CHAPTER 112
Arteriovenous Malformations

Phuong D. Nguyen
Oriana D. Cohen
Evan P. Nadler

Introduction

An arteriovenous malformation (AVM) is defined as an abnormal communication between an artery and vein that bypasses a capillary bed. These lesions may present as isolated, innocuous cutaneous naevi, or they rarely may take the form of life-threatening systemic shunts involving large portions of the body. They may occur at any site, involve any organ, and violate normal tissue planes. AVMs are present at birth, and are neither neoplastic nor proliferative. As such, they grow commensurate with the child.

AVMs are best characterised by the type of abnormal vascular channel, the degree of blood flow, and the structures involved. The most common sites of these lesions are the pelvis, extremities, and intracranial circulation.[1] Cutaneous AVMs are usually noted at birth but are given little attention due to their innocent appearance. A standard approach to management of AVMs does not exist due to the rare need for treatment. Furthermore, AVMs are frequently associated with additional findings and fall under the auspices of multiple syndromes[2] (Table 112.1).

Table 112.1: Syndromes with associated arteriovenous malformations

Syndrome	Arteriovenous malformation
von Hippel-Lindau disease	Cerebelloretinal haemangioblastomatosis
Klippel-Trenaunay syndrome	Naevus, varicose veins, limb hypertrophy
Kasabach-Merritt syndrome	Platelet consumption, kaposiform haemangioendothelioma, or tufted angiomas
Parkes-Weber syndrome	Microfistulous arteriovenous communication
Maffucci syndrome	Cavernous haemangioma, dyschndroplasia, osteochondromas
Sturge-Weber syndrome	Encephalotrigeminal haemangiomatosis
Servelle-Martorell syndrome	Cavernous haemangioma, limb hypotrophy
Rendu-Osler-Weber syndrome	Hereditary haemorrhagic telangiectasia
Louis-Bar syndrome	Ataxia telangiectasia
Sturge-Weber syndrome	Facial capillary malformations
Riley-Smith syndrome	Macrocephaly, pseudopapilloedema, lymphaticovenous malformation

Demographics

The prevalence of congenital AVMs is unknown. Differences in nomenclature and the lack of an accepted classification contribute to the inability to collectively analyse reported cases. In the Western world, congenital AVMs account for only 1 in 10,000 hospital admissions.[2] This rate likely represents an underestimate of the true prevalence because most lesions are initially asymptomatic. Although congenital AVMs are present at birth, they are often not diagnosed and treated until later in life as they become more clinically apparent. One-half of all congenital AVMs occur in the extremities, with two thirds of these occurring in the lower limb.[3] There is a paucity of epidemiologic data from Africa and it is unclear whether the data provided from the West are appropriate for the African region. Diarra et al. described 20 cases of vascular malformations at a single African institution over a 4-year period with a female-to-male ratio of 1.5:1 and an average patient age of 15.5 years at presentation.[4] However, little other data regarding the incidence or prevalence of AVMs on the African continent are available.

Embryology and Pathology

Embryology

During the third week of foetal life, mesenchymal cells differentiate into primitive capillary clusters. By the 48th day of gestation the capillary clusters connect with feeding arteries and draining veins. AVMs are a result of structural abnormalities formed during foetal development and are therefore not neoplasms. Vascular malformations occur as a result of hypoplasia, hyperplasia, aplasia, or any combination of any of these vascular structures. In the foetus, an AVM can be detected only on prenatal ultrasound if the AVM is very large or results in foetal hydrops.

Pathology

AVMs contain enlarged vascular spaces lined by nonproliferating endothelium, and not the mitotically active endothelial cells of a haemangioma. Thus, AVMs do not undergo the different stages of growth and involution seen in haemangiomas. They have an increased ratio of endothelial cells to smooth muscle cells of 214:1, as compared to a ratio of 10:1 to 62:1 found in normal vessels.[5] Histologic features include:

- ectatic capillaries, veins, or lymphatics;
- thin basement membranes; and
- absence of rapid endothelial turnover.

Natural History

In contrast to haemangiomas, AVMs do not improve nor resolve with time. Generally, an AVM will grow in parallel with the child's growth.

Clinical Presentation

History

Vascular malformations are present at birth but are not necessarily obvious. The presentation of the lesion differs, depending on the aetiology of the lesion and its location. In 1982, a biologic classification of vascular anomalies was proposed that separated true haemangiomas (neoplasms) from vascular malformations and was based on cellular characteristics correlated with both physical examination and natural growth history.[6]

Unlike haemangiomas, vascular malformations do not undergo rapid growth and involution; rather, they grow in proportion to the body. AVMs are often high-flow lesions. Fast flow typically becomes evident in childhood; hormonal changes during puberty or minor

trauma may trigger expansion. A cutaneous AVM presents as a mass under the skin with noted warmth, a dermal stain, palpable thrill, audible bruit, or visible pulsation (Figure 112.1). Capillary vascular malformations appear to follow sensory nerve distribution and have a purplish hue. Venous malformations are easily compressible and swell with dependent positioning. Unlike malignant tumours, AVMs are lined by mature endothelial cells, which do not proliferate to a greater extent than normal cells. Enlargement occurs as a result of blood flowing through "paths of least resistance," and the voluminous blood flow accounts for the progressive dilatation of the preexisting channels. If flow through the fistula is large enough, the distal organ may suffer permanent ischaemic changes, such as wasting or gangrene due to "stealing" of blood through the fistula. A clinical staging system introduced by Schobinger is useful for documentation of AVM in any anatomic site[7] (Table 112.2).

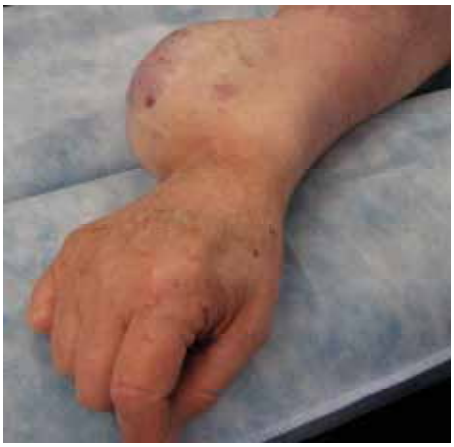

Figure 112.1: Upper extremity AVM presenting as a large mass under the skin in an adult.

Table 112.2: Schobinger staging for arteriovenous malformations.

Stage	Description
I (quiescence)	Pink bluish stain, warmth, and arteriovascular shunting
II (expansion)	Same as stage I, plus enlargement, pulsations, thrill, bruit, and tortuous/tense veins
III (destruction)	Same as stage II, plus dystrophic skin changes, ulceration, bleeding, persistent pain, or tissue necrosis
IV (decompensation)	Same as stage III, plus cardiac failure

Physical Examination

A palpable thrill and bruit are often present in large fistulas. The distal arterial blood flow may be limited, depending on the size of the fistula shunt, which may present as a diminished distal pulse with or without symptoms of ischaemia. Frank gangrene of the end-organ occasionally can be seen. The resultant venous hypertension also may result in brawny oedema, stasis skin changes, and, ultimately, chronic venous ulcers. When large or multiple arteriovenous communications affect an entire extremity during early life, before epiphyseal closure, increased bone growth and limb hypertrophy or hypotrophy may occur, such as in the Klippel-Trenaunay syndrome.

Complications

Overlying ischaemic ulcers, adjacent bone destruction, or local hypertrophy may occur. In rare instances, the increased venous return to the heart combined with an increase in plasma volume may produce cardiac enlargement and congestive heart failure. Placental AVMs may result in a significant shunt from the maternal to the foetal circulation, producing hydrops foetalis.[8] Further complications include pain, haemorrhage, ulceration, cardiac effects, and destruction of surrounding structures. Therefore, treatment requires elimination of this lesion.

Investigations

Most congenital AVMs are recognised easily on physical examination and do not warrant further investigation. However, in patients requiring therapy, diagnostic studies are often useful to determine the type and extent of the lesion. However, the clinician must balance the utility of imaging with the cost in areas where resources are limited. Several imaging options are effective, as discussed here.

Ultrasonography

Ultrasonography (US) is a useful screening examination, but is highly operator dependent. When combined with colour-flow imaging (duplex scan), it can be helpful in differentiating slow-flow anomalies (mainly venous and lymphatic types) from fast-flow arterial anomalies. Comparison with the normal contralateral limb will demonstrate a sharp contrast with the arterial signal at a corresponding level. Due to its relatively low cost, US may be the modality best suited to the African setting for cases that require imaging. However, the major drawback to this technique is limited delineation of the size of the lesion and its relation to adjacent structures.

Computed Tomography

Contrast-enhanced computed tomography (CT) may give the practitioner additional information not available on US. The appearance of vascular malformations on CT vary, depending on their origin and location, but the full extent of the lesion is often delineated. Venous malformations typically have heterogeneous enhancement and sometimes calcifications. The cost of CT scanning may be prohibitive in developing regions; thus, its use should be reserved for cases for which a surgical resection is to be undertaken and the extent of the lesion is in question.

Magnetic Resonance Imaging and Angiography

Magnetic resonance imaging and angiography (MRI/MRA) is perhaps the most accurate radiologic study to evaluate vascular lesions. Magnetic resonance is able to differentiate vascular malformations from haemangiomas and is able to easily distinguish high-flow lesions from low-flow lesions. An additional advantage is that MRI avoids the use of contrast agents and exposure to radiation. Again, however, the cost of this study may render it of limited value in the African setting.

Angiographic Evaluation

Angiographic evaluation, consisting of arteriography, venography, or fistulography, may be the most useful diagnostic tool for AVMs. It is also useful as a therapeutic adjunct in certain instances. Arteriographic findings suggestive of AVMs include:

- arterial dilatation and tortuosity;
- blushing or puddling of dye in the vascular channels;
- visualisation of the arteriovenous fistula itself;
- early venous filling; and
- dilatation of the draining venous channel.

Treatment

Therapy for AVM should be adapted to the extent, location, and degree of disability produced by the lesion. Treatment is rarely indicated during infancy or early childhood for a stage I AVM, unless postnatal high output heart failure caused by shunting is evident. In this circumstance, prompt embolisation or surgical excision may be necessary. In general, treatment is usually reserved for symptomatic lesions (e.g., recalcitrant ulceration, ischaemic pain, bleeding, increased cardiac output), cosmetically unacceptable lesions, and lesions in critical locations (e.g., encroaching on orifices or key organ structures, including the mouth or eye) that may otherwise be asymptomatic.

The disability from the lesion must be weighed against the extent of disfigurement caused by excisional therapy and the cost and availability of the various nonsurgical techniques. Port wine stains are best ablated by using laser photocoagulation. Venous malformations of the extremities with symptoms of venous hypertension may benefit from the use of external compression stockings. Additionally, they may sometimes be treated by using laser therapy, sclerotherapy, or surgical removal.

Therapy for arteriovenous malformations consists of angiography with selective embolisation or complete surgical excision. Embolisation is particularly useful for lesions not accessible to surgery, such as in deep tissue planes, or in patients for whom resection would cause a significant deformity. Transcatheter embolisation alone, although often necessary multiple times, is sufficient to eliminate or improve symptoms in a high percentage of patients.[1] The most effective agents for embolisation seem to be cyanoacrylate adhesives administered through the technique of superselective catheterisation of arterial branches allowing access to the nidus of the AVM. Absolute alcohol seems to be an effective agent for sclerotherapy of lower flow venous malformations. Simple ligation is ineffective, with high rates of recurrence.

Embolisation has generally failed for large lesions but is useful when performed within 24 hours preceding operation to reduce blood loss at the time of excision. Occasionally, hypothermia and cardiac bypass are required to minimise blood loss during surgical excision of large lesions. If it is feasible to remove the entire mass and preserve limb function, complete excision should be attempted and should include ligation of all feeding vessels. Proximal ligation of feeding vessels in AVMs without resection of the nidus often results in continued enlargement of the AVM and increased recruitment of smaller feeding and draining vessels.[1] Furthermore, proximal ligation may make subsequent transcatheter therapy impossible by obstructing access. The nidus and usually the involved skin must be excised widely (Figure 112.2). However, if the overlying skin is normal, it can be saved. The most accurate way to determine the completeness of the resection is observing the pattern of bleeding from the wound edges.[9] The defect should be primarily closed with either local tissue or distant tissue free-transfer using a microsurgical technique. If there is any question about the adequacy of resection, depending on the location of the defect, temporary coverage with a split thickness skin graft is often the best strategy.

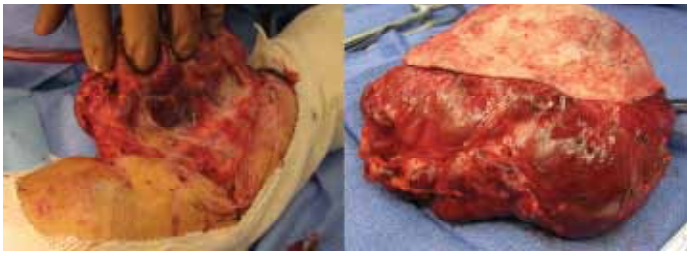

Figure 112.2: Dissection of AVM from upper extremity (left); AVM specimen including resected overlying skin, en bloc (right).

Postoperative Complications

Surgical site infection and local wound complications, as seen in any skin or soft tissue procedure, may be seen with resection of cutaneous AVMs. Unless the lesion is completely resected, there is a reasonable chance for recurrence. For sclerotherapy, direct puncture of the nidus is required in conjunction with local arterial and venous occlusion from embolisation of feeding arteries. There is a high risk of severe neurologic and soft tissue damage with this combined method. For AVMs found in solid organs, the complications associated with resection mirror those seen after resection for other pathology.

Prognosis and Outcome

The surgeon must be aware that surgical resection may still result in residual arteriovenous connections, as congenital AVMs are almost never confined to a single anatomic segment of the arterial tree or to circumscribed anatomic regions. Patients may be followed for years by clinical examination, US, or MRI for signs of occult recurrence. However, clinical examination is likely the most cost-effective method in developing regions such as Africa.

Ethical Considerations

In consideration of limited resources and patient follow-up, procedures that may require multiple visits, such as transcatheter embolisation, may not be accessible or practical. Surgical resection thus remains the primary modality of treatment in these circumstances, ideally as a single-stage definitive treatment. In addition, diagnostic technologies such as MRI may not be readily available, and less expensive strategies such as clinical examination and US may determine the extent of surgical resection.

Evidence-Based Research

At this time, no prospective randomised studies exist that compare surgical excision to angiographic embolisation in peripheral and organ-based AVMs. Often, these modalities are used in an adjunctive fashion. Furthermore, the majority of evidence-based literature pertains to intracranial AVMs. Tables 112.3 and 112.4 report experiences in AVM management.

Table 112.3: Evidence-based research.

Title	Vascular malformations of the upper limb: a review of 270 patients
Authors	Upton J, Coombs CJ, Mulliken JB, et al.
Institution	Division of Plastic Surgery, Department of Surgery, and the Division of Vascular and Interventional Radiology, Children's Hospital, Harvard Medical School, Boston, Massachusetts, USA
Reference	J Hand Surg Am 1999; 24(5):1019–1035
Problem	Evaluation and categorisation of 270 vascular malformations in the upper extremity over a 28-year period.
Intervention	During the study period, 260 surgical resections in 141 patients were completed. Magnetic resonance imaging with and without contrast best demonstrated the site, size, flow characteristics, and involvement of contiguous structures for all types of malformations. Resections were restricted to well-defined regions and often completed in stages.
Comparison/ control (quality of evidence)	The surgical strategy in all groups was to thoroughly extirpate the malformation with preservation of nerves, tendons, joints, and uninvolved muscle, and to perform microvascular revascularisation and skin replacement as required. Preoperative angiographic assessment with magnified views were an important preoperative adjunct before well-planned resection of fast-flow AVMs.
Outcome/ effect	Symptomatic slow-flow malformations and types A and B fast-flow anomalies were resected without major sequelae. Type C arterial anomalies, which included diffuse, pulsating lesions with distal vascular steal, progressed clinically and resulted in amputation in 10 of 14 patients. The complication rate was 22% for slow-flow lesions and 28% for fast-flow lesions.
Historical significance/ comments	The role of selective angiography and embolisation is still evolving, and this retrospective study suggests a preoperative algorithm that includes these techniques before planned excisions of most fast-flow lesions. Although this study did not directly compare head-to-head imaging modalities or even therapy that did or did not include surgery, it is valuable in that it reviews one of the largest reported experiences in a highly specialised and renowned vascular malformation treatment center.

Table 112.4: Evidence-based research.

Title	Transcatheter embolization of extremity vascular malformations: the long-term success of multiple interventions
Authors	Rockman CB, Rosen RJ, Jacobowitz GR, et al.
Institution	Department of Vascular Surgery, New York University Medical Center, New York, New York, USA
Reference	Ann Vasc Surg 2003; 17(4):417–423
Problem	Alternative therapy for management of congenital vascular malformation in the extremity.
Intervention	Superselective catheterisation of feeding vessels and transcatheter administration of embolic agents were performed in 50 patients. Indications for therapy included severe pain, haemorrhage, congestive heart failure, distal extremity ischaemia or ulceration, and mass effect causing significant oedema or other functional disturbance of the extremity. Embolic agents used for arteriovenous malformations included rapidly polymerising acrylic adhesives (*n*-butyl cyanoacrylate (NBCA) or isobutyl cyanoacrylate (IBCA)) and polyvinyl alcohol foam particles (Ivalon).
Comparison/ control (quality of evidence)	Retrospective review of 50 patients over 15 years of upper- and lower-extremity arteriovenous malformations utilising transcatheter embolisation therapy.
Outcome/ effect	Predominantly venous lesions were treated by sclerotherapy with injection of ethanol. Arteriovenous and arterial lesions were treated by embolisation via the arterial branch feeding vessels with cyanoacrylate. The most common vessels involved and treated were branches of the profunda femoris and tibial arteries (83% of lower-extremity lesions), and branches of the brachial and radial arteries (82% of upper-extremity lesions). Patients required a mean of 1.6 embolisation procedures (range 1–5) over a mean period of 57 months. Sixteen patients (32%) underwent more than one embolisation procedure. Of these, 1 was a planned staged procedure and 15 were performed secondary to residual or recurrent symptoms. Adjunctive surgical procedures were performed subsequent to embolisation in three cases (6%). Ninety-two percent of patients remained asymptomatic or improved at a mean follow-up of 56 months. There was one case of limb loss (2%). Diffuse extremity vascular malformations are difficult to eradicate completely, and recurrences are common.
Historical significance/ comments	As a retrospective review, this study lacks predictive power of the proposed treatment strategy of transcatheter embolisation. However, this study still retains value, as it is one of the largest studies reporting the outcome of transcatheter embolisation. The authors acknowledge that for patients in whom significant symptoms do develop, the optimal treatment is probably complete surgical resection of the superficial, limited lesion when this is possible. However, they further suggest that even though transcatheter embolisation is not a cure, it is highly successful for symptom relief in complex lesions, albeit this may require multiple procedures. Subsequently, with the knowledge that surgical extirpations are difficult and perhaps even impossible for some larger lesions, they assert that transcatheter embolisation is the treatment of choice in these situations.

Key Summary Points

1. Lesions are present at birth and are nonproliferative, unlike haemangiomas.
2. Arteriovenous malformations may be observed unless they become symptomatic.
3. Investigative measures help identify the extent of the lesion and include ultrasound, computed tomography with contrast, and magnetic resonance imaging.
4. Treatment, if necessary, consists of complete surgical excision when possible.
5. If the lesion is not easily accessible or resection would cause undue morbidity, selective embolisation may improve symptoms.
6. Recurrence is not uncommon if the lesion is not completely resected.

References

1. Riles TS, Jacobowitz GR. Surgical management of vascular malformations. In: Rutherford RB, ed. Vascular Surgery, vol. 2, 6th ed. Elsevier Saunders, 2005, Pp 1646–1650.
2. Kasirajan K, Ouriel K. Vascular malformation and arteriovenous fistula. In: Greenfield LJ, ed. Surgery: Scientific Principles and Practice, Vol. 3, 3rd ed. Lippincott Williams & Wilkins, 2001, Pp 1859–1871.
3. Tice DA, Clauss RH, Keirle AM. Congenital arteriovenous fistulae of the extremities. Archiv Surg 1963; 86:460.
4. Diarra O, Ba M, Ndiaye A, et al. Vascular dysplasia in vascular surgery in an African area: 28 cases at the Dakar teaching hospital. J Maladies Vasculaires 2003; 28:24–29.
5. Sheehan M, Bambini DA. Hemangiomas and vascular malformations. In: Arensman RM, Bambini DA, Almond PS, eds. Vademecum Pediatric Surgery. Landes Bioscience, 2000, Pp 65–68.
6. Mulliken JB, Glowacki J. Hemangiomas and vascular malformations in infants and children: a classification based on endothelial characteristics. Plastic Reconstruct Surg 1982; 69:412–422.
7. Kohout MP, Hansen M, Pribaz JJ, et al. Arteriovenous malformations of the head and neck: natural history and management. Plastic Reconstruct Surg 1988; 102:643–654.
8. Liechty KW, Flake AW. Pulmonary vascular malformations. Sem Pediatr Surg 2008; 17:9–16.
9. Connors JP III, Mulliken JB. Vascular tumors and malformations in childhood. In: Rutherford RB, ed. Vascular Surgery, vol. 2, 6th ed. Elsevier Saunders, 2005, Pp 1626–1645.