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Original Research Article

Surgical Management of Arteriovenous Malformations in Combination with Endovascular Embolization

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Abstract:

Background: Arteriovenous malformations are part of the spectrum of vascular anomalies—a diverse group that includes both superficial vascular tumors and malformations. Over the past decade, various treatment modalities have been used, including endovascular embolization, surgical excision, laser therapy, or combined approaches. Among these, surgical excision remains the most important and definitive treatment for AVMs, especially when complete resection is achievable.

Methodology: The present study was planned in the Department of Plastic Surgery, Shri Krishna Medical College and hospital, Muzaffarpur, Bihar. Over the past decade, various treatment modalities have been used, including endovascular embolization, surgical excision, laser therapy, or combined approaches. Among these, surgical excision remains the most important and definitive treatment for AVMs, especially when complete resection is achievable.

Patient and Method: Our study included a total of sixteen patients managed for arteriovenous malformations (AVMs). A male predominance was observed, with twelve male patients (75 %) and four female patients (25 %). The onset of the malformation occurred before the age of 25 in 75 % of cases. All patients were symptomatic at the time of diagnosis and presented with a swelling or mass, ranging in size from 4 cm to 18 cm. The localization of AVMs varied among patients. Two patients (11.1%) had frontal involvement, six patient (33.3%) had upper limb involvement, eight patient (44.4%) had lower limb involvement and two patient (11.1%) had abdominal involvement.

Surgical Procedure: The aim of surgery is to remove the whole of the primarily pathologic tissue. At operation, and indeed on imaging, only the secondary pathology is visible, so the margins of the primary pathology, or nidus, must be inferred from the location of these visible secondary vessels. Surgical Planning It is critically important that all available imaging is reviewed in detail before surgery with the aim of localizing the nidus. Since the nidus is not generally visible, even on angiography, its boundaries must be inferred from the location of the visible secondarily involved vessels.

Results and Discussion: A fundamental aspect of our surgical technique is the systematic dissection through healthy, anatomically unaffected tissue planes, away from the nidus. This approach not only improves the completeness of excision but also significantly reduces intraoperative bleeding and operative time. While embolization remains a valuable adjunct, it is the precision of the surgical act—respecting vascular planes and ensuring meticulous hemostasis—that ultimately determines functional and aesthetic outcomes. Outcomes were favorable in most cases, with good scar quality and preserved function.

Conclusion: Treatment of vascular anomalies in appropriately selected patients in a single operative stage is safe with a low complication rate and can range from simple excision to use of microvascular free flap, providing pain relief, restoration of function, and repair of aesthetic deformities. Imaging-guided surgical excision, supported by selective embolization, is a safe and effective strategy for managing sAVMs, minimizing complications and recurrence.

Keywords: Arteriovenous malformation, Vascular anomalies, Surgical excision, Embolization.

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Introduction

Arteriovenous malformations are part of the spectrum of vascular anomalies—a diverse group that includes both superficial vascular tumors and malformations. According to the classification

proposed in 1982 by Glowacki and Mulliken. [1,2], and later endorsed by the International Society for the Study of Vascular Anomalies (ISSVA) in 1996 (with an update in 2025) .[3] AVMs are considered vascular malformations rather than tumors. Hemodynamically, they are categorized as fast-flow malformations, in contrast to slow-flow malformations, differing in characteristics, clinical course, and implications. Vascular anomalies can be separated into 2 broad categories: vascular malformations and vascular tumors, including hemangiomas.[4] Vascular malformations are congenital malformations present at birth resulting from errors in vascular embryogenesis causing abnormal development of arterial, venous, or lymphatic vessels. Current classification by The International Society for the Study of Vascular Anomalies categorizes vascular malformations into simple malformations, combined malformations, malformations of major named vessels, and malformations associated with other anomalies.[5] Further classification can delineate the malformations into low/slow flow and high/ fast flow. Low-flow connections include venous and lymphatic malformations, while high-flow connections include arteriovenous malformations (AVMs) and arteriovenous fistulae. Each category contains further classification to properly identify a lesion. Venous malformations can be further classified into 4 distinct groups: sporadic venous malformations, cutaneo-mucosal venous malformations, glomuvenous malformations, and sporadic blue rubber nevus syndrome. [6] A recently growing body of literature has identified underlying genes and pathways involved in vascular malformations. The endothelial receptor tyrosine kinase TIE2 (TEK) gene, for example, has been identified in approximately 50% of venous malformations, while the phosphoinositide 3-kinase/protein kinase B/mammalian target of the rapamycin pathway is involved in several vascular anomalies. [7,8]

Early treatment for symptomatic AVMs is essential, as their natural progression often leads to tissue destruction and functional impairment. Over the past decade, various treatment modalities have been used, including endovascular embolization, surgical excision, laser therapy, or combined approaches. Among these, surgical excision remains the most important and definitive treatment for AVMs, especially when complete resection is achievable. [9]

Hemangiomas classically present at birth or in the first few weeks of life, undergo several months of cellular proliferation followed by involution of the lesion; vascular malformations, meanwhile, are present at birth, although they may be clinically undetectable, and grow in conjunction with the patient, never regressing. The varying clinical courses can be in part explained by differing underlying physiology of these lesions. Hemangiomas are endothelial neoplasms, while vascular malformations occur due to in-utero errors in vessel formation. [11,12] When vascular malformations are present, the severity can vary from minor, imperceptible lesions, to painful, even life-threatening lesions. Existing literature focuses largely on lesions of the head and neck area. [13,14] The minimal literature on lesions of the extremities, which includes primarily case series, has been either more subjective or focused on lesions with more dramatic clinical presentation, such as limb size discrepancy. [10,15–19] While we continue to learn more about the pathophysiology and new potential treatments for the management of these lesions, there remains a lack of consensus on optimal management. [20,21] In this study, we aim to present our experience with the management of symptomatic vascular anomalies of the extremities to assess their clinical and surgical characteristics in addition to outcomes following surgical excision.

We performed a retrospective study of patients treated with surgical excision for vascular anomalies in the extremities at Department of Burn and Plastic Surgery, Shri Krishna Medical College and hospital, Muzaffarpur.

This retrospective study included eighteen cases of arteriovenous malformations (AVMs) managed in our Department of Burn and Plastic Surgery, Shri Krishna Medical College and hospital, Muzaffarpur between July 2024 and March 2026. Patients were selected based on a confirmed diagnosis of AVM using imaging techniques (such as Doppler ultrasound, MRI, or angiography). Cases with incomplete medical records or inadequate follow-up data were excluded. The main objective of this study was to report and clarify the surgical management of AVMs, with the aim of contributing to the development of a standardized treatment protocol. This study was conducted in accordance with institutional ethical standards, written informed consent was obtained from all patients or their legal guardians.

Methodology

The present study was planned in the Department of Plastic Surgery, Shri Krishna Medical College and hospital, Muzaffarpur, Bihar. Over the past decade, various treatment modalities have been used, including endovascular embolization, surgical excision, laser therapy, or combined approaches. Among these, surgical excision remains the most important and definitive treatment for AVMs, especially when complete resection is achievable. 9 Cases with incomplete medical records or inadequate follow-up data were excluded. The main objective of this study was to report and clarify the surgical management of AVMs, with the aim of

contributing to the development of a standardized treatment protocol. Data were retrospectively collected from hospital records and postoperative follow-up visits. Informed consent was obtained from all patients prior to inclusion in the study.

This study was conducted in accordance with institutional ethical standards, written informed consent was obtained from all patients or their legal guardians.

Patient and Method: The present study was planned in the Department of Plastic Surgery, Shri Krishna Medical College and hospital, Muzaffarpur, Bihar.

Our study included a total of eighteen patients managed for arteriovenous malformations (AVMs). A male predominance was observed, with twelve male patients (75 %) and four female patients (25 %). The onset of the malformation occurred before the age of 25 in 75 % of cases. All patients were symptomatic at the time of diagnosis and presented with a swelling or mass, ranging in size from 4 cm to 18 cm. The localization of AVMs varied among patients. Two patients (11,1%) had frontal involvement, six patient (33.3%) had upper limb involvement, eight patient (44.4%) had lower limb involvement and two patient (11.1%) had abdominal involvement. The diagnosis was clinically established and confirmed by paraclinical investigations in all cases. Doppler ultrasound was performed in all patients. It revealed hypoechoic lesions containing multiple vascular structures, with fast-flow and arteriovenous shunting, resulting in very high flow velocities, elevated diastolic flow and low resistance index (< 0.5) which is useful in distinguishing other vascular malformations. A CT angiography was performed in fourteen patients (70 %) to assess the extent of the malformation, as well as its arterial supply and venous drainage. MRI angiography was conducted in six patients (30%), allowing a precise evaluation of the deep extension of the lesion.

Surgical management began with a meticulous imaging-based assessment to determine the full extent of the arteriovenous malformation and guide the operative approach. Resection was performed by carefully dissecting along healthy anatomical planes surrounding the lesion, in a manner reminiscent of oncologic surgery, to ensure complete and safe removal. This strategy also aimed to minimize the risk of uncontrollable bleeding, due to the pathological enlargement of the involved vascular structures. Direct dissection of the nidus was intentionally avoided, as manipulating it during surgery could have triggered massive haemorrhage. However, imaging confirmed that the nidus was centrally located within the malformation, making its removal possible through en-block excision of the entire lesion.

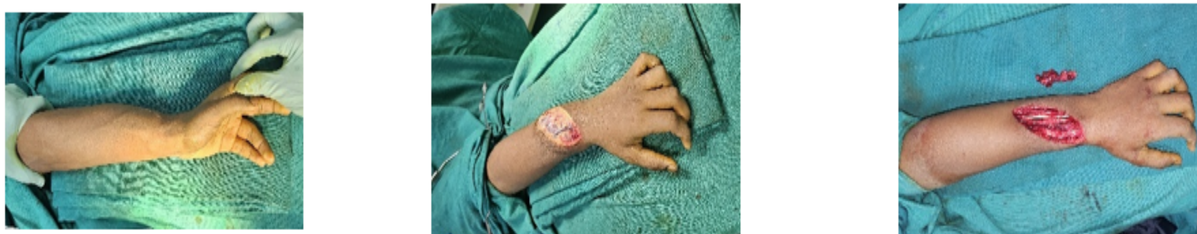
Among those who underwent surgery, wound closure was achieved by direct suture in all the cases. The mean postoperative follow-up was 14 months. Evaluation of morphological outcomes showed generally satisfactory scar quality, as reported by the patients. Functionally, no sequelae were noted in patients with extremities AVMs. However, one patient with a lower lip AVM presented with a recurrence, later on given sclerotherapy.

Surgical Procedure: Resection of a large arteriovenous malformation (AVM) can be one of the most challenging surgical procedures in vascular anomalies. Although the problem of haemostasis draws the most attention, reducing the high recurrence rate after surgery is the true challenge.[22] The technical principles of surgery are the same as for any other resection, but surgery must be guided by an understanding of the unique biology and anatomy of AVM. Surgical Pathology of AVM I find it helpful to think of an AVM in terms of primary and secondary pathology. The primary pathology of an AVM is the traditional “nidus,” the multiple direct connections between the arterial and venous system. These are microscopic and diffuse, and mostly invisible to the naked eye. Their limits, the surgical margins, are therefore difficult to define. Sometimes the nidus is discontinuous. The secondary pathology consists in the altered morphology of arteries which carry blood to the nidus and veins which drain from it. High shear stress and pressure cause these vessels to become tortuous, dilated, and thin-walled. While the 10 pathologies intermingle, they are not the same. The secondary pathology extends well beyond the primary, but while it may at times itself become a problem due to pressure, bleeding or aneurysm formation,[23] it is reactive and in general can be expected to resolve if the primary pathology is corrected. The aim of surgery is to remove the whole of the primarily pathologic tissue. At operation, and indeed on imaging, only the secondary pathology is visible, so the margins of the primary pathology, or nidus, must be inferred from the location of these visible secondary vessels. Surgical Planning It is critically important that all available imaging is reviewed in detail before surgery with the aim of localizing the nidus. Since the nidus is not generally visible, even on angiography, its boundaries must be inferred from the location of the visible secondarily involved vessels. Each imaging modality may contribute information about the nidus. For small, superficial AVMs, angiography may not be necessary because the nidus can be identified on ultrasound, but for larger lesions it is essential. The surgeon should try to be in attendance when the angiography is performed to understand the three dimensional anatomy of the lesion. For superficial lesions, I use a hand-held doppler at the start of the procedure to map out the margins and locate larger feeding vessels. For larger lesions, a repeat

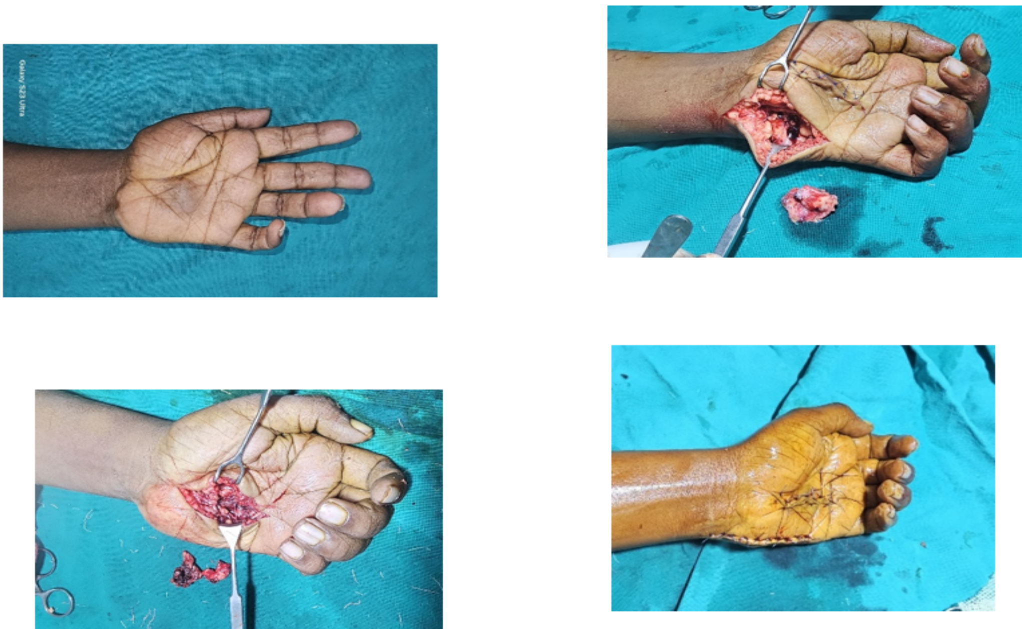
ultrasound immediately before surgery is more useful to indicate landmarks on the skin. Haemostasis, Although most surgeons use preoperative embolization for AVM surgery,[24] I have not done it. Wherever possible, dissection should begin at the proximal arterial supply and progress toward the lesion. This both gains control of the blood supply and helps in localization of the nidus. Feeding arteries are identified and tagged with a flexible loop but not necessarily ligated which would impede identification of the nidus. Dissection must always be on a broad front, to avoid creating a bleeding problem at a site where access is difficult. In particular, it is important to avoid dissecting the deep surface of the lesion before the lateral margins are defined. When resecting a large AVM, areas of profuse bleeding are often encountered where control is difficult to achieve. The first question in this circumstance should be "Am I in the nidus?." Moving the plane of dissection even a short distance may improve progress if it takes dissection outside the nidus to a region where discrete vessels can be identified and ligated. Otherwise, it is sometimes necessary to dissect slowly, suture ligating either side of the plane of dissection before and after each cut. Over enthusiastic retraction can tear the fragile vessels around an AVM, giving the impression that suturing of existing bleeding points has not been effective. Maintaining a forward progress in the overall operation is sometimes a challenge. Careful dissection at various sites around the lesion can gradually improve access and reduce the blood flow. Follow-up Recurrence of AVM after surgery is a consequence of incomplete ablation of the primary pathology. Unlike cancer surgery where pathological tissue is palpably and often visibly different from the surrounding normal tissue, the margins of the nidus cannot easily be distinguished at surgery. Except in well-defined lesions, this makes recurrence of the lesion likely, and all but inevitable in some. I use ultrasound as a screening tool for follow-up, beginning 6 months after the procedure and at 6 monthly intervals. The presence of low-resistance flow is an indication for angiography and treatment, if necessary. Repeated surgery or interventional radiological treatment of residual disease is often required and may be curative. Conclusion The risk of catastrophic bleeding makes resection of a large AVM a challenging and stressful procedure, but the real challenge lies in knowing where to place the margins of excision to prevent recurrence.

Gallery

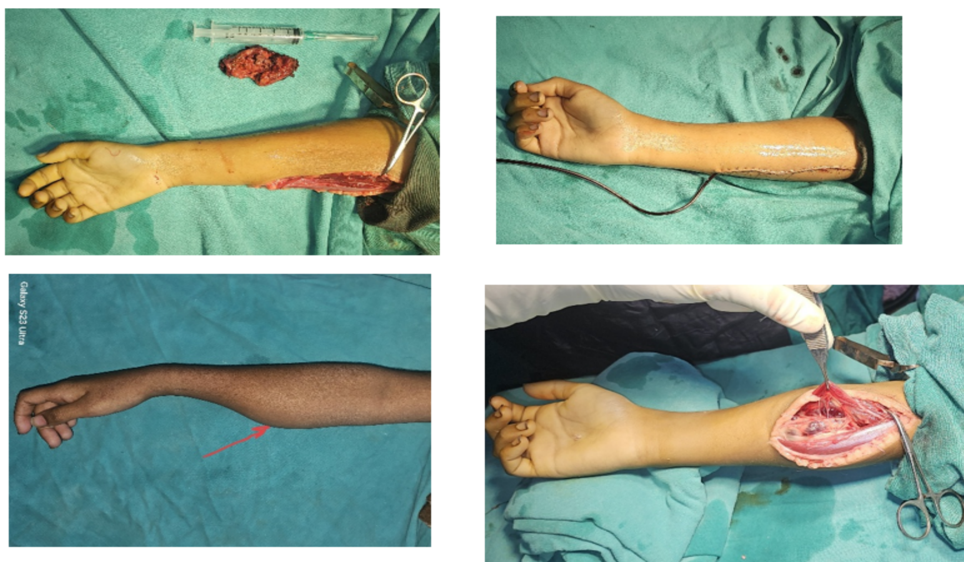
Picture 1: AVM Arm



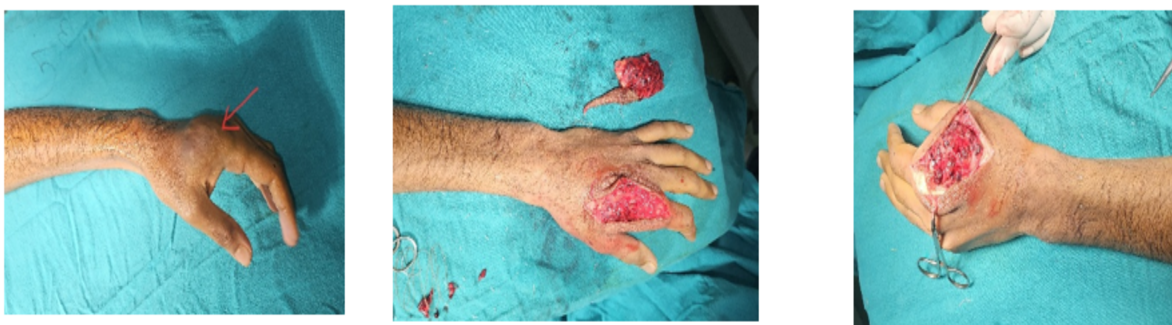
Picture 2: AVM Forearm



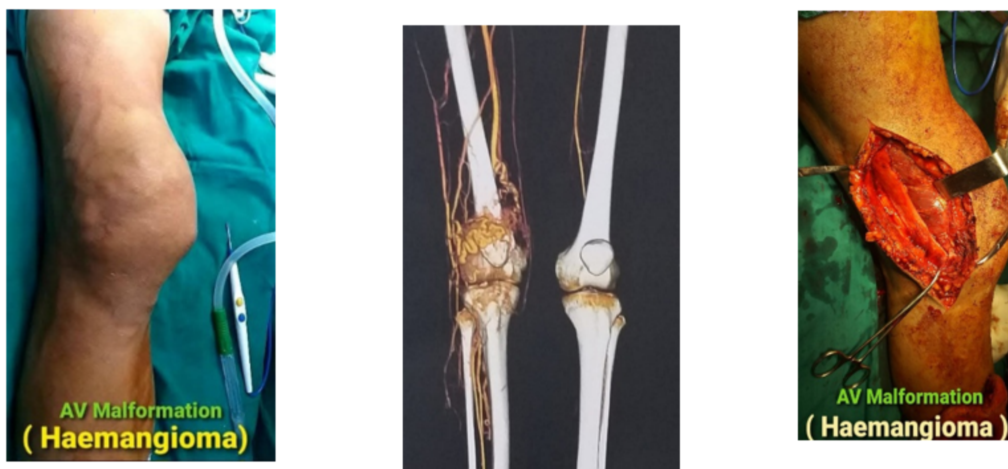
Picture 3: AVM Hand



Picture 4: AVM Forearm



Picture 5: AVM Hand



Picture 6: AVM KNEE

Results and Discussion

Congenital arteriovenous malformations (AVMs) represent a significant therapeutic challenge due to their complex vascular architecture, unpredictable clinical behavior, and potential for recurrence. While asymptomatic lesions may not require immediate intervention, treatment becomes necessary when complications arise or when lesions interfere with function or aesthetics. Absolute indications for intervention include hemorrhage, secondary ischemic complications, ulceration, and high-output cardiac failure resulting from substantial arteriovenous shunting. Relative indications, on the other hand, include progressive pain, functional impairment, and cosmetic disfigurement, which may significantly affect the patient's quality of life. [25]

Some investigators [26] have suggested six different therapeutic tactics and surgical techniques that have been proven as effective for the treatment of vascular malformations. These are: (1) reconstructive surgery, (2) surgery to reduce the haemodynamic activity of the vascular defect, (3) surgery to extirpate the malformed vessels, (4) combined therapy, (5) unconventional therapy, and (6) the multidisciplinary approach to treatment. Surgical treatment alone can cause massive bleeding during the operation. Most surgeons recommend preoperative embolo/sclerotherapy. [27] Surgeons should consider several important points during the surgical treatment of AVM. The first is that the nidus of AVM should be completely removed for achieving a complete cure of AVM. The remnant AVM may grow and get bigger than before treatment within a short period of time. Ligation of the feeding artery without removal of nidus should be avoided. In this case, other collateral vessels and quiescent AVMs will grow fast and the AVM may get bigger than before. If the feeding artery of the AVM is ligated, further embolo/sclerotherapy was impossible because there will be no accessible route for embolo/sclerotherapy. [28] Historically, AVMs were treated primarily through surgical excision or ligation of the feeding arteries. However, these approaches often led to massive hemorrhage, given the difficulty in delineating the true extent of the malformation. [29] The nidus, typically composed of a tangled network of dysplastic vessels, is rarely well circumscribed, and without complete excision, recurrence is common. Moreover, inta lesional surgical excision carries a high risk of intraoperative bleeding, especially in lesions with high-flow characteristics. These factors highlight the limitations of traditional surgical management and underscore the need for multimodal therapeutic strategies. The advent of endovascular techniques has revolutionized the management of AVMs. Transarterial and transvenous embolization, particularly when performed preoperatively, have become essential adjuncts to surgery. The use of novel embolic agents, such as Onyx, NBCA, and ethanol, allows for targeted occlusion of the nidus and feeding vessels, thus reducing intraoperative blood loss and enabling safer, more controlled resections. In our series, three patients benefited from preoperative embolization.

Surgeons should optimally strive for complete resection of the AVM, much like in head and neck oncology, aiming for full nidus removal while preserving surrounding structures. Given the high vascularity and the altered anatomy often observed in AVMs, surgical planning must be guided by thorough preoperative imaging to accurately assess the extent of the lesion and identify key vascular structures. The excision should ideally be performed in anatomically unaffected tissue, at a distance from pathological vessels, to allow better vascular control and minimize the risk of excessive bleeding. Even in cases where preoperative embolization is performed, meticulous dissection and step-by-step ligation of feeding vessels remain essential to ensure

safe and complete resection while limiting intraoperative complications. Embolization remains a valuable therapeutic option, but it is not always sufficient as a standalone treatment. The literature highlights that intralesional resection remains a challenging procedure due to the high risk of massive hemorrhage. In our approach, we favor excision through healthy tissue planes, avoiding direct contact with the nidus. Nevertheless, one of the major intraoperative challenges is the presence of prominent feeding vessels. Additionally, even tissues adjacent to the malformation—though seemingly unaffected—may be hypervascularized due to their proximity. Therefore, meticulous step-by-step hemostatic control is crucial throughout the procedure to minimize the risk of uncontrolled bleeding. In our study, all patients underwent complete resection of malformation with ligation of feeding vessels. The postoperative outcomes were generally favorable, with no functional sequelae observed in patients with facial AVMs. Only one patient, who had a scapular AVM involving the trapezius muscle, developed a postoperative deficit in shoulder elevation. This underscores the importance of balancing radical excision with preservation of function, especially in musculoskeletal locations. [30,31] In our experience, embolization alone was not considered a curative option, as residual nidus and tissue sequelae were consistently observed after such procedures. Patients usually presented to our department with symptomatic and disfiguring lesions, making them candidates for surgical excision rather than embolization alone. Surgery was therefore reserved for accessible lesions with significant aesthetic or functional impact, while embolization was used only as an adjunct to facilitate safe resection. A paragraph clarifying these indications has been added to the Discussion section. Most surgeons recommend preoperative embolo/sclerotherapy. [32] Surgeons should consider several important points during the surgical treatment of AVM. The first is that the nidus of AVM should be completely removed for achieving a complete cure of AVM. The remnant AVM may grow and get bigger than before treatment within a short period of time. Ligation of the feeding artery without removal of nidus should be avoided. In this case, other collateral vessels and quiescent AVMs will grow fast and the AVM may get bigger than before. If the feeding artery of the AVM is ligated, further embolo/sclerotherapy was impossible because there will be no accessible route for embolo/sclerotherapy. [33] The postoperative complications were more common for the AVMs of the extratruncular infiltrating type than for AVMs of the extratruncular limited type. The patients with extratruncular infiltrating AVMs had more diffuse lesions and these required more embolo/sclerotherapy for surgery. Among the 10 patients with the infiltrating type, five patients (50%) were operated on more than two times because of their non-healing surgical wounds. However, only two (20%) out of the nine patients with the limited type underwent more than two operations. All AVMs do not need to be treated if they do not cause serious problems. If the AVM itself causes problems like cosmetic problems, compression to adjacent structure or complications like the 'steal' phenomenon, bleeding or heart failure, then treatment of the AVM should be considered. Despite these advances, AVM treatment remains challenging. Recurrence remains a concern, particularly in cases where complete excision is not achieved Furthermore, while embolization has improved safety and outcomes, it carries its own risks, including non-target embolization, skin necrosis, and nerve injury. Careful preoperative planning, often involving multidisciplinary collaboration, remains essential. [31,32]

Finally, our experience supports the essential role of surgical excision in the management of AVMs, particularly when guided by careful preoperative planning and supported by selective embolization. A fundamental aspect of our surgical technique is the systematic dissection through healthy, anatomically unaffected tissue planes, away from the nidus. This approach not only improves the completeness of excision but also significantly reduces intraoperative bleeding and operative time. While embolization remains a valuable adjunct, it is the precision of the surgical act—respecting vascular planes and ensuring meticulous hemostasis—that ultimately determines functional and aesthetic outcomes. Further studies with larger series and longer follow-up are needed to confirm the durability of these results. [33,34,35] The AVM is generally not a life threatening disease, but the massive bleeding or wide tissue necrosis related to surgery and/or embolo/sclerotherapy might be life threatening. In conclusion, surgical treatment of AVM is a challenging issue for vascular surgeons. To minimise the complications related with surgery, a multidisciplinary team approach should be considered.

Conclusion

Our study highlights the effectiveness of surgical excision in AVMs, particularly when performed through healthy tissue planes and guided by imaging. Preoperative embolization, when indicated, enhances surgical safety. Despite the small sample size, our results are encouraging and call for further studies to optimize treatment protocols.(Table 1) Surgery for vascular malformations of the upper and lower extremity can be a safe and effective treatment option, although some cases are better off when treated non-surgically. Literature shows various complication rates for non-surgical treatment of upper and lower

extremity vascular malformations. To determine in which case surgery is the better option, we should identify factors leading to surgical complications by reporting specific patient and lesion characteristics of the complicated cases. Treatment of vascular anomalies in appropriately selected patients in a single operative stage is safe with a low complication rate and can range from simple excision to use of microvascular free flap, providing pain relief, restoration of function, and repair of aesthetic deformities.

Table 1. Clinical summary of patients: site of resection, preoperative embolization, and type of closure.

Patient	Area of resection	Pre-operative embolization (arteries)	Closure (primary/secondary)
1	Frontal region	No	Primary closure
2	Frontal region	Yes (superficial temporal artery)	Local flap
3	Upper limb	No	Primary closure
4	Upper limb	No	Primary closure
5	Upper limb	No	Local flap
6	Upper limb	No	Primary closure
7	Upper limb (forearm)	Yes (anterior interrosous artery)	Primary closure
8	Upper limb	No	Local flap
9	Lower limb	No	Primary closure
10	Lower limb	No	Primary closure
11	Lower limb	No	Primary closure
12	Lower limb(vastus lateralis)	Yes (Lateral gednicular artery)	Local flap
13	Lower limb	No	Primary closure
14	Lower limb(vastus medialis)	Yes (medial genicular artery)	Primary closure
15	Lower limb	No	Primary closure
16	Lower limb	No	Random flap
17	Abdominal (para umbilical region)	Yes (para umbilical vessels)	Primary closure
18	Abdominal	No	Local flap closure

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