Imaging and Percutaneous Treatment of Vascular Anomalies

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ABSTRACT

Vascular anomalies are an extensive group of malformations of the arterial, venous, and lymphatic systems, either in isolation or, more often, in combination. Although mostly congenital, they can occasionally be acquired as well. They present a challenge both for workup and therapy. This article attempts to describe some of their main anomalies, their workup, and their therapies, with the goal of increasing the comfort level of endovascular therapists.

KEYWORDS: Vascular anomalies, malformations, hemangiomas, percutaneous endovascular therapy, embolization

Objectives: Upon completion of this article, the reader should be familiar with the diagnosis, understand the classification of vascular anomalies and interventional radiology treatment options available.

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Vascular anomalies are congenital lesions involving arterial, venous, capillary, and lymphatic systems. They can be disfiguring, painful, and, rarely, life-threatening. In addition to congenital vascular anomalies, arteriovenous fistulas (AVFs) can be acquired vascular lesions.

CLASSIFICATION AND TERMINOLOGY

Before 1982, terminology and classification systems were complex and inconsistent. A variety of terms were used including “birthmarks” and “angiomas.” Various forms of classification were proposed based on vessel architecture by Virchow, on histopathology by Stout and Lattes, and so on.¹ The suffix *-oma* indicates growth by cellular

proliferation. However, the terms *hemangiomas* and *lymphangiomas* are widely and incorrectly used to describe vascular malformations, which are not tumors.

Distinction is important because diagnosis and classification guide treatment, and incorrect treatment can result in scarring, disfigurement, progression, or iatrogenic worsening. The Vascular Anomalies Center at Boston Children’s Hospital found that the referring diagnosis was incorrect in 47% of cases, leading to incorrect treatment in 75%. Fourteen percent still underwent improper treatment despite having a correct diagnosis.²

The currently accepted classification (Table 1) is a modification of Mulliken and Glowacki’s 1982 classification. It was adopted by the International Society for

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Table 1 Modified Mulliken Glowacki Classification

Vascular Tumors	Vascular Malformations
Hemangiomas	High Flow
-Classical Infantile	-Arteriovenous malformations
-Noninvoluting congenital hemangiomas (NICH)	-Arteriovenous fistulas
-Rapidly involuting congenital hemangiomas (RICH)	
Others	Low Flow
-Kaposiform hemangioendotheliomas	-Venous
-Angiosarcoma	-Capillary
-Tufted angioma	-Lymphatic
	Mixed

the Study of Vascular Anomalies (ISSVA) (<http://www.issva.org>) and is based on histology and biological behavior.¹⁻³ As further progress is made, this classification may be modified or updated.

The two main categories of vascular anomalies are tumors and vascular malformations. Vascular tumors have cells with increasing mitotic activity, whereas malformations are regional, developmental abnormalities containing mature, nonproliferating cells and a normal rate of cell replication. Malformations grow with the child but also undergo enlargement due to hormonal influence or trauma. They may also enlarge by distension, bleeding, infection, thrombosis, or enlargement of preexisting smaller vessels. In contrast, tumors grow by cell proliferation.

HIGH-FLOW MALFORMATIONS

High-flow vascular malformations are comprised of arteriovenous malformations (AVMs) and AVFs. These are congenital malformations, thought to represent regional defects. They are disorganized tangles of vessels with arteriovenous shunts without intervening capillary beds. They grow with the child; hence, they may not present until later in life when they are large enough to cause symptoms. Arteriovenous malformations have an identifiable nidus with feeders (Fig. 1), whereas AVFs are direct arteriovenous communications without an intervening nidus (Fig. 2). They have a bimodal distribution, with ~50% presenting at birth with deformity and the rest presenting after the age of 10 years.⁴ High-flow malformations are less common than low-flow lesions and often require treatment due to debilitating symptomatology and the risks if left untreated. They can also be seen as a part of syndromes such as Osler-Weber-Rendu syndrome. Hereditary hemorrhagic telangiectasis and pulmonary AVMs require special consideration and important technical details and are beyond the scope of this article.

Figure 1 Digital subtraction angiography of a thigh arteriovenous malformation shows a nidus (arrow) with multiple feeders from the profunda femoris and superficial femoral artery.

Clinical Findings

The presentation and findings are based on their location, particularly the depth of the lesion and the adjacent organs that may be involved. Physical examination can

Figure 2 Left external carotid angiogram showing direct shunting from arterial branches to venous sinus without presence of a nidus is suggestive of a dural arteriovenous fistula.

Figure 3 Axial contrast-enhanced computed tomography of the pelvis shows a nidus with dilated vessels in the right adnexa (double arrow).

even be normal in patients with deep lesions. The most commonly reported sites are the extremities and the pelvis.⁵ Superficial locations, such as face/neck and extremities, can present with cosmetic deformity, pain, swelling, weakness, nerve palsy, and ulceration with bleeding. Findings include swelling, dilated superficial veins, ulceration, skin hyperpigmentation, bony overgrowth, lysis, and vascular bruits. Deeper lesions may, in addition, present with organ-specific dysfunction, symptoms arising from the steal phenomenon, and local mass effect. The latter has been demonstrated in pelvic AVMs.⁶ The most concerning complication is high-output cardiac failure. Although rare, this has been described in extremity (Parkes-Weber syndrome), pelvic, and hepatic lesions.⁶ Diffuse extremity AVMs have a high amputation rate (> 50%).

Imaging

Despite a good physical examination, diagnosis and management of high-flow lesions rely on imaging. Goals are to diagnose the type of vascular malformation, distinguish high-flow from low-flow lesions, and define the anatomic extent and involvement of adjacent structures. Attempts to further classify AVMs on imaging can be very challenging given the individuality of the lesions.⁵ However, the Spetzler-Martin classification for central nervous system (CNS) AVMs uses imaging criteria.⁷ Imaging workup can include multiplanar computed tomography angiography (CTA), ultrasound (US), and magnetic resonance imaging (MRI).

Plain radiography has a limited role. In osseous lesions, particularly in extremities, erosion or hyper-

trophy is seen. Limb length discrepancies can be measured.⁴ Computed tomography angiography with reconstructions has been used in differentiating AVMs from hemangiomas. Computed tomography (CT) would show the intensely enhancing nidus with hypertrophied feeder arteries and draining veins (Fig. 3). Both lesions appear as vascular masses on standard axial imaging; however, reformats can distinguish the mass-like hemangioma from a tangle of vessels in the AVMs⁸ (Fig. 4). Three-dimensional (3D) reformatted imaging

Figure 4 Three-dimensional computed tomography angiography of face shows an arteriovenous malformation involving the left orbit. Feeding vessels (arrowheads) and nidus (arrow) are clearly depicted.

Figure 5 Coronal T2-weighted magnetic resonance imaging of gluteal region showing a large arteriovenous malformation with hypointense areas (arrow) is suggestive of flow voids, indicating high flow.

is also useful for patient counseling and surgical planning. Magnetic resonance imaging is standard in most centers for workup of a malformation. Signal voids on spin-echo or less reliably bright signal on gradient-echo imaging indicate high-flow lesions (Fig. 5).⁹ Magnetic resonance imaging is also the best modality for evaluating involvement of adjacent soft tissues and visceral organs. Ultrasound/Doppler can be an inexpensive, noninvasive tool in evaluating flow dynamics (Fig. 6); however, its use is limited to more superficial lesions. Intervening bowel can preclude its use for deeper lesions. A few authors have described the use of nuclear imaging in high-flow lesions. Transarterial lung perfusion scans and whole-body blood pool scans are used to evaluate

Figure 6 Color Doppler ultrasound of the pelvis (right adnexa) showing a large hypervascular area with aliasing in the high-flow areas (arrow) is suggestive of an arteriovenous malformation.

the extent of arteriovenous (AV) shunting as well as measure adequacy of treatment.¹⁰

Treatment

Treatment of AVFs involves interruption of flow through the direct communication. Embolization directly across the lesion is done often with coils, although other agents have been described. Treatment of AVMs is difficult, complex, and focused on eradication of the nidus rather than feeders. The high flow makes AVMs difficult to treat. Furthermore, improper treatment can exacerbate the lesions by stimulating growth and making the lesion more difficult to treat.¹⁰

Historically, treatment included surgical ligation of feeding arteries. This was usually unsuccessful due to recruitment of new and unusual feeders the size and tortuosity of which made treating the remaining lesions more difficult or impossible. Lesions that are easily accessible and don't, or minimally, involve surrounding tissues are surgically resected. These are usually the minority.

Complete transcatheter cures are unusual, and the focus is on palliation. Multiple treatments and a combination of transcatheter embolization and surgery may be needed. General anesthesia is preferred both for pain control and to prevent motion. Pretreatment with steroids is done to control inflammatory response.¹¹ Endovascular treatment is very challenging given the complexity and individuality of AVMs and also because there are worldwide differences of opinion. The goal of transcatheter embolization is embolic casting of the nidus. The agents used have a low viscosity for adequate delivery through a microcatheter, a fast setting time for casting, and their long durability.¹² Liquid agents that are the mainstay of treatment include glue (isobutyl or n-butyl-cyanoacrylate [NBCA]) and Onyx (ethylene-co-vinyl alcohol [(EVOH] in dimethyl sulfoxide [DMSO]). Approved for use in the United States in 2000, NBCA has been the agent of choice for many.⁶ The rapid polymerization can limit the level of occlusion and increase the potential for adhesion of the catheter¹⁰⁻¹²; however, controlling the rate of polymerization can overcome this to some extent. Some advocate glue in presurgical embolization because it also serves as a surgical guide.

Recently, Onyx has been extensively used for AVM therapy. Because it has an easier learning curve than glue, it has gained popularity. It requires DMSO-compatible catheter systems. Also, DMSO dose limits are an important consideration in children.

Particle agents such as polyvinyl alcohol (PVA) or engineered microspheres¹² are also an option, with the longest experience being with PVA. A size of 150 to 500 μm is suggested as optimal⁶ to prevent embolizing the feeding vessels and to limit nontarget embolization.

Polyvinyl alcohol is economical, but can clump, resulting in proximal occlusion. Engineered spheres with calibrated sizes have also been advocated (e.g., Embospheres). A superabsorbent polymicrosphere (SAP-MS) has been used in Japan.¹³ These particles are essentially inert and are calibrated in 50- μ m intervals up to 350 μ m. They swell 2 to 3.5 times when in serum for several minutes. Short-term results are promising for a good particle option with a very low toxicity.¹³

Although very effective in low-flow lesions, sclerotherapy is ineffective in treatment of high-flow lesions because of rapid washout. Nevertheless, sclerotherapy with absolute ethanol has been described in peripheral AVMs. Ethanol causes vascular denudation with acute thrombosis. Good distal occlusion is needed both to prevent complications arising from flow into systemic circulation and to provide adequate treatment. This can be achieved using occlusion balloons or external compression.^{5,10,11,13-15} The approach is either endovascular or direct puncture with concurrent monitoring of systemic and pulmonary artery pressures. If mean pulmonary artery pressure exceeds 25 mm Hg, a nitroglycerine bolus followed by continuous infusion is administered.¹¹

Target vessel catheterization and agent delivery is usually similar. Microcatheter or direct access to the nidus is obtained.¹⁵ Care must be taken to avoid vasospasm, which can prematurely end therapy. Nitroglycerine can be used to reduce the spasm.¹⁵ Premature embolization of the draining veins should also be avoided because it can result in hypertension in the AVM and lead to rupture. Transvenous access has also been attempted but is not the route of choice; it is typically used in conjunction with transarterial access. Once the catheter is in a good position, diagnostic angiography is performed to characterize the lesion and feeders. "Flow-arrested" angiography with the help of blood pressure cuffs or outflow occlusion devices can be undertaken as a technique variation.¹⁵ Once characterized, trial injections without an embolic/sclerosant agent are performed to estimate the volume and rate of injection needed to fill only the nidus. Casting of the nidus is then performed (Fig. 7). Post-embolization syndrome can also occur and is treated symptomatically.¹⁵

Outcomes/Follow-up

Admitting patients overnight for monitoring and pain control provides the advantage of evaluating for adequacy of treatment and complications¹¹. Patients treated with ethanol may require intensive care unit (ICU) admissions to continue nitroglycerine therapy. In one series, 12% of 55 patients had major complications and 45% experienced minor complications¹¹. In another recent ethanol series, 48% of 66 patients had mostly minor complications; however, a small number of permanent nerve injuries occurred as well.⁵ Jacobowitz

Figure 7 Postembolization angiogram of thigh arteriovenous malformation (AVM) shows nonfilling of the AVM with Onyx and glue casts seen (arrowheads).

et al reported a series of 50 patients using particle and liquid agents (primarily glue and PVA) with no major complications. They also reported that 92% of the patients were improved over a 56-month follow-up period.

One area of debate is the indication or need for additional surgical treatment after embolization. Previous studies have shown that many patients with extremity AVMs will ultimately require amputation. Embolization may delay amputation for several years and assist in future surgical procedures.^{13,15}

All lesions need clinical follow-up to evaluate for reduction or resolution of symptoms/findings. Most centers advocate noninvasive imaging for assessment. Invasive imaging is reserved for patients with recurrent symptoms or complications.

VENOUS MALFORMATIONS

Venous malformations (VMs) are the most common vascular malformations. They consist of clusters of abnormal channels lacking normal smooth muscle, endothelium, and functional valves.¹⁶ As a result, they become distended, filled with blood, and undergo repeated cycles of thrombosis/thrombolysis. Chronic clot can calcify and cause phleboliths. Based on their distribution, VMs are divided into focal, multifocal, and diffuse categories, and this has some predictive value as to their natural history and response to therapy.^{17,18} Focal lesions consist of abnormal interconnecting spaces

that are sequestered from systemic flow, and they typically drain through small channels to normal adjacent veins. These usually respond most favorably to direct sclerotherapy. Multifocal lesions consist of scattered focal lesions and are commonly seen with familial VMs (blue rubber bleb nevus syndrome, glomuvenous malformations, Maffucci's syndrome). Diffuse VMs involve multiple tissue layers and are more difficult to treat. The malformed veins commonly have direct communication with larger central veins (which can also be malformed).¹⁸ Treatment requires multiple sessions and carries a greater risk of systemic effects of the sclerosing agent.

Clinical Findings

Venous malformations are present at birth and grow in proportion to the patient, becoming more symptomatic at puberty. Aching pain and swelling typically are experienced with dependent positioning or exercise of the affected body part. Due to stasis, these vessels are prone to thrombosis, resulting in more acute pain or swelling. In infants and younger children, they can cause reduced range of motion in the extremities and hands, and can delay walking if on the plantar surface of the foot. Head and neck lesions can be disfiguring and even cause mass effect on the airway.¹⁹ Evaluation begins with a comprehensive physical examination, including evaluation for skin involvement, tenderness, range of motion, peripheral pulses, and positional changes. Blood clots within the lesion are felt as warm, tender, rubbery areas. Usually there is a bluish discoloration of the overlying skin. Skin ulceration is uncommon and bleeding is rare. It is important to exclude a high-flow lesion, which will greatly impact therapeutic options. This is easily done with an US-Doppler because high-flow lesions show arterial Doppler shift. Patients with extensive VMs should undergo a coagulopathy workup due to the high incidence of disseminated intravascular coagulopathy (DIC) and its impact on therapy and outcomes.²⁰

Imaging

Imaging workup of VMs is best done with MRI.^{21–26} Protocol should include T1, T2, or inversion recovery (with fat saturation), as well as dynamic contrast-enhanced magnetic resonance angiography (MRA) images. Gradient-echo sequences can be helpful to identify flow voids and phleboliths. Gadolinium enhancement is used to differentiate between venous and lymphatic malformations (venous will enhance) and also to exclude tumors. On T2-weighted sequences, VMs are seen as hyperintense channels with internal septations (Fig. 8). Flow voids indicate a high-flow lesion. Magnetic resonance imaging characterizes the type of the lesion (focal/diffuse/multifocal), the extent and involvement of

Figure 8 Magnetic resonance T2 fat-saturated image shows an extensive upper extremity venous malformation that extends into the chest wall. Note the involvement of the underlying muscles in the upper extremity.

adjacent structures, and the drainage pathways. On US, VMs appear as mixed echogenicity lesions with low monophasic flow (Fig. 9). Occasionally no flow is seen due to stasis. Clots in the vascular spaces and phleboliths may also be seen. Arterial waveforms indicate a high-flow lesion. Computed tomography can also be used to locate the lesion and assess involvement of adjacent structures; however, due to the radiation involved, it is not a preferred examination. If CT is performed, VMs typically have nonspecific delayed enhancement (Fig. 10), which is sometimes peripheral. Computed tomography angiography with 3D reformats has been shown to help distinguish VMs from other vascular lesions.⁸ Angiography is usually done in the same setting

Figure 9 Color Doppler ultrasound of a venous malformation in the dorsum of the foot. Note lack of aliasing, indicating slow flow in contrast to arteriovenous malformations.

Figure 10 Coronal contrast enhanced computed tomography of a noninvoluting congenital hemangioma involving the left lateral cheek and temporal region shows an intensely enhancing mass (*) with a feeder vessel (arrow).

as intervention and shows normal arteries with no AV shunting. Pooling of contrast can be seen on delayed images (Fig. 11), but due to stagnant flow, opacification of the lesion is usually incomplete and deep veins are not well seen. Direct venography is the most common invasive method of imaging VMs. Lobular venous lakes and varicosities are common findings.¹⁸ Outflow is typically slow and seen via small communicating venous channels. Larger veins that communicate directly with the deep veins are seen more commonly with diffuse VMs, and systemic embolization is more of a risk in these.

Treatment

Knowledge of these lesions is often limited or incorrect. Thus, it is important to educate the families and to

describe the effects and goals of sclerotherapy. The usual goal is not total cure, but rather reduction in size and symptoms. Lesions that impair function require more aggressive therapy. Families should understand that multiple sessions and therapies may be required. No treatment may be warranted if the lesion is not symptomatic. Compression stockings may be beneficial as a conservative measure. Surgical resection, alone or in conjunction with percutaneous therapy, may be of value in select cases (Fig. 12).

Percutaneous sclerotherapy is the mainstay. Sclerosing agents are used to damage the endothelium with subsequent inflammation and fibrosis. The underlying regional malformation is not affected, and only the injected vessels are treated. Multiple sclerosing agents are available, but absolute ethanol and various detergent sclerosants are most commonly used.

Ethanol is the most potent agent, causing cell denudation and thrombosis.²⁷ Side effects include swelling, tissue necrosis, peripheral nerve injury, pulmonary vasospasm, arrhythmias, cardiovascular collapse, and death.^{14,17,28-33} Due to the high-risk profile, ethanol use is much less common now and mainly for lesions not responding to detergents. Careful planning with the anesthesiologist should be done so he or she is aware of and anticipates the potential complications. A total dose of 1 cc/kg ethyl alcohol (EtOH) should never be exceeded. In addition, dosage should be limited to 0.1 cc/kg every 10 minutes.^{14,17} Ethanol can be injected undiluted or be opacified with Ethiodol.¹⁷ Detergent agents also damage the endothelial cells with resulting thrombosis and fibrosis.^{34,35} They are more commonly used because they have a much lower rate of serious complications than ethanol. Three percent sodium tetradecyl sulfate (STS) is the sclerosing agent of choice. Foaming the detergent gives greater volume coverage and increases contact time and efficacy.³⁶ Other agents include sodium morrhuate (has higher rates of allergic reactions) and polidocanol (has added anesthetic effect).

Figure 11 Venogram in a patient with Parks-Weber syndrome shows anomalous deep venous anatomy. This was in addition to the high-flow lesions (not shown).

Figure 12 Spot image during angiogram for preoperative embolization shows a large facial venous malformation with liquid embolic material (arrow) in it.

Prehydration helps manage hemoglobinuria, a common side effect of detergent sclerotherapy. Percutaneous US access is performed with a 20- or 22-gauge Teflon-sheathed needle (Fig. 13), with three to five sites commonly accessed at each session. Following a direct injection venogram to confirm intralesional location and characterize outflow, foamed 3% STS is injected slowly

Figure 13 Venogram during sclerotherapy of a venous malformation shows venous channels and lakes.

under fluoroscopic guidance. The injection is stopped if central venous drainage or extravasation is seen or if skin blanching occurs. After the procedure, a sodium bicarbonate (NaHCO_3) solution (75 mEq/L NaHCO_3 in 5% dextrose in water [D5W]) is run at twice maintenance until the urine is clear. A dose of ketorolac at the end of the procedure can help to manage postoperative pain. Usually patients can go home the evening of the procedure. Patients with head/neck lesions frequently require overnight monitoring to assure no airway compromise occurs. Swelling is greatest in the first 24 hours. If this is a concern, intravenous (IV) corticosteroids can be given (dexamethasone, 0.1 mg/kg every 8 hours) while the patient is in the hospital. Narcotic pain medications are rarely needed.

Endovascular diode laser treatment has also been described as a treatment option.³⁷ The laser wavelength is selective for the tertiary hemoglobin peak and has a limited depth penetration in blood, resulting in successful treatment with limited side effects and complications. Radiofrequency ablation has been recently described for use in VMs that are too small or are inaccessible to percutaneous sclerotherapy.³⁸

Follow-up

Fibrosis of the lesions continues for 1 to 2 months after sclerotherapy. To maximize each treatment, follow-up visits are every 2 to 3 months to assess results and make decisions regarding further sessions. Treatment success is tailored to the individual patient and is based on symptomatic improvement and not on imaging findings.

Significant relief can be seen even if imaging does not support a size reduction.

LYMPHATIC ANOMALIES

Lymphatic malformations (LMs) are uncommon lesions and are classified as truncular and extratruncular.³⁹ The extratruncular form is known as cystic or cavernous lymphangioma. The truncular form represents primary lymphedema.⁴⁰ This article focuses on the extratruncular forms. These are comprised of abnormal dilated lymphatic channels, which can be microcystic (<2 cm in diameter), macrocystic, cavernous, or combined. Seventy-five percent are cervical in location but can be found anywhere in the body. Abnormal lymph channels may be associated with either capillaries or venous channels to form mixed lesions.

Clinical Findings

Lymphatic malformations are frequently identified at birth or in early childhood.⁴¹ They present as a focal mass or swelling, which enlarge with infection or bleeding. Pain, mass effect, and oozing affect quality of life. Some lesions also have a cutaneous component, which appears as raised vesicles. Serious complications

such as chylothorax have been noted with Gorham's syndrome.

Imaging

Cross-sectional imaging is required before therapy to identify deeper portions of the lesion and to identify nearby associated structures. Magnetic resonance imaging is the modality of choice. Macrocystic lesions follow fluid signal on all sequences. Sometimes, protein within the fluid can result in T1 hyperintensity. As opposed to VMs, minimal to no enhancement is present in macrocystic lymphatic malformations. Microcystic lesions appear more solid on MRI and can enhance. The walls are of variable thickness and typically enhance. Patients commonly present with prior CT scan, as it is readily available and the initial diagnosis is a tumor. Findings include a lobular fluid density mass with minimal mass effect and little or no perceptible wall or septations. No enhancement of the macrocystic component is seen, although mixed lesions or microcystic ones can show enhancement (Fig. 14A–C). Three-dimensional reformatted CT has been shown to be helpful in characterization.⁸ Ultrasound is used extensively during the procedure for planning puncture sites.

Figure 14 (A) Contrast-enhanced axial computed tomography through the neck shows a large nonenhancing cystic mass consistent with cystic hygroma. (B) Mixed macro- and microcystic lymphatic malformation. T1-weighted coronal shows the macrocystic portion as high signal, with the superficial microcystic portion minimally hyperintense to muscle. (C) Ultrasound shows the more homogeneous macrocystic portion containing swirling proteinaceous fluid, with superficial microcystic region.

Treatment

Treatment of LMs is usually done for cosmetic deformity, infection, mass effect, and lymphatic leak. Although surgical resection was used extensively in the past, sclerotherapy is becoming accepted as the treatment option of choice.^{17,40,42,43} It is less invasive, has an acceptable complication rate, and has a short recovery time. Many different sclerosing agents have been reported. These include but are not limited to alcohol, doxycycline, and bleomycin; Sotradecol, Picibanil (OK-432), and Ethibloc^{17,44–48} have also been described but are not currently approved in the United States. Bleomycin is not recommended due to risk of pulmonary fibrosis. Picibanil has shown promise in European and Asian studies and is currently used in the United States as part of research protocols.⁴⁰ It consists of a solution of killed group-A streptococci in a suspension containing penicillin. The exact mechanism is unknown, but it is thought to incite an inflammatory response with sclerosis.

Macrocystic lesions are accessed with US guidance. Fluid is aspirated completely. A small amount of contrast is injected to confirm intralesional placement, followed by injection of the sclerosing agent at a volume similar to the aspirated amount. Lesions requiring a larger volume or those near vital structures (such as orbital lesions) are treated with doxycycline diluted to 10 mg/mL mixture with contrast. This is injected under fluoroscopic guidance and not aspirated after the procedure. A light pressure dressing is placed postinjection to reduce leakage of the liquid. Microcystic lesions can also be injected directly through a needle using small volumes of doxycycline. It is not necessary, or possible, to opacify these small lesions with contrast. Proper position is confirmed on aspiration of straw-colored liquid (Fig. 15). A variation in this technique has been described by Shiels: Lesions are accessed with a needle, and a small 4F to 5F pigtail catheter is placed. A sequential dual drug sclerosis is performed with 3% Sotradecol

followed by EtOH. The catheter is connected to bulb drainage and left in place for 2 to 3 days before removal. This technique has shown promise, with a low requirement for repeated therapies.⁴⁹

Following sclerotherapy, patients are discharged on the same day. Tylenol is usually sufficient for pain control. A 7- to 10-day course of antibiotics postprocedure to prevent infections is described by some authors.¹⁷

Follow-up

The patient should be contacted by telephone shortly after discharge from the hospital, and then come in for a follow-up examination in 6 to 10 weeks to assess outcome. Ultrasound can be used to determine response to treatment. Repeat sessions may be required.

HEMANGIOMAS

Hemangiomas are benign congenital tumors comprised of proliferating endothelium and are the most common tumor of infancy with an incidence of 3 to 12%.^{50–52} Hemangiomas require little or no treatment, although particular locations, patterns of distribution, or larger lesions can lead to significant morbidity or mortality and require more aggressive treatment. Embryonic segmental distributions, lesions in the head and neck or midline over the spine, or more than five cutaneous lesions should trigger further imaging because they may be associated with CNS or visceral hemangiomas.^{52–58} Of note, Kasabach-Merritt syndrome (characterized by platelet trapping, thrombocytopenia, and coagulopathy) is not associated with hemangiomas.⁵⁹ Noninvoluting congenital hemangioma (NICH), a variation of hemangioma, does not passively involute and requires surgical resection. Rapidly involuting congenital hemangioma (RICH), also rare, rapidly involutes and, unless in an endangering location, can simply be observed.^{60,61}

INFANTILE HEMANGIOMA

Infantile hemangioma (IH) is the most common tumor of infancy, occurring in 3 to 12% of infants.^{50–52} Often thought to be a birthmark, it presents at birth or within the first few weeks of life.^{51,53} It undergoes rapid growth in the first year of life, then gradually involutes, with 70% involution by age 7 years.^{1,51,52,62} Diagnosis often is made by history and physical examination, although a minority will require further imaging. If appearance or behavior is atypical, biopsy is required to exclude tumors such as angiosarcoma, Kaposiform hemangioma, and tufted angioma.^{8,26,50,53,56,58,63–67} Retrospective studies have identified female sex, white race, and prematurity, among others, as risk factors for IH.^{51–54,68–70} There are competing theories as to whether IH stems from a

Figure 15 Lateral spot image during injection sclerotherapy shows the sclerosant opacified with contrast outlining the different cystic compartments (arrows).

mutation within an endothelial cell, or from an ectopic focus of embolized placental cells, or from a rest of endothelial cell precursors.^{53,71-75}

Clinical Findings

Infantile hemangioma presents within the first few weeks as a premonitory mark, an area of hypopigmentation, ulceration, or bluish discoloration. Growth rates vary, although trends have been noted where smaller lesions expanded and involuted more rapidly than larger lesions.⁵³ The Hemangioma Investigator Group (HIG) trial describes an anatomical distribution with further subdivision.^{53,54}

Size, location, and morphological subtype are independent risk factors for complications with the segmental morphological subtype and perineal and facial lesions carrying the greatest risk. Morbidities associated with IH are ulceration; airway obstruction; and visual, auditory, respiratory, and/or cardiac compromise.^{53,54} Lesions with segmental distribution and with mixed superficial and deep components tend to ulcerate versus having a localized distribution and superficial depth. Half of the ulcerations bleed but only 2% experienced "significant" blood loss.⁶⁸

Location-specific concerns need to be remembered, as follows:

- **Ocular:** Mass effect from this IH on the developing eye can result in amblyopia,^{53,76-78} either from pressure changing the contour of the cornea or from interference with extraocular muscles. It may also cause closure of an eye that limits visual input.⁷⁶ Treatment should begin with the first signs of compromise.
- **Head and Neck:** This is the most common location of IH, where it usually is benign. Ulceration and infection can cause scarring with psychological effects.
- **Laryngeal:** Although rare, this is the most frequent visceral manifestation of IH.^{53,79-81} It presents early with stridor and follows the classic pattern of growth and prolonged involution. It usually requires no intervention, although some cases can be complicated by subglottic stenosis (a predictor for needing therapy), infection, and death.⁸⁰
- **Hepatic:** Although rarely involved, IH of the liver can be complicated. Christison-Lagay et al proposed a classification based on clinical and radiological parameters as focal, multifocal, or diffuse.^{42,66,82-86} Focal IH tends to present at birth and follow a more rapid involuting course. Multifocal lesions are seen more often in the setting of multiple skin hemangiomas. Both types may have high-flow shunts with associated cardiac failure. Diffuse hepatic hemangiomas were those too numerous to count and at times completely replacing the hepatic parenchyma. They present earlier due to mass effect limiting ventilation and

high venous return to the heart, requiring early management.(Fig. 16A, B)

- **Lumbosacral:** This IH is associated with tethered cord, spinal dermoid, and lipomyeloschisis.^{53,87} Given the relative ease of noninvasive imaging (US at age < 4 months, MRI at age > 4 months, or inconclusive US) and the morbidity of delayed diagnosis, screening is warranted.⁵³

Imaging

Although history and physical examination are often sufficient, the size, location, and clinical symptoms may trigger diagnostic imaging. To better characterize the type and extent of the lesion, the workshop on IHs recommended imaging in: (1) large hemangiomas of the head and neck; (2) hemangiomas overlying the spine and sacrum, and involving the perineum; (3) patients with more than four cutaneous lesions; and (4) patients presenting with Kasabach-Merritt with possible biopsy.^{50,53}

Ultrasound is often first-line imaging for superficial lesions, especially those adjacent to the orbit and lumbar spine and sacrum. Lesions with high vessel density and high Doppler shift were characteristic of IH.⁶³ Ultrasound can delineate anatomic boundaries, which are predictive of clinical outcomes. Magnetic resonance imaging is the mainstay because it provides excellent soft tissue differentiation, and MRA can be done with or without a contrast agent^{25,50,53,58} (Fig. 17). Infantile hemangiomas are isointense on T1-weighted sequences and hyperintense on T2 and short tau inversion recovery (STIR) sequences; they enhance with gadolinium in a homogenous fashion. Hepatic lesions were seen as well-defined masses with low T1 and high T2 signal relative to the hepatic parenchyma. They enhance centripetally with central heterogeneity secondary to necrosis and/or thrombosis.⁸² Digital subtraction angiography (DSA) is reserved for patients in need of potential intervention.^{83,88} Kassarian et al classified lesions into: (1) "classic" hemangiomas with filling of abnormal feeding vessels, contrast stagnation, and no macroscopic shunt; (2) high-flow nodules without shunt; (3) high-flow nodules with arteriovenous shunts; (4) high-flow nodules with portovenous shunts; and (5) high-flow nodules with both shunt components^{85,86} (Figs. 16C, D). The presence of shunt vascularity was a predictor of the need for embolization or surgery relative to medical management alone.^{53,86} Although not used frequently, CT also can accurately delineate lesions (Fig. 18). Rapid acquisition, excellent spatial resolution, and 3D reconstruction make CT an effective tool.⁸

Treatment

Most IH undergo involution without need of medical or surgical intervention, although a subset (38%) can cause

Figure 16 Axial (A) and coronal (B) T1 fat-saturated postcontrast images. A large enhancing mass is seen in the left lobe of the liver (arrow). Selective left hepatic angiogram shows classical peripheral filling (C) of this mass, and a subsequent image (D) shows early filling of the venous outflow in the form of the dilated left hepatic vein (double arrows).

Figure 17 Axial postcontrast fat-saturated T1-weighted image through the thigh shows an enhancing lesion in the left lateral thigh with phleboliths (arrows) in it.

Figure 18 Noncontrast axial computed tomography of the mandible shows a soft tissue mass in the superficial tissues with a phlebolith (arrow) in it suggestive of a hemangioma.

significant morbidity and mortality necessitating intervention.^{52–55,57,68,89} Monitoring the patient with repeat physical examinations and counseling the parents is extremely important for early detection of need for therapy. In early intervention, the goal is to hasten the proliferative phase to limit comorbidities. Later treatment is often to reduce scarring and its associated effects.

Systemic corticosteroids are first-line therapy, although no standardized dose exists for their administration. Doses range from 2 to 5 mg/kg/d of prednisone for 4 to 12 weeks with efficacy ranging from 25 to 90%.^{53,81,90–92} High-dose corticosteroids can cause multiple known side-effects making short-term follow-up important.^{53,90,93,94} Direct intralesional corticosteroid injection has also been used and is thought effective for smaller, localized lesions.^{53,95,96} For hemangiomas refractory to first-line corticosteroid therapy, interferon and vincristine therapy has been described.^{53,55,97–100}

Cutaneous laser use is described both in the proliferating and involuted phases, although it is more readily used during the latter stage to lessen residua and improve cosmesis. Laser ablation during the proliferating phase, especially with superficial lesions, may cause rapid involution and minimize scarring.^{37,53,57,81,101–105} Lasers should be adjunctive to medical management, and lower doses are used to incite focal endothelial injury and platelet adhesion rather than frank capillary destruction.⁵³

Transcatheter therapies have a very specific role, mainly as embolization to control cardiac failure from shunting or respiratory compromise. It is commonly needed in infantile hemangiomas of the liver (incorrectly referred to as hemangioendotheliomas).^{82,83,88,106–110} Assessing the shunt is important because arterial embolization with portohepatic venous shunts is ineffective

and increases the likelihood of hepatic necrosis. These shunts can be treated via transvenous, transarterial, or transhepatic methods.^{88,106} Embolic material is chosen based on the size and number of vessels feeding the lesion. Gelfoam, PVA, and NBCA can be used alone or, more often, in conjunction with microcoils.^{106–110} Other devices (e.g., Amplatzer Vascular Plug and detachable balloons) have also been used with success.¹⁰⁶ Procedures are staged to prevent necrosis with close monitoring for complications. Medical management is continued until complete regression of the lesion occurs. Embolization has also demonstrated benefit for head and neck lesions, with a few case reports of transcatheter arterial embolization for symptomatic facial and laryngeal hemangiomas whose extent limits surgical excision. Rapid response was noted in all with few complications.^{111–114}

Percutaneous embolization and sclerosis are also used for superficial lesions with success. These treatments are adjunctive to medical/surgical management.^{115–118} Rapid and long-term results are favorable with minimal complications, none of which are severe.

Surgical excision can be done at any stage. Its goal is to prevent adjacent organ compromise and limit deformity.^{53,57} Surgery is also used for scar revision and reconstruction.

For ocular lesions, systemic corticosteroids with contralateral eye-patching is the first-line therapy. Direct, intralesional corticosteroid injections can be done but carry risk of ophthalmic artery embolization.⁹⁵ Surgical excision is reserved for lesions threatening vision.⁵³ Laryngeal lesions having < 30% stenosis do not require intervention, and those with < 50% respond well to steroid management alone.⁸¹ Therapy is dictated by the severity of airway compromise. Bitar et al all noted success with carbon dioxide (CO)₂ laser (88.9%) and intralesional steroids (86.4%).⁸¹

Outcomes/Follow-up

Hemangiomas frequently require no treatment and little follow-up owing to their natural, involuting course. For those requiring treatment, short-term follow-up (2 to 4 weeks) is recommended depending on the clinical scenario. Ultimately, most will resolve without note, although there may be a residual fibrofatty mass or scarring.

NONINVOLUTING CONGENITAL HEMANGIOMA AND RAPIDLY INVOLUTING CONGENITAL HEMANGIOMA

A rare vascular tumor, NICH is very similar to IH with notable exceptions.⁶¹ From a treatment standpoint, embolization is not needed and surgical resection is recommended only for symptomatic lesions.⁶¹ The hemangioma subtype RICH rapidly involutes after birth and rarely requires treatment.

Figure 19 Flowchart provides a sample protocol for managing vascular anomalies, including multidisciplinary workup and treatment for vascular anomalies. IH, infantile hemangioma; MRI, magnetic resonance imaging; CTA, computed tomography angiography; US, ultrasound; CHF, congestive hepatic fibrosis; NICH, Noninvoluting congenital hemangioma.

Table 2 Imaging Characteristics of Vascular Anomalies

Type	General Morphology	Enhancement	Phlebolith	High Flow
Hemangioma	Solid mass	Intense	No	Yes
Vascular tumor (kaposiform hemangioendothelioma, etc.)	Solid mass	Intense	No	Yes
AVM/AVF	Vessels	Intense	No	Yes
Venous Malformation	Vessels	Delayed	Yes	No
Lymphatic Malformation	Cystic or solid (if microcystic) mass	Depends on degree of solid versus cystic	No	No

AVM, arteriovenous malformation; AVF, arteriovenous fistula.

KAPOSIFORM HEMANGIOMA AND TUFTED ANGIOMAS

Kaposiform hemangioma (KH) is a rare vascular tumor (with only a small number of case reports) of infants and adolescents that is distinct from IH. It is often associated with Kasabach-Merritt syndrome.^{119,120} Tufted angiomas (TAs) are rare lesions and closely related to KH.^{121,122}

In addition to replacing platelets in lesions complicated by Kasabach-Merritt syndrome, treatment of KH and TA is variable with multiple pharmacological and surgical options. No single or multimodality therapy has proven superior.^{55,59,79,121–125}

CONCLUSION

Vascular anomalies are a complex group of conditions. Although the various entities are described individually, it is not uncommon to have an overlap or a combination. Before treating these lesions, it is necessary to become

familiar with them and also to be comfortable in performing a workup that will enable you to decide the mode of therapy. It is helpful to develop a workup protocol similar to that in Fig. 19, along with a brief table of imaging features (Table 2). Often, multiple different therapeutic approaches are needed and require a multidisciplinary approach. Family and referring physician education will go a long way in making appropriate referrals and setting realistic goals.

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