Vascular Malformations: Approach by an Interventional Radiologist

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Semin Plast Surg 2014;28:91–103.

Abstract

Keywords

- ▶ vascular malformation
- ▶ sclerotherapy
- ▶ embolization

Children with vascular malformations are best managed with a multidisciplinary team of specialists. Interventional radiology may deliver primary treatment such as staged sclerotherapy and embolization for malformations that are poor candidates for primary surgical resection or play a supportive role such as preoperative or intraoperative embolization. A thorough understanding of vascular morphology and flow dynamics is imperative to choosing the best treatment tool and technique. In this review, the author discusses the selection of techniques and tools used to treat vascular malformations based on their angiographic morphology.

Venous Malformations (Low Flow)

Management of patients with symptomatic venous malformations (VMs) starts with a conservative approach. Regular daytime use of a custom-made compression stocking and muscle strengthening exercises together play a very important role in reducing the severity and frequency of pain. Extremity elevation and application of ice are useful adjunctive measures during acute painful episodes. Correction of leg-length discrepancy improves pain related to gait imbalance. Prophylactic anticoagulation is helpful in alleviating pain in patients with extensive VMs with evidence of localized intravascular coagulopathy.

Indications for invasive treatment include (1) unsatisfactory pain relief using conservative measures, (2) bleeding episodes from superficial VMs, and (3) functional impairment and deformity. In patients with extensive VMs, the treatment is focused to the symptomatic region.

Technique

Treatment is performed under general anesthesia. Intravenous antibiotic prophylaxis is administered using cefazolin 25 mg/kg. Clindamycin (10 mg/kg) is used in patients with penicillin allergy and for intraoral procedures. A Foley catheter is placed for procedures more than 2 hours duration.

The region of interest is prepped and draped. For extremity VMs (▶ **Fig. 1A**), the entire extremity is prepped and draped and a 22G peripheral intravenous (IV) line is placed on the dorsum of the hand/foot followed by digital subtraction step table venography of the extremity (▶ **Fig. 1B**).¹ The VM is accessed under ultrasound (US) guidance and digital subtraction venography is performed using road map imaging (▶ **Fig. 1C**). The venographic morphology is used to divide VMs into four categories and this classification dictates treatment plan.² Common choice of ablation tools and agents include

1. Sclerosants: 3% sodium tetradecyl sulfate (STS), absolute alcohol, bleomycin
2. Endovenous laser
3. Liquid embolic agents: Onyx and n-butyl cyanoacrylate (n-BCA)
4. Mechanical occlusion devices: Coils and Amplatzer plug

A. Type I VM: Sequestered VM with Minimal Venous Drainage (▶ **Fig. 1D**)

1. Technique/agent: These VMs are treated using the double-needle technique.³ Two or more needles are inserted within the VM. The sclerosant injected through the distal needle displaces blood and contrast within VM, which exit

Fig. 1 Type I (sequestered) vascular malformation (VM) treated using the double-needle technique. (A) Coronal T2 weighted magnetic resonance image (T2W MRI) shows three focal intramuscular VMs within the right pelvis and thigh as well-circumscribed hyperintense lesions (arrows) with a few internal flow voids suggestive of phleboliths. (B) Step-table venogram shows normal short saphenous (diamond red arrow) and great saphenous (dashed red arrow) veins. Paired deep veins of the calf drain into superficial femoral vein (SFV; bent arrow). Note reflux of contrast from SFV into intramuscular VM above knee (black arrow). (C) Digital subtraction venogram shows VM with no drainage. Note injection (black arrow) and vent (red arrow) needles. (D) Diagrammatic representation. Distal needle injects sclerosant and proximal needle acts as “vent” needle. (E) Postsclerotherapy step-table venogram shows resolution of reflux into VM. (F) Postsclerotherapy x2. Coronal T2W MRI shows good response.

through the second proximal needle. The proximal or vent needle provides a path of low resistance for the sclerosant, reducing the risk of overdistension, extravasation, and extension of sclerosant into previously nonvisualized draining veins. 3% STS is the preferred agent for this VM.

2. Mechanism of action: STS incites endothelial cell inflammation, which leads to fibrosis.
3. Concentration and dose: 3% STS; 0.5 mL/kg, maximum 20 mL
4. Preparation of STS foam: 3% STS is mixed with Ethiodol and air in an 8:2:5 ratio to create foam. The detergent properties of STS allow formation and maintenance of microbubbles, which obtain a coating of the sclerosant-oil emulsion. The microbubble formation reduces egress of the sclerosant from the VM thus increasing endothelial contact time and sclerosis.
5. Injection of STS foam: The foam is injected under US and road map imaging. The peripheral IV is flushed with

pressurized saline during sclerosant injection to reduce the risk of deep venous thrombosis secondary to inadvertent extension of sclerosant into deep veins. Postsclerotherapy step table venography is repeated (→Fig. 1E) to confirm deep venous patency. Several treatments at 6- to 8-week intervals are performed until the desired end point is achieved. Follow-up magnetic resonance imaging (MRI) is obtained 3 months after the last treatment session (→Fig. 1F).

B. Type II VM (VM with Drainage into Normal Veins) and VM with Slow Venous Drainage (→Fig. 2)

1. Technique/agent: Double-needle technique, 3% STS/absolute alcohol
2. Absolute alcohol—mechanism of action: Alcohol causes protein denaturation and dehydration of endothelial cells with instant platelet adhesion and thrombosis. In addition,

Fig. 2 Vascular malformation with slow venous drainage treated using the double-needle technique. (A) Diagrammatic representation. (B) Axial T-2 weighted magnetic resonance image shows left occipital subcutaneous VM. (C) Digital subtraction venography shows VM (red arrow) draining into multiple small veins (black arrow). (D) C-arm computed tomography scan shows extracranial location of contrast. (E) Double needle technique: Pink 20G angiocatheter acts as “vent.” (F) Ultrasound shows instant thrombosis.

there is a pronounced inflammatory response (commonly requiring steroid administration) leading to fibrosis. Although alcohol is more potent than STS, it has higher local and systemic toxicity. It is, therefore, less favorable agent for superficial cutaneous and mucosal VMs as well as those close to major nerves.

3. Concentration and dose: 98%; 1 mL/kg, maximum 50 mL

C. Type III VM (VM with Drainage into Dysplastic Veins) and VM with Rapid Venous Drainage (► Fig. 3)

Liquid sclerosants would rapidly drain out of these VMs and not have sufficient endothelial contact time to produce inflammation and fibrosis. In addition, they would put the draining vein at risk of thrombosis. Hence, VM with rapid venous drainage are initially treated using a liquid embolic agent (n-BCA/Onyx) to occlude the outflow of the VM. This is followed by injection of sclerosant using single or double-needle technique. The outflow of a VM could also be occluded using coils (► Fig. 4) or occlusion balloon. Tourniquets are also useful, but less desirable because they may result in overdistention of the VM and extravasation if not used with caution followed by sudden release of a bolus of sclerosant into the draining veins upon tourniquet release.

1. Technique/agent: n-BCA/Onyx/coils for outflow occlusion followed by sclerosant injection
2. Mechanism of action:
 - a. n-BCA (Tru-fill, Cordis Inc, Bridgewater Township, NJ) is a permanent liquid embolic and tissue adhesive that rapidly polymerizes on contact with blood and forms a permanent cast of the vascular bed. It is mixed with

Ethiodol to provide radiopacity and dilution to allow penetration into the venous outflow of the VM without extension into normal veins.

- b. Onyx (Onyx, Ev3) is a mixture of ethylene-vinyl alcohol copolymer (EVOH), dimethyl sulfoxide (DMSO), and tantalum. The copolymer precipitates as the DMSO diffuses into blood and forms a cast of the vascular bed.

D. Type IV VM: VMs Composed of Dysplastic Veins (► Fig. 5)

1. Technique/Agent: Coils/Amplatzer plug
2. Large dysplastic deep veins need occlusion with precision using mechanical occlusion devices such as the Amplatzer vascular plug and detachable coils. This may be combined with liquid embolic agents.

E. VMs in Special Locations

- VM near airway (► Fig. 6):

1. Technique/Agent: Double-needle technique, bleomycin
2. Mechanism of action: Bleomycin is a cytotoxic, anti-neoplastic antibiotic derived from *Streptomyces verticillus*. It induces single- and double-stranded DNA breaks and is an endothelial sclerosant. Of all agents, it causes the least amount of inflammatory response and is useful for treating intramuscular, orbital and airway related VMs where tissue edema may impair function.
3. Concentration and dose: 1 Unit/mL; 0.5 Unit/kg, maximum 15 Units
4. Bleomycin precautions: To reduce the risk of cutaneous pigmentation, use of tape is avoided when

Fig. 3 Vascular malformation with rapid venous drainage treated with outflow occlusion using n-BCA followed by sclerosant injection. (A) Diagrammatic representation. (B) A 15-year-old girl with multiple painful bluish subcutaneous nodules on left upper abdomen (glomovenous malformation [GVM]). (C) Ultrasound shows echogenic subcutaneous nodule (white arrows) with central vessels (red arrow). 25G needle placed within nodule. (D) Venography shows rapid drainage into internal thoracic veins (black arrow). Native image shows needle position (white arrow). N-BCA injection into GVM (red arrow) without extension into draining veins. (E) 1.5% sodium tetradecyl sulfate injected using 25G butterfly needle into subcutaneous nodules. (F) Postsclerotherapy x4. Improved appearance and pain.

possible (e.g., by using Thomas tube holder, securing endotracheal tube using mask strings, or taping nasal ray tube to a head turban). When tape is unavoidable, barrier protection is used on skin prior to application of tape and electrocardiogram (ECG) pads. The ECG pads are left in place for 48 hours during which time skin scratches and injury is avoided. To reduce the risk of pulmonary fibrosis, pre- and post-operative chest x-ray and lung function tests are performed.

- Extensive body wall VM (→ Fig. 7):

1. Large extensive venous spaces require a large volume of sclerosant for treatment, which increases the risk of local and systemic toxicity. The addition of endovenous laser for selected large venous spaces allows the VM to be treated with a smaller volume of sclerosant with less postprocedure pain.
2. A 5F x 15 cm Yueh centesis needle catheter (Cook Medical Inc, Bloomington, IN) is used to access a venous space under US along its long axis. A bare laser fiber is advanced coaxially such that the tip of the fiber protrudes 1 cm beyond the catheter. This is followed by activation of the laser fiber during slow pull back of catheter-fiber

Fig. 4 Vascular malformation (VM) with rapid venous drainage treated with outflow occlusion using coils followed by sclerosant/ Onyx injection. (A) Diagrammatic representation. (B) A 15-year-old boy with diffuse multicompartmental intramuscular VM. Multiple episodes of venous thrombosis necessitated long-term anticoagulation. (C) VM accessed using 21G needles. Outflow occlusion using coils (black arrow) followed by injection of Onyx (red arrow).

combination under US monitoring. In addition, the US transducer is used to apply simultaneous manual compression to the venous space to increase contact between the fiber and the endothelium. The laser system used at our institution is Nd-YAG 1320 nm with 600-micron laser fiber.

Complications of Treatment

1. Hemoglobinuria and oliguria: This is an adverse effect of STS and alcohol due to self-limited hemolysis and urinary excretion of excess hemoglobin (that cannot be bound to haptoglobin). Generous prophylactic hydration in the periprocedure period is the most useful preventative

Fig. 5 A 14-year-old girl with acute thrombosis of dysplastic intramuscular veins in left calf. (A) Clinical photograph shows left calf swelling. (B) Coronal and axial T-2 weighted magnetic resonance image shows multiple tubular intramuscular veins. (C) Longitudinal and transverse ultrasound images show thrombosed anomalous intramuscular vein. (D) Step-table venogram shows the anomalous vein (solid red arrow) and normal anterior tibial veins (solid black arrow) draining into paired popliteal veins (dashed black arrow). (E) Selective venogram of anomalous vein followed by embolization with Amplatzer plug and coils. (F) Postembolization venogram through foot (PIV) shows occlusion of anomalous vein with predominant drainage into great saphenous vein. Selective posterior tibial (PT) and anterior tibial (AT) venograms show preserved paired veins with drainage into paired popliteal veins.

and therapeutic measure for this condition. In addition, urine alkalinization and diuretics are useful adjuncts.

2. Skin blistering and necrosis: This is managed with meticulous wound care, application of topical antibiotic, use of nonadhesive dressings supplemented with oral antibiotics, if needed.
3. Mucosal ulceration: This usually heals spontaneously. Antiseptic oral mouth wash and oral antibiotics reduce the risk of secondary infection.
4. Deep vein thrombosis (DVT): Intraprocedural DVT is managed with systemic heparinization and clot aspiration.
5. Skin pigmentation: Usually fades with time, but may leave residual pigmentation

Lymphatic Malformations (LMs; Low Flow)

1. Indications for treatment: Pain, recurrent bleeding, functional impairment, deformity.
2. Technique: All procedures are performed under general anesthesia. The involved area is prepped and draped.
3. Agents and tools:
 - a. Doxycycline: Most commonly used agent in a concentration of 10 mg/mL. It has very low local and systemic toxicity.
 - b. Bleomycin: Useful for superficial, intramuscular, and orbital LMs due to its advantage of causing minimal swelling.

c. STS and alcohol: Useful for LMs that do not respond to doxycycline and are also used as primary agents by some operators.⁴

d. OK-432: A lyophilized powder of group A *Streptococcus pyogenes* that stimulates healing by inducing an immune response and is effective in treatment of macrocystic LM.⁵

e. Surface laser: Is used for treatment of symptomatic superficial cutaneous lymphatic vesicles

4. Technique:

Ultrasound-guided cannulation of lymphatic cysts is performed. Macrocysts (> 2 cm) (→ Fig. 8) are typically cannulated using a 20G angiocatheter followed by decompression of cystic fluid. Microcysts (< 2 cm) (→ Fig. 9) are cannulated using 21G or 25G needle primed with sclerosant and injected without prior aspiration.

The injection and distribution is monitored using both US and fluoroscopy and additional needles are placed to fill the malformation as completely as possible. The needle tracts are embolized using microfibrillar collagen slurry prior to removal. Antibiotic-coated nonadhesive dressing is applied to the treated areas. Surface laser is used for palliation of cutaneous lymphatic vesicles that cause repeated bleeding.

Orbital lymphatic malformations deserve special attention (→ Fig. 10). Bleomycin opacified with contrast is our preferred

Fig. 6 A 12-year-old boy with painful vascular malformation (VM) of the right side of the tongue. (A) Clinical photograph. (B) Ultrasound (US) shows sponge-like venous spaces (arrow). (C) Double-needle technique with sodium tetradecyl sulfate egress through 21G "vent" needle and echogenic microbubbles on US. (D) Postsclerotherapy x2. Complete pain relief. (E) Coronal T-2 weighted magnetic resonance images pre- and posttreatment show minimal residual VM.

agent. Baseline vision testing and intraocular pressure measurement is performed. 5–7-French (F) pigtail catheters are used to drain macrocysts followed by injection of bleomycin opacified with contrast while microcysts are cannulated using 25G needle and injected. Ultrasound and fluoroscopy are used to monitor the injection. Intraoperative pre- and postsclerotherapy intraocular pressures are measured. Postoperative vision and pressure monitoring is continued for 24 hours and drainage catheter removed when 24-hour output is < 1 mL.

Complications of Treatment

1. Allergic reaction: Allergic reaction to doxycycline is rare and could be clinically confused with cellulitis. In these patients, a different agent such as bleomycin could be used.
2. Skin ulceration: This results from extravasation of sclerosant and is managed with topical and oral antibiotics and wound care.

Arteriovenous Malformations (High Flow)

Symptomatic arteriovenous malformations (AVMs; pain, bleeding, tissue ischemia, venous hypertension, high output state) are selected for treatment. A staged approach is used

with multiple treatments spaced at 6- to 8-week intervals until the treatment endpoint (pain relief, wound healing, improvement in high-output state) is reached.

1. Technique: All procedures are done under general anesthesia. Detailed selective and superselective angiography is performed. A 4F arterial sheath with a 4F 0.038" guide catheter is preferred for children < 10 kg with a 5F access system for the rest. Because Onyx is a critical embolic agent, Onyx compatible microcatheters (Rebar 18, Echelon10, Marathon) are preferred to avoid catheter exchanges. Systemic anticoagulation is monitored with ACT (activated clotting time) and intra-arterial vasodilators (e.g., nitroglycerine) are administered to reduce the risk of vessel thrombosis and spasm during the procedure. The goal of the treatment is to deliver the embolic agent into and ablate the AVM nidus and its proximal draining vein, while avoiding reflux into normal arteries and veins.⁶

2. Agents used:

- a. Sclerosants: Absolute alcohol
- b. Liquid embolic agents: n-BCA, Onyx
- c. Mechanical occlusion devices: Coils and plugs

3. Treatment algorithm: AVMs are classified based on the angioarchitecture of the nidus and, depending on the type

Fig. 7 Use of an endovenous laser. (A) A 12-year-old girl with extensive subcutaneous and intramuscular chest wall vascular malformation. (B) Laser fiber (red arrow) advanced through 5F Yueh catheter (black arrow). (C) Ultrasound shows tip of laser fiber (solid white arrow) 1 cm beyond catheter and echogenic microbubbles produced during endovenous laser (dashed white arrow).

Fig. 8 Sclerotherapy of a macrocystic lymphatic malformation (LM) using doxycycline. (A) Right axillary LM with internal hemorrhage seen as mixed hyperintense (fluid filled) and hypointense (blood filled) cysts on coronal T-2 weighted magnetic resonance image (T2W MRI). (B) Ultrasound-guided aspiration of hemorrhagic fluid and injection of doxycycline opacified with contrast under fluoroscopy. (C) Postsclerotherapy x2. Minimal residual disease on MRI.

Fig. 9 Sclerotherapy of a mixed macrocystic-microcystic lymphatic malformation (LM) using bleomycin. (A) Diffuse infiltrative LM of the left hand seen as multiple hyperintense cysts on coronal and axial T-2 weighted magnetic resonance images. (B) Cannulation of cysts using 20G angi catheters. (C) Fluoroscopic image shows distribution of bleomycin. (D) Postsclerotherapy x2. Reduction in volume of LM and improved pain.

of AVM, a transarterial, a transvenous, and/or a direct percutaneous approach can be used for treatment.⁷

- Type I (arteriovenous fistula): This AVM has less than three arteries that shunt to a single vein (►Fig. 11). This AVM could be closed from the arterial or venous side using an endovascular or percutaneous approach.
- Type II (arteriolo-venous fistula): This AVM has multiple arterioles that shunt to a single vein (►Fig. 12). This AVM is best approached from the venous side with intentional reflux of embolic material into the feeding arteries when possible.
- Type IIIa (arteriolo-venous fistula with nondilated fistula): This AVM has fine multiple shunts between arterioles and venules that appear as a blush or fine

striation on angiography (►Fig. 13). Transarterial route is the only way to reach the fine nidus of this AVM.

- Type IIIb (arteriolo-venous fistula with dilated fistula) (►Fig. 14): This AVM has multiple shunts between arterioles and venules, which appear as a complex vascular network on angiography. Any of the three approaches may be used.

Summary

Symptomatic vascular malformations that are not suitable candidates for complete primary surgical excision could be treated with interventional radiology techniques. An understanding of the anatomy and flow characteristics of each malformation is helpful in choosing the appropriate tool and technique to treat and also predict risks and complications of treatment. Treatment

Fig. 10 Orbital lymphatic malformation (LM) treated using bleomycin. (A) A 7-year-old boy with mixed macro-microcystic LM of left orbit with repeated internal hemorrhage. (B) Ultrasound-guided placement of 2 × pigtail catheters (arrows) followed by injection of bleomycin opacified with contrast. (C) Measurement of pre- and postsclerotherapy intraocular pressures. (D) Postsclerotherapy x1 clinical and improvement on magnetic resonance image.

Fig. 11 Type I arteriovenous malformation. A 14-year-old boy with phosphatase and tensin homolog (PTEN) mutation. (A) Popliteal and selective peroneal angiograms show arteriovenous fistula (AVF) between a dilated beaded peroneal artery (red arrow) and vein (blue arrow). (B) Percutaneous access using 5F vascular sheath. (C) Venography through sheath (dashed black arrow) shows peroneal vein (dashed blue arrow) draining into paired popliteal veins (solid blue arrow). Solid red arrow points to arterial catheter. (D) Transvenous embolization using Amplatzer vascular plug (red arrow) and coils (black arrow) with resolution of arteriovenous shunting.

Fig. 12 Type II arteriovenous malformation. A 43-year-old man with severe calf and ankle pain and swelling. (A) Magnetic resonance angiography shows arteriovenous (AV) shunting in midcalf (red arrow) with early filling of the femoral vein (white arrow). (B) Lateral projection of popliteal angiogram shows multiple muscular branches of the peroneal and posterior tibial artery (red arrows) feeding a large venous sac (solid blue arrow) with early filling of the popliteal vein (dashed blue arrow). Percutaneous coil embolization (black arrow) of the venous sac was performed with resolution of AV shunting and pain. (C) Recurrence of calf pain and ankle swelling after 6 months. Selective peroneal branch angiogram shows arterio-venous (red arrow) fistula (bent black arrow). Solid black arrow shows microcatheter tip. Transarterial embolization using occlusion balloon and Onyx (dashed red arrow) followed by percutaneous venous sac access (purple arrow) and Onyx injection into venous sac with reflux into arterial feeders (red bent arrow). (D) Postembolization angiogram shows resolution of shunting.

Fig. 13 Type IIIa arteriovenous malformation (AVM). Abdominal wall AVM supplied by deep circumflex iliac artery (*red arrow*), nidus (*black arrow*), and venous drainage into intercostal vein (*blue arrow*). Vasospasm led to contrast extravasation (*purple bent arrow*). AVM was subsequently treated percutaneously.

Fig. 14 Type IIIB arteriovenous malformation (AVM). A 13-year-old girl with Parkes-Weber syndrome. (A) Lateral projection of popliteal angiogram shows arterio- (*red arrow*)-venous (*blue bent arrow*) fistula in the proximal foot. (B) Selective posterior tibial branch angiogram (*solid red arrow*) and embolization using n-BCA (*dashed red arrow*). (C) Retrograde transvenous access (*black arrow*) with reflux of contrast into AVM (*red arrow*) using orthopedic tourniquet. (D) N-BCA (*black arrow*) injection and postembolization angiogram with improvement in arteriovenous shunting.

is typically staged at 6- to 8-week intervals until the desired clinical outcome is achieved and the lesion treated as completely as reasonably achievable. A regular clinical follow-up is important to ensure that the patient's expectations and concerns during the course of the treatment are addressed.

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