Preoperative Epoxy Embolization Facilitates the Safe and Effective Resection of Venous Malformations in the Hand and Forearm

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Abstract

Background: The standard of care for treatment of low-flow venous malformations (VMs) is percutaneous sclerotherapy. These lesions are seldom surgically resected, especially if the malformation is in an anatomically difficult location. Percutaneous sclerotherapy is safe and effective. However, the drawbacks to sclerotherapy are the need for repeated treatments and risks of skin ulceration, deep venous thrombosis, scarring/contractures, and nerve damage. Surgical resection can be difficult because of intraoperative bleeding, intraoperative lesional decompression, and difficulty in localization. **Methods:** We describe our initial experience with 11 patients who underwent surgical resection of VMs located in the hand and forearm after preembolization of 27 total sites using n-butyl-cyanoacrylate or ethylene vinyl alcohol copolymer. **Results:** Of the 11 patients treated, 5 had focal VMs, 3 had multifocal VMs, and 3 had diffuse VMs throughout the affected extremity. Four of the 5 patients with focal VMs were followed for at least 1 year, and no further treatment was required. All 3 of the patients with diffuse VMs have required ongoing treatment. No major functional impairments were reported, and there were no major procedure-related complications. **Conclusions:** Overall, embolization of the malformation before surgical resection facilitated localization, demarcation, and removal of the lesion.

Keywords: epoxy, embolization, surgical resection, vascular anomaly, venous malformations

Introduction

Venous malformations (VMs) are vascular anomalies characterized by low flow and gravity dependence on clinical examination.⁹ They can affect any part of the body and account for approximately one-half to two-thirds of all vascular anomalies.⁵ They have an estimated prevalence of approximately 1% in the general population.⁴ Elastic compression is a first-line nonoperative treatment for VMs when located in the extremities.¹⁰ If nonoperative measures fail to control symptoms, treatment options include percutaneous sclerotherapy, surgical excision, laser photocoagulation, photodynamic therapy, or a combination thereof.^{1,2}

Sclerotherapy is the preferred treatment in most vascular anomaly centers and is ideally suited for localized malformations.² Diffuse malformations are harder to manage and are treated with the goal of improving the most symptomatic areas rather than complete obliteration of the lesion. Common sclerosant agents include sodium tetradecyl sulfate, ethanol, and bleomycin.^{1,12} Although generally safe and effective, there are limitations to sclerotherapy. For larger VMs, repeated injections are often needed for symptomatic control.¹³ Meticulous technique is required to spare normal

soft tissues, including muscles, tendons, and nerves. Despite this, complications occur in up to 12% of cases and include swelling, neurologic deficits (transient or permanent), skin blistering, necrosis, hemoglobinuria, fibrosis/contractures, and renal impairment.⁸ Of all the agents, ethanol is the most commonly used because of its low cost, but it is associated with the highest rate of serious complications.^{2,10} More recently, bleomycin has gained popularity for the treatment of VMs because it is thought to result in less postprocedure inflammation. There are minimal long-term data regarding efficacy of bleomycin, and there are lifetime dose limits.¹²

In anatomically sensitive areas such as the deep forearm, surgical resection has the potential to offer definitive

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treatment while mitigating the risks of nerve and tendon damage. However, localization and complete resection can be challenging because of lesion decompression after preoperative exsanguination of the extremity and intraoperative bleeding.⁷ For these reasons, surgical excision is indicated for only very localized, symptomatic lesions.¹⁰ Staged resections can be performed for malformations that involve difficult anatomic areas of the hand and upper extremity.¹³ Surgical resection of VMs can also produce poor cosmetic results and high rates of recurrence.⁸ Secondary procedures are often required for release of contracture, scar revision, tissue expansion, and local flap transfer. Treatments in the forearm and hand usually require more physical therapy and rehabilitation than other locations.¹³

Surgical resection and sclerotherapy are thus limited in their ability to fully obliterate VMs in complex anatomical locations such as the forearm or hand. Because of the risk of injury to nerves and tendons, these interventions must be approached with caution and are often centered on relieving focal symptoms rather than complete removal of the VM.

The purpose of this study is to report on a combined treatment approach for VMs that may provide a safer and more effective option than sclerotherapy or surgical resection alone.

Materials and Methods

This retrospective study was approved by the local institutional review board.

Patients

We reviewed medical records of patients with hand or forearm VMs who had undergone percutaneous embolization followed by surgical resection by 1 board-certified orthopedic hand surgeon. Eleven patients (6 female) underwent resections of VMs located in the hand or forearm after preoperative embolization at 27 total sites. The mean patient age was 17 years (range, 2-47 years).

Preoperative Embolization Technique

The patients in this study were percutaneously preembolized with ethylene vinyl alcohol (EVOH) copolymer (Onyx LES, ev3 Endovascular, Plymouth, Minnesota) or n-butylcyanoacrylate (n-BCA; TRUFILL n-BCA Liquid Embolic System, Codman Neuro, Raynham, Massachusetts) to facilitate en bloc surgical resection. Preoperative embolization was completed by an experienced interventional radiologist using n-BCA, EVOH copolymer 18 (6% EVOH), or EVOH copolymer 34 (8% EVOH). Lesions were analyzed for size, volume, involvement of surrounding tissues, and depth on preprocedural magnetic resonance images (MRIs) by 1 experienced musculoskeletal radiologist and 2 experienced interventional radiologists. Before the procedure, target

locations were identified and circled with a skin marker to define the margins of the symptomatic areas. Patients underwent general anesthesia and intraoperative nerve monitoring depending on the location of the lesion.

The VM was percutaneously accessed with a 21-gauge needle at multiple sites, depending on size and extent of the lesion, using ultrasound guidance. After needle placement, contrast was injected to evaluate flow dynamics and venous drainage and to estimate the amount of embolic agent required. The lesions were evaluated for the presence and size of draining veins and whether there were any areas of communication between different portions of malformation. Additional access points were obtained as needed if a portion of a VM was found to be noncommunicating with the rest of the lesion. The n-BCA or EVOH copolymer 18/34 embolic agent was prepared for injection into each site under fluoroscopic guidance. The decision to use n-BCA or EVOH copolymer was at the discretion of the interventional radiologist performing the procedure.

Careful attention was paid to the presence of draining veins to minimize distal, nontarget embolization. Embolization was stopped if increased resistance or pressure was noted or when the targeted portion of VM was fully embolized as indicated by fluoroscopy (Figure 1a). Access sites were then reassessed for any residual lesion using ultrasonography. The number of treatment sites and extent of embolization were determined clinically at the time of therapy. After completion of the procedure, all needles were removed, hemostasis was achieved, and the patient was transferred to the recovery room.

Surgical Technique

Surgical resection was typically performed within 1 to 7 days after the embolization (mean, 3.6 days; range, 0-14 days). Patients were placed under general anesthesia, and in all cases, the arm was elevated and exsanguination was performed from the wrist toward the upper arm, followed by inflation of a tourniquet around the upper arm. To help identify the previously embolized VM, we used a C-arm fluoroscopic unit to localize the lesion before the incision (Figure 1b). After initial incision, fascial layers were divided, and muscles and tendons, if not involved with the malformation, were retracted and protected. Care was taken to identify the nerves and evaluate if there was any involvement of the nerve within the VM. Lesions that had been injected with n-BCA or EVOH copolymer appeared dark and firm and were generally easily identifiable (Figure 1c). The lesions were then carefully excised en bloc (Figure 1d). If large feeding arteries were encountered, they were clamped, the tourniquet was deflated, and the distal arterial supply to the hand was evaluated to ensure adequate flow before resection. Fluoroscopy was used during and after the operation to evaluate completeness of the surgical resection

Figure 1. A 20-year-old man with a venous malformation of the left wrist. (a) Fluoroscopic image at the completion of the percutaneous embolization with ethylene vinyl alcohol (EVOH) copolymer (Onyx LES; ev3 Endovascular, Plymouth, Minnesota). Two sites were injected with EVOH copolymer 18 (second needle not shown). (b) Intraoperative fluoroscopic view of the venous malformation just before resection. (c) Intraoperative view of the venous malformation showing visible channels of EVOH copolymer. (d) Pathologic gross specimen of the en bloc venous malformation. (e) Postresection intraoperative fluoroscopic image after en bloc removal of the venous malformation. Lateral (f) and anteroposterior (g) views of the left forearm 1 week after resection of the venous malformation.

(Figure 1e). All surgical specimens were sent for pathologic evaluation. The tourniquet was then slowly deflated to decrease systemic dissemination of any potential inflammatory components from the previous embolization procedure. The surgical wounds were closed, and a drain was left in place when possible. Postoperative conventional radiographs were also taken to monitor the extent of the surgical resection (Figures 1f and 1g). Patients were discharged home and returned 1 week after surgery to have dressings/drains removed and lesions evaluated. At that time, if needed, patients were referred to occupational hand therapy

for fitting of custom splints and directed physiotherapy. A combined procedure performed on a VM located in the forearm is depicted in Figure 2.

Follow-Up

Two interventional radiologists and 1 musculoskeletal radiologist independently reviewed all MRIs of the VMs, assessing for size, volume, and involvement of surrounding tissues. Assessments of embolization and surgical techniques were made by reviewing clinical notes and through

Figure 2. A 16-year-old boy with a venous malformation of the right forearm. (a) Preoperative magnetic resonance image, axial T2 with fat saturation images showing the multicompartmental venous malformation of the right forearm with involvement of the flexor tendons. (b) Preembolization ultrasound image of the venous malformation showing the abnormal venous sacs targeted during the embolization procedure. (c) Single fluoroscopic image of the venous malformation at the completion of the embolization procedure. Three sites were injected with ethylene vinyl alcohol (EVOH) copolymer 18 (Onyx LES; ev3 Endovascular, Plymouth, Minnesota; all 3 needles remain in place). Intraoperative views of the venous malformation after embolization showing the venous channels filled with EVOH copolymer in situ (d) and after en bloc removal of the venous malformation (e).

direct communication with the operating interventional radiologist and surgeon. Outcomes were evaluated on the basis of operative notes and follow-up clinic visits. Follow-up included a short-interval clinic visit and then a follow-up visit within 6 to 8 weeks. Long-term follow-up is ongoing for evaluation of lesion recurrence. Follow-up imaging with ultrasonography and/or MRI was obtained as needed to evaluate for recurrence and other complications.

Results

We studied 27 malformations: 10 located in the hand, 8 in the forearm, 6 at the elbow, and 3 in the wrist. The lesions were evaluated for size and involvement of surrounding

soft tissues on the preprocedural MRI. Because of motion artifact or suboptimal MRI acquisition, 6 lesions could not be assessed for size, and 3 lesions could not be assessed for soft-tissue involvement. The mean lesion volume was 9.4 mL (range, 0.95-43.5 mL). There was nerve involvement in 75% of the lesions (18 of 24), and tendon involvement in 25% (6 of 24). Twenty-five percent (6 of 24) of the lesions were subcutaneous, 29% (7 of 24) were subcutaneous and intramuscular, 29% (7 of 24) were intramuscular, and 17% (4 of 24) were intramuscular and periosseous. EVOH copolymer was used to treat 19 of the 27 malformations (mean volume, 3.9 mL; range, 0.5-14.9 mL), and n-BCA was used to treat the remaining 8 lesions (mean volume, 2.4 mL; range, 0.6-5.5 mL).

Table 1. Follow-Up Information for the 11 Patients Treated With the Combined Approach.

Patient	Age, y	Sex	VM characteristics ^a	No. of sites embolized/excised	Clinical follow-up		MRI follow-up	
					Time	Results	Time, y	Results
1	2-6 ^b	F	Diffuse VM of the left UE	8	5 y	Recurrence of pain at all treated sites. VM treatment is ongoing with numerous repeat treatments throughout the left UE.	5	Recurrence of VM at all treatment sites. Persistent, diffuse VM noted throughout the left UE.
2	20	F	Focal VM of the right hypothenar	1	5 y	Persistent, mild paresthesias and pain, but symptoms are substantially improved from before the combined procedure. No further treatment.	5	Small remnant VM in the region of treatment, decreased in size and enhancement from before excision.
3	2	M	Focal VM of the left antecubital fossa	1	5 y	No recurrence of symptoms. Now with increased ROM at the elbow.	5	Near-complete resolution of treated VM.
4	7	F	Focal VM of the right midforearm	1	1 y	Decreased pain at the treatment site. No further treatment.	1	Near-complete resolution of treated VM.
5	20	F	Multifocal VM of the right hand	3	2 y	Recurrent pain at site of VM in index finger. Asymptomatic at remaining treatment sites. No further treatment.	2	Recurrence of the VM at all 3 treatment sites.
6	29	F	Focal VM of the right thenar eminence	1	1 wk	Good initial postoperative healing. Lost to follow-up after this visit.		No repeat MRI.
7	47	M	Multifocal VM of the right hand	3		Lost to follow-up.		No repeat MRI.
8	20	M	Focal VM of the right forearm	1	3 y	Resolution of pain at the treatment site with normal strength and ROM. No further treatment.	3	Small remnant, decreased in size and enhancement from before excision.
9	37	F	Multifocal VM of the right hand and upper arm	2	1 wk	Good initial postoperative healing. Lost to follow-up after this visit.		No repeat MRI.
10	29	M	Diffuse VM of the left UE	3	5 y	Recurrence of pain at all treated sites. VM treatment ongoing with numerous repeat treatments throughout the left UE.	5	Recurrence of VM at all treatment sites. Persistent, diffuse VM noted throughout the left UE.
11	16	M	Diffuse VM of the right UE	3	2 y	Decreased pain at sites of excision, especially more focal lesion at the elbow. Patient still has pain in other areas of the VM. Treatment is ongoing.	2	Focal lesion at the elbow has nearly completely resolved. The more distal treatment site shows recurrence of the VM. Persistent, diffuse VM noted throughout the right UE.

Note. VM = venous malformation; MRI = magnetic resonance imaging; F = female; UE = upper extremity; M = male; ROM = range of motion.

^aVMs were classified as follows: focal, if there were 2 or less discrete VMs in close proximity; multifocal, if there were 2 or more discrete VMs located in different parts of the extremity; or diffuse, if there was VM involvement throughout the extremity.

^bPatient was treated multiple times during a 4-year period.

Long-term follow-up of these cases is ongoing. Detailed follow-up information for the 11 patients is provided in Table 1. The VMs were classified as focal if there was 1 discrete VM within the extremity, multifocal if there were 2 or more discrete VMs located in different parts of the extremity, or diffuse if there was VM involvement throughout the extremity. In total, there were 5 focal VMs, 3 multifocal VMs, and 3 diffuse VMs. Of the 5 patients with focal VMs, 4 showed near-complete resolution of the treated

lesions on follow-up; 1 patient was lost to follow-up. Three patients with focal VMs have more than 3 years of follow-up, and one has 1 year of follow-up. Of the 3 patients with multifocal VMs, 2 were lost to follow-up. The other has 2 years of follow-up with recurrence of the lesions at all 3 treatment sites; however, no repeat treatments have been performed. All 3 patients with diffuse VMs have required continued treatment. In these patients, 14 lesions were treated, and all but 1 of these sites have required repeat

intervention. The 1 site that did not require repeat intervention was a focal lesion near the elbow, isolated from the other areas of diffuse VM.

No major functional impairments were reported in any patient. There were no major procedure-related complications from the embolization procedure or the surgical resection in any patient. Blood loss was minimal in all cases, and no patient required a blood transfusion. All patients were monitored overnight in the hospital after both procedures and were discharged home the next day.

Discussion

This study represents our initial clinical experience using the combined approach of percutaneous embolization and subsequent surgical resection to treat VMs of the forearm and hand. The advantage of preembolizing a VM before resection is the transformation of an otherwise friable lesion with indistinct boundaries into one that readily collapses into a firm mass more easily dissected and surgically removed en bloc. When resection of a VM is done without embolization, there is collapse and spillage of blood, often making it difficult to delineate the boundaries of the lesion. Leakage further makes it difficult to determine whether the VM has been completely resected. The preembolization of VMs with EVOH copolymer or n-BCA before removal or debulking thus greatly facilitated surgical resection.

Definitive treatment measures for VMs have been elusive. Currently, the “gold standard” is percutaneous sclerotherapy. However, patients, especially those with diffuse or large VMs, often need repeated sclerotherapy, which increases the risk of a complication. In addition, percutaneous sclerotherapy is limited near complex structures close to tendons and nerves of the forearm. Percutaneous sclerotherapy is thus often targeted to only the most accessible, symptomatic areas of the VM. By using the combined approach of preembolization with n-BCA or EVOH copolymer followed by surgical resection, we hoped to provide patients with a more definitive treatment option.

In the cases presented here, embolization provided a clearly demarcated target for lesion resection. Intraoperatively, it was found that in all cases, preresection embolization allowed for clear visualization of the target lesions and facilitated resection because key structures such as nerves and tendons were easily identified. This technique has been useful in other regions of the body with lesions in close proximity to complex structures such as in the head and neck. In 2008, Cil et al³ described the treatment of VMs in the craniofacial region in 13 patients. In 2011, Garcia et al⁶ described the treatment of low-flow venous lesions of the orbit in 3 patients. In addition, our results are in line with the currently published research. The largest published series to date are the reports by Upton et al¹³ and Sofocleous

et al.¹¹ Upton et al¹³ reported on 125 VMs of the upper extremity, most of which were treated surgically. Unfortunately, no outcome data were reported, but they did report a complication rate of 22%. Sofocleous et al¹¹ reported treating 17 patients with VMs of the upper extremity. Of these 17 patients, embolization was attempted in 13 patients, with 12 reporting initial symptomatic improvement. The mean symptom-free interval was 30.5 months.

The combined technique reported here had more durable results in patients with focal VMs than in those with multifocal VMs or diffuse VM involvement of the entire extremity. Our initial experience did not include enough patients to make definitive conclusions in this regard, but 4 of 5 patients with focal VMs showed at least near-complete resolution of the treated lesion. The other patient was lost to follow-up, so it is unclear if the treated VM resolved. In all 3 patients with diffuse VMs, symptoms failed to improve and treatment remains ongoing. Interestingly, in one of the patients with a diffuse VM, an isolated VM was treated near the elbow, and this lesion has not recurred and the focal area of pain at the elbow has resolved. This fits with our overall impression that, at this time, this combined treatment technique is best reserved for more focal lesions.

This study is limited by the fact that it is retrospective, that it lacks a “control” arm of sclerotherapy or surgery alone, and that it has a small sample size with limited follow-up. Although we are optimistic that our combined approach will provide patients with another safe and effective treatment option, this technique has limitations. Access to physicians who are willing to perform these complex procedures is limited, and coordination of multiple procedures can be challenging if the proper infrastructure is not in place. Another drawback of preembolization is the high cost of agents like EVOH copolymer and TRUFILL n-BCA. Our results show that using our combined technique had poor results in patients with multifocal or diffuse VM involvement of the extremity. Further investigation of this combined technique is warranted to better identify the ideal patient and to compare long-term outcomes with those of sclerotherapy or surgical resection alone.

Conclusion

A combined approach of preoperative embolization followed by surgical resection appears to be a safe and effective treatment for focal VMs of the hand and forearm but may not be adequate for patients with multifocal VMs or diffuse VM involvement of the extremity. Further study is warranted to determine if this combined approach offers a more effective and durable alternative to the use of sclerotherapy or surgical resection alone.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

No patient-identifying information was included in this article.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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