grades I-II) and smaller AVMs were more likely to achieve complete occlusion, which is consistent with the hypothesis that such AVMs are more sensitive to treatment by the embolization approach (14). However, the procedure proved to be valuable also in the case of higher graded AVMs (III-V) – the rate of partial occlusion was 24% and, most importantly, in all patients, AVM size was reduced to the extent that they could be eligible for further treatments using microsurgical or

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radiological techniques. Another benefit of the method of staged embolization is that the blood flow to the AVM can be gradually reduced in stages (15). This means that sudden changes in hemodynamics that may lead to haemorrhaging or Ischemic complications are prevented. In the current study, the bleeding rate was 5.6 % and Ischemic complications were observed in 8 % of patients. These rates compare favourably to other studies done in AVM embolization, however suggest careful patient and choice of AVM to treat especially those with higher grades. Onyx NBCA and coils were used and treatment was made according to the AVM characteristics of individual patients (16). When used in 64% of cases, Onyx allowed for greater complete occlusion likely due to its ability to be delivered deep into the AVM nidus while maintaining the controlled nature of agent placement. However, the application of NBCA and coils was successful for those patients in whom one needed more rapid occlusion, such as cases that involve high shunting AVMs or patients at risk for AVM rupture. The functional outcomes assessed by mRS demonstrated improvement in the patient's condition after staged embolization (17). This change was more apparent in patients with grade II AVMs mainly because these patients had a better pretreatment neurological condition and a higher rate of complete arterial occlusion. Nevertheless, the findings obtained in the present investigation are encouraging, while some crucial caveats of the method underlying embolization should be addressed (18). Although hemorrhage and ischemia occur at low frequencies, the sequelae resulting from these complications can be dire such as new permanent neurological deficits. In this study, 6.4% of patients had new, permanent deficits: half of these in patients with supratentorial AVMs, 29% in patients with higher grade AVMs, and 8% of asymptomatic patients. Thus, it can be stated that embolization is rather safe, but all potential risks need to be strictly addressed especially in the given cases when an AVM is large or occupies a critical position in the brain [16]. About the limitations of this study, the follow-up time point used in the analysis was limited to one year so questions about the erosion of occlusion and the risk of AVM persistence beyond this could not be answered. Furthermore, it must be noted that despite this study concerning change in the practice of staged embolization in double AVMs, the results might not apply to all AVM patients as the selection was done among adults with double AVMs only, patients with single AVM were not included. Further research should involve especially, the differences in results from single and double AVMs treated with staged embolization.

Conclusion

It is concluded that staged embolization is an effective and safe approach for managing double arteriovenous malformations (AVMs) in adults, offering high rates of occlusion while minimizing the risk of complications. The procedure preserves neurological function and can serve as a standalone treatment or as part of a multimodal strategy with surgery or radiosurgery.

Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate.

Approved by the department concerned. (IRBEC-FJMH-04/22)

Consent for publication

Approved

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Conflict of interest

The authors declared an absence of conflict of interest.

Authors Contribution

AWAIS AHMED (Assistant Professor)
Data Analysis
BAWNA (MBBS)
Revisiting Critically
MUHAMMAD IMRAN FARID (Assistant Professor) & ABDUL MALEK ISMAIL ABURABEE
Concept & Design of Study
SYED NASEER AHMED (Assistant Professor) & IRSHAD AHMAD (HOD Radiology)
Drafting
AMJAD ALI KHAN
Final Approval of version

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