https://doi.org/10.3329/bjns.v14i1.88974

Original Article

Single-Stage Microsurgical Resection of Spetzler-Martin Grade III–V AVMs in Resource-Limited Settings: A Retrospective Outcome and Complication Analysis

Azam I[1], Ahmed N[2], Subhan KI[3], Razzaque SS[4], Bhuiyan S[5], Ashraf JB[6], Kabir MS [7], Sarker SC[8], Anam AAJ [9], Jahid K M A[10], Islam N[11]

Conflict of Interest:

Funding Agency:

Contribution to Authors: Dr. Md Isma Azam, Dr. Nazmin Ahmed,

Manuscript Priparation: Dr. Nazmin Ahmed

Data Collection: Dr. Kazi Irfan Subhan, Dr. Syed Shahreor Razzaque, Dr. Md. Sharif Bhuiyan, Dr. Junayed Bin Ashraf, Dr. Md. Nurnabi Islam

Editorial Formatting: Dr. Muhammad Shahriar Kabir, Dr. Syed Shahreor Razzaque

Received: 01 May, 2024

Accepted: 01 June, 2024

Abstract:

Objective: Cerebral arteriovenous malformations (AVMs) are complex vascular anomalies that often present with hemorrhage or seizures in resource-limited settings. High-grade AVMs pose significant surgical challenges, yet microsurgical resection remains the most definitive treatment with the highest obliteration rates.

Aims: This study aimed to evaluate the feasibility and outcomes of single-stage microsurgical resection for high-grade cerebral AVMs.

Materials and Methods: A retrospective analysis was conducted on 13 patients with Spetzler-Martin (SM) Grade III-V AVMs who underwent single-stage microsurgical resection between 2020 and 2025. Demographic information, clinical presentations, angioarchitecture details, perioperative complications, and outcomes were recorded. Post-operative complications were assessed via immediate post-operative brain CT scans, and follow-up CT angiograms at 3 months evaluated AVM resection completeness. Functional outcomes were measured using mRS scores at the last follow-up (range: 3 months to 5 years).

Results: The mean patient age was 29.84 years, with a male predominance (male-to-female ratio 1.6:1) and a higher incidence of left-sided AVMs (1.6:1). The most common presenting symptoms were hemiparesis (n=7) and convulsions (n=6). Angio-architecturally, 7 patients had SM Grade III and 6 had SM Grade IV AVMs. Complete microsurgical resection was achieved in all cases (100%). Perioperative complications included cortical injury and resection bed hematoma (n=4), intraoperative brain swelling, osteomyelitis, Stevens-Johnson syndrome, and cerebral venous sinus thrombosis (each, n=1). Functional outcomes improved in 8 patients, remained unchanged in 3 patients, and 2 patients died due to perioperative complications.

Conclusion: Single-stage microsurgical resection demonstrates favorable neurological outcomes despite the complexity of lesions and associated risks. However, factors traditionally considered predictive of unfavorable outcomes was not significantly correlated with poorer outcomes.

Key words: Arteriovenous malformations; Functional outcome; Microsurgery, Spetzler-Martin grades; Complications

List of Abbreviation:

AVM	Arteriovenous malformation	MRI	Magnetic resonance imaging
CT	Computed tomography	mRS	Modified Rankin Scale
CVST	Cerebral venous sinus thrombosis	SMG	Spetzler martin grade
DSA	Digital subtraction angiography	NPPB	Normal perfusion pressure breakthrough bleeding
ICP	Intracranial pressure		

Introduction:

Brain arteriovenous malformations (AVM) are considered congenital cerebrovascular lesions characterized by an abnormal mass of dilated arteries and veins, connecting directly without an intervening capillary bed [1]. They can be incidental or present with headaches, seizures, or most commonly intracranial hemorrhage associated with significant mortality and morbidity [2]. Because of advanced medical imaging in developed countries, the majority of patient harboring AVM lesions are typically asymptomatic when they are detected or investigated unlike in our part of the world where majority of patient come with hemorrhage or rapid deterioration of the consciousness level [3]. When the rupture occurs, it is documented as a significant cause of neurological deficit for the reason that it is the origin of intracranial hemorrhage or seizure. AVM generally presents about 1/100,000 of all population [4].

1. Dr. Md Isma Azam, MS, Assistant Professor, Department of Neurosurgery, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email:zicodmc@gmail.com
2. Dr. Nazmin Ahmed, MS, Assistant Professor & Associate Consultant, Department of Neurosurgery, Ibrahim Cardiac Hospital & Research Institute (A Centre for Cardiovascular, Neuroscience & Organ Transplant Units), Shahbag, Dhaka, Bangladesh. Email: nazmin.bsmmu@gmail.com
3. Dr. Kazi Irfan Subhan, MS, Neurosurgeon, Department of Neurosurgery, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: Irfan.subhan.ns@gmail.com
4. Dr. Syed Shahreor Razzaque, MS, Assistant Professor, Department of Neurosurgery, Shaheed Suhrawardy Medical College & Hospital, Dhaka, Bangladesh. Email: shopnochary2004@gmail.com
5. Dr. Md. Sharif Bhuiyan, MS, Assistant Professor, Department of Neurosurgery, Z H Sikder Womens Medical College Hospital, West Dhanmondi, Dhaka, Bangladesh. Email: ssquite@gmail.com
6. Dr. Junayed Bin Ashraf, MS, Medical officer, Department of Neurosurgery, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: junash9@gmail.com
7. Dr. Muhammad Shahriar Kabir, MS, Registrar, Department of Neurosurgery, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: Dr.m.s.kabirbd@gmail.com
8. Dr. Shajib Chandra Sarker, MS, Registrar, Department of Neurosurgery, Sher-E-Bangla medical College hospital, Barishal, Bangladesh. Email:shajibchandrasarker94@gmail.com
9. Dr. A An Jahinul Anam, MBBS, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: fayedk73@gmail.com
10. Dr. K M Abu Jahid, MBBS, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: jahid.jony0501@gmail.com
11. Dr. Md. Nurnabi Islam, MBBS, Dhaka Medical College & Hospital, Dhaka, Bangladesh. Email: nurnabiislam.marmc@gmail.com

Corresponding author: Dr. Nazmin Ahmed, MS, Assistant Professor & Associate Consultant, Department of Neurosurgery, Ibrahim Cardiac Hospital & Research Institute (A Centre for Cardiovascular, Neuroscience & Organ Transplant Units), Shahbag, Dhaka, Bangladesh. Email: nazmin.bsmmu@gmail.com ORCID: 0000-0002-6308-8498 Phone: 01798625387

Given the risk for hemorrhagic stroke, resection remains the gold standard for treating cerebral AVMs. Compared to the other modalities available, surgery averages 95.9% complete obliteration versus 22.1% for endovascular treatment and 67.4% for radiosurgery [5]. This present study represents the authors' experiences with 13 high grade cerebral AVM patients with microsurgical treatment to retrospectively evaluate outcome score by modified Rankin Score (mRS) during 2020-2025.

Materials and Method

Study Design and Setting

This was a retrospective study conducted between 2020 and 2025 at two tertiary care hospitals in Bangladesh: Dhaka Medical College Hospital and Sirajul Islam Medical College Hospital. Ethical approval was obtained from the respective institutional review boards, and informed written consent was secured from all participants or their legal representatives.

Participants

Thirteen patients with Spetzler-Martin (SM) Grade III-V cerebral arteriovenous malformations (AVMs) were included. Patients diagnosed with SM Grade I and II AVMs, those with recurrent AVMs, and cases requiring staged surgical resection or combined endovascular and microsurgical approaches were excluded.

Data Collection

Patient data were collected retrospectively using a structured data collection form, including demographic information (age, gender), detailed clinical presentation, duration and type of symptoms, and preoperative neurological status assessed using the modified Rankin Scale (mRS).

Imaging and Diagnostic Protocol

Diagnosis and surgical planning involved preoperative imaging, including magnetic resonance imaging (MRI), computed tomography angiography (CTA), and digital subtraction angiography (DSA) for large or anatomically complex AVMs. AVM angioarchitecture details, such as nidus size, eloquent location, arterial feeders, venous drainage patterns, and presence of intranidal aneurysms were recorded.

Surgical Technique

All patients underwent single-stage microsurgical resection performed by experienced neurosurgeons. Surgical planning included detailed analysis of preoperative imaging, with routine intraoperative utilization of Doppler ultrasonography and indocyanine green (ICG) angiography to facilitate precise delineation and ensure complete resection of AVM nidus. Standard microsurgical techniques were employed, emphasizing preservation of adjacent normal brain tissue.

Postoperative Care and Follow-Up

Immediate postoperative CT scans were conducted to identify complications such as resection bed hematomas, cerebral edema, or venous infarction. Follow-up CTA was performed at three months post-surgery to confirm complete resection. Clinical follow-up evaluations were systematically conducted at two weeks, three months, six months, and annually thereafter for up to five years. Functional outcomes were evaluated longitudinally using mRS scores and compared against preoperative baseline mRS values.

Results

Patient Demographics and Clinical Presentation

Between 2020 and 2025, 13 patients with SM Grade III-V AVMs underwent microsurgical resection. The mean age at diagnosis was 29.84 years (range: 24–72 years), with a male predominance (male-to-female ratio of 1.6:1) and a greater frequency of left-sided AVMs (left-to-right ratio of 1.6:1). The most common presenting symptom was hemiparesis, occurring in 7 patients (53.8%), followed by seizures in 6 patients (46.2%). The majority of AVMs (n=10, 76.9%) were located in eloquent brain regions.

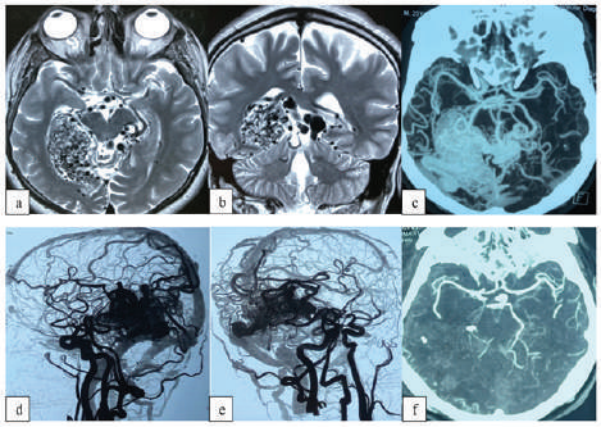

Figure 1: A 26-year-old man with right medial temporal AVM. Axial (a) and coronal (b) T2W-MRI demonstrated a tangle of multiple dot like and branching flow voids occupying right sided medial lobe, posteromedial to the temporal horn. (c) CTA showing a compact nidus of about 7x6.5x 5 cm in diameter. TRCTA and lateral (d) and oblique (e) views show arterial feeders from multiple branches of the right middle cerebral artery and posterior cerebral artery. The AVM has a deep venous drainage into the basal vein of Rosenthal (Spetzler-Martin grade 4). (f) Follow up CTA demonstrated complete resection of the AVM. Here, AVM: arteriovenous malformation; TRCTA: time-resolved computed tomography angiogram; T2W-MRI: T2 weighted magnetic resonance imaging.

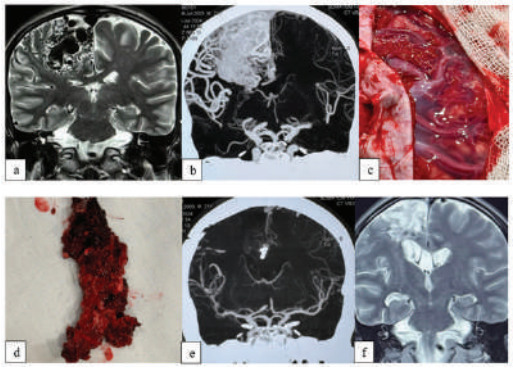

Figure 2: A 24-year-old man with left frontal AVM. (a) Coronal T2W-MRI demonstrated multiple dilated dot like and branching, coalescing flow voids occupying left frontal lobe. (b) CTA showing a compact nidus of about 7x 5 cm, extending medially to falx cerebri and filling the parasagittal angle. The AVM is feeded by branches from ACA, MCA, PCA and drained into SSS (Spetzler-Martin grade 4). (c) gross appearance of the malformation, after durotomy. (d) chocolate reddish resected specimen, of about 5x 2.5 cm. (e) Post-operative CTA ensured complete resection of the malformation. (f) Follow up MRI after 3 months showing no residual with mild encephalomalacic changes. Here, AVM: arteriovenous malformation; T2W-MRI: T2 weighted magnetic resonance imaging; ACA: anterior cerebral artery; MCA: middle cerebral artery; PCA: posterior cerebral artery; SSS: superior sagittal sinus; CTA: computed tomography angiogram.

AVM Angioarchitecture

Of the 13 AVMs, 7 were categorized as SM Grade III, and 6 as SM Grade IV. Most AVMs (n=10, 76.92%) received arterial feeders from two major arterial territories, while two AVMs (15.38%)

had feeders from three major arterial territories. Venous drainage was either superficial or deep in 5 cases each, with the remaining 3 cases exhibiting both superficial and deep venous dra inage.

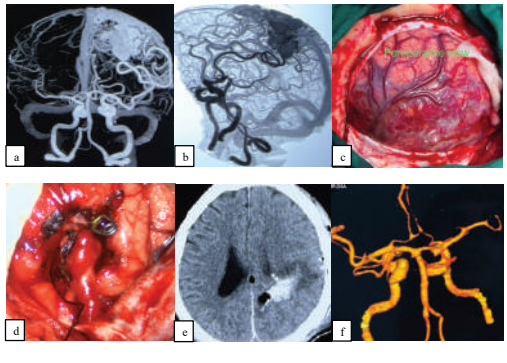

Figure 3: A 72 year-old male with left parietal AVM. TRCTA (a) antero-posterior and (b) left oblique view show multiple feeding vessel arise from both ACA and MCA, feeding a huge compact nidus of about 7x 6.5 x 4 cm in diameter with presence of intranidal aneurysm. The AVM is draining into SSS (Spetzler-Martin grade 4). (c) Intra-operative photograph showing gross appearance of the malformation after retraction of dural flap. (d) Complete resection with hemostasis ensured in the resection bed. (e) Patient developed a small resection bed hematoma at post-operative CT scan which later on spontaneously resolved. (f) 3DCTA ensured complete resection of the malformation. Here, AVM: arteriovenous malformation; TRCTA: time resolved computed tomography angiogram; ACA: anterior cerebral artery; MCA: middle cerebral artery; SSS: superior sagittal sinus; 3DCTA: 3 dimensional computed tomography angiogram.

Surgical Outcomes and Complications

Complete microsurgical resection was achieved in all cases (100%), as confirmed by follow-up CTA at 3 months postoperatively. Perioperative complications included cortical injury and resection bed hematoma in 4 patients (30.8%), intraoperative brain swelling in 1 patient (7.7%), osteomyelitis in 1 patient (7.7%), Stevens-Johnson syndrome in 1 patient (7.7%), and cerebral venous sinus thrombosis in 1 patient (7.7%), none in 6 patients [Figure: 4]. Two patients (15.4%) died due to severe perioperative complications (brain swelling and resection bed hematoma).

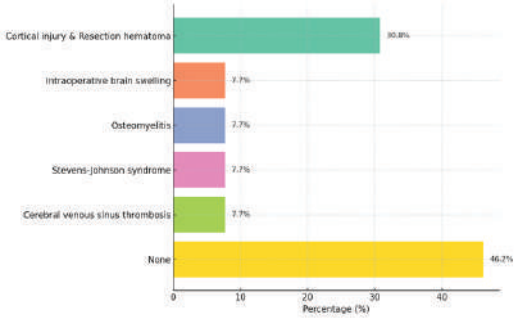

Figure 4: Perioperative surgery complications.

Functional Outcomes

Functional outcomes, assessed by mRS scores, improved postoperatively in 8 patients (61.5%), remained unchanged in 3 patients (23.1%), and deteriorated leading to mortality in 2 patients (15.4%) [Figure 5]. No statistically significant differences were observed in perioperative complications or functional outcomes when comparing SM Grade III and IV patients ($p > 0.05$, Chi-square test).

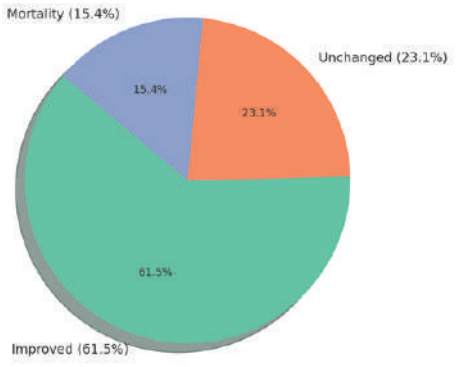

Figure: 5. Functional outcomes, assessed by mRS scores

Discussion

Microsurgical resection is widely accepted as a safe and effective treatment modality for low-grade AVMs (Spetzler-Martin Grade I–II), especially when located in non-eloquent brain areas, as it offers immediate cure with a low complication profile. However, for higher-grade AVMs (Grades IV–V), treatment is often more complex, and a multimodal approach, including embolization, stereotactic radiosurgery, and staged microsurgery is generally preferred. Stereotactic radiosurgery, focused irradiation, can be effective for malformations that are smaller than 3.5 cm, but complete obliteration requires approximately 1–3 years after treatment and cure is not always obtained. Delayed complications such as hemorrhage in the latency period and radiation edema or necrosis can occur as late complications. Embolization as an adjuvant therapy can be done for large AVM (SM Grade IV–V) or to obliterate small AVMs [6-9].

Ponce and Spetzler proposed a simplified 3-tier classification in 2011, grouping SM Grades I–II as Class A (recommended for surgery), Grade III as Class B (suitable for multimodal therapy), and Grades IV–V as Class C (often managed conservatively or with palliative interventions) [10]. Furthermore, ARUBA trial (A randomized trial of unruptured bAVMs) suggested superiority of conservative management over intervention for the prevention of the primary outcome, death resulting from any cause, or symptomatic stroke at follow-up [11,12]. Though, Ponce and Spetzler show surgical resection only for Class A and ARUBA trail show medical treatment superior for all types of brain AVMs, the outcomes of patients in our study where Class B and Class C were treated micro surgically goes against the reported literatures [10].

In our case series, all 13 patients with SM Grade III–V AVMs underwent single-stage microsurgical resection. Despite the higher grade and inherent risks, 61.5% experienced improved functional outcomes, and complete AVM obliteration was achieved in 100% of cases. This high rate of success aligns with prior reports demonstrating superior obliteration rates following surgery compared to radiosurgery or embolization. The hemorrhage risk associated with untreated AVMs or delayed treatment may outweigh the perioperative risks in select high-grade cases, particularly in resource-limited settings. Some studies have advocated for conservative management due to the risks associated with surgery in eloquent regions. However, repeated hemorrhagic events can lead to progressive neurological decline, ultimately tipping the balance toward surgical intervention. Although surgical risk in eloquent cortex for SM Grade III–V AVMs can approach 41%, [13]. our findings suggest that careful patient selection, surgical expertise, and appropriate intraoperative adjuncts can mitigate these risks.

In our context, microsurgical resection was chosen universally due to several factors: lack of access to radiosurgical facilities, delayed presentation, financial constraints, and limited follow-up adherence. Five patients presented with acute neurological deterioration and required urgent hematoma evacuation alongside AVM resection. These real-world constraints necessitate individualized treatment planning and reinforce the practicality of microsurgery in similar settings.

Therefore, microsurgery could be the most reliable modality for complete obliteration of AVM and prevention of long-term complication related to conservative management done in high grade brain AVM. On the other hand, considering other literature, case fatality after microsurgery may be higher than other treatment modalities due to selection bias because in patients who present with hemorrhage, surgery is more often performed in the acute phase. We operated all high-grade AVMs with SM Grade III–V as most cases presented with hemorrhage, low Glasgow Coma Scale and rapid deterioration of neurological status, therefore, we had gone for urgent craniotomy and removal of hematoma along with AVM resection at same setting in 5 cases.

The outcomes of patients, in particular Grade III–V, highlights that microsurgical treatment alone may be justified in this subset of patients as well. The finding of Grade III–V patients, regardless of grading system, have better clinical outcome which can be an eye opening for Neurosurgeons in resource limited setting. Furthermore, the result also highlights the need of prospective, multicentric data to better identify patients who may benefit most from microsurgical treatment alone. In particular, AVM patients diagnosed at a higher age seem to bear a higher proportion of AVM hemorrhage and are more likely to show additional risk factors (i.e., concurrent arterial aneurysms). Therefore, according to literature, older age was associated with higher case fatality. But, in our series, 2nd case was 72-year-old male, who diagnosed as SMG IV exhibit excellent outcome in 3.5 years follow up (mRS=0). Surgical risk has been reported to be associated with increasing nidus size, and presence of both superficial and deep venous drainage. The presence of deep perforating arterial supply is also associated with an increased risk of surgical morbidity in high grade AVMs. The deep perforating artery supply is also more common in large, complex AVMs which by themselves are associated with higher risk of surgery [14].

In our series, two patients died due to intraoperative brain swelling and resection bed hematoma. The possible explanation lies behind this might be occlusion of complex high-grade AVM can modify local hemodynamics and, in rare cases, may cause significant brain edema or even intracerebral hemorrhage. Two hypotheses prevail in the literature regarding occasional onset of hemorrhage and edema following AVM occlusion [15]. One patient developed Steven Johnson syndrome (SJS) at 1st post-operative period as a consequence of phenytoin administration. Although literature reported phenytoin induced severe form of SJS, [16,17], our patient did not need any ventilator support. The condition steadily improved with the administration of steroid (dexamethasone) for 2 weeks. Next complication was development of osteomyelitis, due to presence of pseudomonas. We have removed autologous bone flap and continued intravenous antibiotic for 6 weeks, followed by oral antibiotic for another 6 weeks. After 3 months, patient underwent cranioplasty with PEEK. Failure to maintain strict asepsis in perioperative period might be a reason behind this complication.

These fatal complications necessitate a deeper understanding of the underlying pathophysiological mechanisms associated with AVM resection in high-grade cases.

Four possible causes of postoperative bleeding in AVM surgery have been described: (1) insufficient surgical hemostasis, (2) bleeding from AVM remnants, (3) normal perfusion pressure breakthrough (NPPB), and (4) venous occlusive phenomena. The first two are relatively common and considered technical complications. NPPB, originally described by Spetzler, refers to the failure of chronically dilated vessels surrounding the AVM nidus to autoregulate once normal perfusion is restored after resection, leading to edema and hemorrhage. In our series, complete resection was confirmed in all cases [18,19]. Therefore, the resection bed hematomas seen in four patients were likely due to NPPB. Of these, two cases (Case 4 and Case 5, Figure 1 & 2) demonstrated spontaneous hematoma resolution.

Two patients (Cases 6 and 7) died following progressive malignant cerebral edema and resection bed hemorrhage. Despite intraoperative decompressive craniectomy and hematoma evacuation, we were unable to control intracranial pressure. Our analysis identified three likely contributors to this catastrophic outcome: (1) the presence of multiple deep perforating arteries (“red devils”) that made hemostasis challenging, (2) perioperative hypertensive episodes reopening fragile coagulated sites, and (3) venous outflow obstruction likely due to compression of cortical veins or sinuses, especially problematic in the supratentorial compartment where collateral venous drainage is limited. Additionally, both patients lacked preoperative dynamic DSA to evaluate AVM flow. Aboukais et al. (2022) reported malignant edema and hemorrhage in 6 of 72 AVM cases and suggested a link with high-flow lesions, advocating for staged resection in such cases [19,20,21].

Another notable complication in our cohort (Case 13) was suspected venous sinus thrombosis, presenting with headache and disequilibrium postoperatively. Although MR venography could not be performed due to economic limitations, CT imaging and clinical features supported the diagnosis. The patient was treated with oral rivaroxaban (10 mg daily) for 6 months, balancing anticoagulation against the risk of hemorrhage. Her symptoms resolved fully by the 3-month follow-up. Literature indicates that infratentorial venous thrombosis may present with fewer symptoms and better outcomes due to more robust collateral circulation. These complications emphasize the need for preoperative hemodynamic assessment, meticulous intraoperative

technique, and vigilant postoperative monitoring, especially in high-grade AVMs with complex vascular anatomy [21,22,23,24,25].

Despite of all those challenging scenario and acceptable complications, the favorable neurological outcome in our series is that, all the surgeries were performed by well trained and experienced surgeon and a dedicated Neurosurgical team. Despite the challenges and complications, our experience underscores the feasibility and potential effectiveness of microsurgical resection for high-grade AVMs in resource-limited settings. All procedures were performed by a skilled and experienced neurosurgical team, which was critical to achieving favorable outcomes.

Novelty of the paper

To our knowledge, this is the first study from Bangladesh to report outcomes of single-stage microsurgical resection for high-grade AVMs (Spetzler-Martin Grade III–V), and one of the few in the global literature addressing this approach in a resource-limited setting. While existing studies often focus on multimodal treatment strategies or conservative management in high grade AVMs, our findings highlight the potential of direct microsurgical intervention as a stand-alone strategy, even in high-risk cases and in the absence of advanced neurointerventional resources. The 100% obliteration rate and favorable functional outcomes (mRS improvement in 61.5% of patients) challenge traditional paradigms that discourage surgery for high-grade AVMs. Our results suggest that, when performed by experienced neurosurgeons in well-selected patients, single-stage microsurgical resection may be not only feasible but also clinically effective and economically viable in low-resource environments.

Limitation of the study

This study is subject to several limitations that must be acknowledged. First, the retrospective design inherently carries the risk of selection bias and limits the ability to establish causality. As all patients were selected for surgery without randomization or comparison to conservative or multimodal strategies, the results may reflect institutional practices rather than generalizable treatment effects. Second, the small sample size (n=13) restricts the statistical power of the analysis and limits subgroup comparisons between SM Grade III and IV AVMs or between patients with different venous drainage patterns and arterial feeders. Third, the absence of a control group precludes definitive conclusions regarding the superiority of microsurgical resection over other treatment modalities or conservative management. Fourth, all procedures were conducted in a single geographic and socioeconomic context, limiting extrapolation to higher-resource environments or institutions with access to radiosurgery and advanced endovascular services. Additionally, while mRS is a widely used and validated outcome metric, it may not fully capture subtle cognitive, emotional, or quality-of-life impairments.

Conclusion

The results of our case series have excellent overall outcome after microsurgical resection. Association of factors which increases the grading system of AVM like eloquence, presence of perforating artery, deep venous drainage and increasing sizes did not correlate with the predicted unfavorable outcomes. Overall, our data suggests good outcome post-surgery but there is a need of prospective, multicentric data to better identify patients who may benefit most from microsurgical treatment alone.

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