Predictive Factors for Response of Peripheral Arteriovenous Malformations to Embolization Therapy: Analysis of Clinical Data and Imaging Findings

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ABSTRACT

Purpose: To find a significant predictive factor for the efficacy of endovascular treatment of peripheral arteriovenous malformations (AVMs).

Materials and Methods: One hundred seventy-six patients (73 male patients and 103 female patients; mean age, 29.4 \( \pm \) years) who underwent treatment for AVMs in the body or extremities were included. Per Schobinger classification, lesions in 31 patients (18%) were stage II, those in 136 (77%) were stage III, and those in nine (5%) were stage IV. AVMs were located in the extremities in 130 patients (74%) and in the trunk in 46 patients (26%). AVMs were angiographically classified as type I (n = 1), type II (n = 36), type IIIa (n = 6), type IIIb (n = 91), or complex type (n = 42). Demographic factors, clinical data, and imaging data were analyzed to determine a statistically significant relationship with overall clinical outcomes.

Results: Overall, 68 patients (39%) were cured, 91 patients (52%) showed a partial response, nine patients (5%) showed no response, treatment failed in seven patients (4%), and treatment aggravated the condition in one patient (1%). The overall complication rate was 45% (79 of 176 patients). Minor complications developed in 62 patients (35%) and major complications developed in 17 (10%). Statistically, the extent of AVMs (odds ratio, 0.199) and angiographic classification (odds ratio, 0.162) were significant predictive factors for overall clinical outcome.

Conclusions: Endovascular treatment of peripheral AVMs, planned with consideration of anatomic extent and angiographic subtypes, is likely to yield good clinical results with low complication rates.

ABBREVIATION

AVM = arteriovenous malformation

Arteriovenous malformations (AVMs) are a subtype of fast-flow vascular malformations of congenital vascular anomaly, as recently classified by the International Society for the Study of Vascular Anomalies (1). The clinical features of AVMs are complex and unpredictable, but they generally behave aggressively, progressing to become more destructive (2,3). Surgical treatment alone is largely unsuccessful (4–6). Therefore, a multidisciplinary approach of surgical and endovascular management is currently used to improve treatment outcomes (3). The results of endovascular treatment for AVMs have been reported in several studies, but these results were limited to small series (7), confined to AVMs in specific anatomic regions (8), or limited to reporting of treatment results (9,10). Therefore, the predictive
factors for AVMs treatment are seldom reported. Despite many patients undergoing endovascular treatment for AVMs, we lack sufficient data on the predictive factors related to the results of treating trunk and extremity AVMs. Therefore, the purpose of the present study was undertaken to find a significant predictive factor for endovascular treatment of peripheral AVMs.

**MATERIALS AND METHODS**

**Patients and Diagnosis**

The institutional research review board approved the review of medical and imaging records for this retrospective clinical study, and waived informed consent. Written consent was obtained from all patients before any procedures. From November 1996 to October 2010, 184 consecutive patients who had AVMs in the extremities or trunk, excluding those in the head and neck, were scheduled for embolization. Indications for treatment of AVMs were the presence of subjective clinical symptoms that make daily life uncomfortable (eg, subjective pain, disfiguring mass), patients with complicating signs of AVMs (eg, ulcer, skin necrosis, secondary infection, hemorrhage, secondary varicosities, and/or limited joint movement), patients with progressively enlarging AVMs over time, and patients with or expecting to have cardio-pulmonary complications (eg, dyspnea, cardiomegaly, or overt heart failure).

Eight patients were excluded because of severe infection (n = 6) or a nonfunctioning affected limb (n = 2). Medical records and imaging data from the remaining 176 patients who underwent embolization of AVMs in the extremities or trunk were retrospectively reviewed. Initial presentations were classified according to Schobinger stage (11): 31 patients (18%) had stage II lesions, 136 (77%) had stage III lesions, and nine (5%) had stage IV lesions.

The study included 73 male patients and 103 female patients who ranged in age from 1 to 70 years (mean, 29.4 y). A total of 123 patients (70%) had no previous treatment for AVMs, and 53 patients (30%) had undergone previous treatment at outside hospitals, which included embolization (n = 15), surgery (n = 26), embolization and surgery (n = 11), and laser treatment (n = 1).

All diagnoses were made by spiral computed tomography (CT; HiSpeed; GE Medical Systems, Milwaukee, Wisconsin), multidetector CT (LightSpeed [GE Medical Systems], Brilliance 40 [Philips, Best, The Netherlands], or Aquilion 64 [Toshiba, Tokyo, Japan]), MR imaging (1.5-T unit; Signa; GE Medical Systems), or some combination thereof. All initial diagnoses based on image data were confirmed by angiography findings obtained during the endovascular treatment.

AVMs were classified based on the anatomic extent of involvement and the angiographic features of the vascular anatomy. Angiographic features of AVMs were classified according to a published classification system (12). The angiographic classifications and numbers of patients within each classification are listed in Table 1.

Lesion locations were stratified into two major categories. Category I (n = 86; 49%) included extremity AVMs without hand or foot involvement and trunk AVMs without involvement of major internal organs. Category II (n = 90; 51%) included extremity AVMs involving the hand or foot and trunk AVMs involving major internal organs.

The overall extent of AVMs was classified as localized (n = 120; 68%) or diffuse (n = 56; 32%; Table 2). A total of 68 patients (39%) had upper-extremity AVMs, of whom 56 (82%) had hand involvement of AVMs. A total of 62 patients (35%) had lower-extremity AVMs, of whom 24 (39%) had foot involvement of AVMs. Forty-six patients...
(26%) had trunk AVMs, of whom 36 (78%) had AVMs above the diaphragm. Forty-three patients (24%) had skin involvement and 24 patients (14%) had bone involvement.

In 75 patients (43%), early draining veins involved only the superficial veins of the limb or trunk. Forty-one patients (23%) had an early draining vein involving the large internal veins (e.g., internal iliac vein) or the deep veins in the affected extremity. Four patients (2%) had direct venous drainage into the central veins, including the vena cava. In 56 patients (32%), the early draining veins involved the deep and superficial veins of the extremities.

Patients were divided into two groups based on the number of feeding arteries: those with three or fewer and those with more than three. A total of 165 patients (94%) had more than three feeding arteries, and 11 patients (6%) had three or fewer feeding arteries. One hundred sixty-seven patients (95%) had pure AVMs and nine patients (5%) had mixed AVMs with low-flow components.

Procedures

The overall treatment plan was determined by a collaborative discussion among multidisciplinary departments from the vascular malformation clinic, including vascular surgery, radiology (intervention and imaging), cardiovascular medicine, pediatric surgery, anesthesiology, plastic surgery, orthopedic surgery, dermatology, nuclear medicine, and rehabilitation medicine. In all patients, AVMs were embolized in an angiography suite under general anesthesia with meticulous monitoring of blood pressure and respiration by an anesthesiologist. A corticosteroid agent (0.1 mg/kg dexamethasone; Yuhan, Seoul, Korea) was administered immediately before the procedure to control tissue swelling. Except in patients younger than 8 years of age and those with a body weight less than 30 kg, a 7-F Swan-Ganz catheter (Baxter, Irvine, California) was placed to monitor pulmonary artery pressure during all initial embolization procedures. Nitroglycerine was administered by continuous intravenous injection at a rate of 0.2–3 μg/min/kg. A bolus injection of nitroglycerin (50–100 μg) was administered if the mean pulmonary artery pressure was greater than 25 mm Hg.

Based on the initial arteriogram, two interventional radiologists (K.B.P. and Y.S.D.) determined in consensus the most efficient access route to the AVM (e.g., intraarterial embolization, direct puncture, or transvenous embolization) and the appropriate embolization materials. In patients who underwent intraarterial embolization, a feeding artery was embolized with ethanol under superselection with a 4-F angiographic catheter or microcatheters (Microferret [Cook, Bloomington Indiana] or Progreat [Terumo, Tokyo, Japan]). In most cases, absolute ethanol (99% ethanol) was used at a rate dependent on the flow velocity, feeding territory volume, and anatomic position of the feeding artery relative to adjacent structures. However, AVMs close to skin area or microfistulous shunts in the hands

![Figure 1](image-url). Cured left buttock AVM (type IIIb) in a 31-year-old woman treated with embolization with intraarterial and direct puncture. (a) Initial CT angiography with maximum-intensity projection shows a large left buttock AVM. (b) Initial angiography at the first sclerotherapy revealed an extensive left buttock AVM with hypertrophied early draining veins. (c) Direct puncture of a feeding artery shows typical hypertrophy of a feeding artery and a draining vein, which were compatible with a type IIIb AVM. Note the casted glue in the draining vein (black arrow) and the 21-gauge needle tip in the feeding artery (white arrow). Pure ethanol was injected directly through the needle. (d) Intraarterial injection at the distal end of the feeding artery shows a fistulous communication between a hypertrophied artery (white arrow) and vein (black arrow). Transcatheter ethanol embolization was performed at the feeding artery. (e) All AVMs were devascularized on the last completion angiography, after seven sessions of sclerotherapy. (f) AVM was cured on follow-up CT angiography performed 1 year after the end of treatment.
or feet were treated with 50%–80% diluted ethanol containing contrast media (Xenetix 300; Guerbet, Roissy, France). The total ethanol dose in a single session was restricted to 1 mL/kg (13), and the total amount of ethanol used ranged from 3 to 70 mL (mean, 26.9 mL). A single-injection dose of ethanol during sclerotherapy was restricted to 10% of the maximum dose (14). When the maximum single dose of ethanol was injected, we waited 5–10 minutes before performing subsequent ethanol injections.

The embolization materials used in the treatment of AVMs were ethanol alone in 116 patients (66%), ethanol with glue (Histoacryl; B. Braun, Tuttlingen, Germany) in five patients (3%), ethanol with coils (stainless-steel embolization coils, Nester coils, or MicroNester coils [Cook], or Interlock Fibered IDC occlusion system [Boston Scientific, Natick, Massachusetts]) in 39 patients (22%), and ethanol with coils and glue in three patients (2%). Coil-only and glue-only embolizations were performed in one patient each. Combined use of ethanol and other embolic materials was performed during the same treatment session. Eleven patients (6%) underwent embolization for AVMs followed by radical resection of the embolized AVM nidus.

One hundred thirty-two patients (75%) underwent one to three embolization sessions, 22 patients (12%) underwent four to six sessions, eight patients (5%) underwent seven to nine sessions, and 14 patients (8%) underwent 10 or more treatment sessions.

The access for treatment was intraarterial in 34 patients (19%), direct puncture in 40 patients (23%), combined intraarterial and direct puncture in 83 patients (47%), and transvenous approach with intraarterial and/or direct puncture in 19 patients (11%).

Direct puncture was performed with 18–21-gauge needles (disposable modified needle; Cook). The needle puncture target was determined on a magnified selective arteriogram, and ethanol was injected at the same concentration and dose as described earlier. Patients with

Figure 2. Cured type II right retroperitoneal AVM in a 16-year-old male patient who presented describing right foot drop. Cure was achieved through transvenous and direct puncture embolization. (a) On initial angiography, there was a large AVM nidus in the right pelvic cavity, and the early opacification of IVC was noted. (b) A right internal iliac arteriogram shows numerous feeding arteries gathering into a single draining vein in the right internal iliac artery. Note the whirling tip of a 4-F catheter placed deep into the right internal iliac vein (black arrow) through a left iliac vein approach. (c) Transvenous coil embolization was performed on the right internal iliac vein through the 4-F catheter. (d) Control angiography of the second session sclerotherapy showed the remaining AVM with IVC opacification despite coil packing of the right internal iliac vein. (e) A direct puncture angiogram of a coil mass with a 22-gauge Chiba needle (white arrow) revealed residual venous space in the coil interstices (black filled arrow) of a dominant early draining vein and regurgitation of contrast media into the right internal iliac vein branches (black open arrow). We performed additional sclerotherapy with pure ethanol through the needle. (f) Control angiography at the third sclerotherapy session showed a cured AVM.
extensive AVMs were treated with intraarterial and direct puncture methods (Fig 1). AVMs with a single dominant early draining vein or an extremely high-flow arteriovenous shunt that required coil embolization were treated by using a transvenous approach or direct puncture. Retrograde venous access was attempted through the femoral or jugular veins (Fig 2). Sometimes, direct venous access into the dominant draining vein was used to advance the catheter tip to the nearest point of the arteriovenous fistula. In some patients, an occlusion balloon was used to prevent coil migration or to reduce the shunt flow velocity. Even if residual AVMs were visible on the final arteriogram, the procedure was stopped when the ethanol dose approached the maximum dose within a session. For residual AVMs, embolization was repeated until maximum ablation of the AVMs was achieved.

Through multistaged sclerotherapy, the treatment schedule was terminated based on follow-up examination in the outpatient clinic. Signs to end the endovascular treatment plan included angiographic cure with symptom improvement, inaccessible residual AVMs with symptom improvement, minimal residual AVMs with successful control of complications (eg, hemorrhage), no additional therapeutic gain expected in view of procedure-related complications, and aggravated or rapidly regrowing AVMs despite treatment.

**Data Analysis**

Overall AVM data were collected and stratified into background clinical data, image analysis data, treatment and techniques, and therapeutic response. Two interventional radiologists (K.B.P. and Y.S.D.) analyzed the image findings and therapeutic response of embolization by consensus. Image data were analyzed to determine the extent of AVMs, the skin involvement, the bone involvement, the number of feeding arteries, the pattern of early draining vein, the angiographic classification (12) (Fig 3), and the AVM features to determine whether they were pure AVMs or combined with other low-flow malformations. The factors related to treatment were the number of treatment sessions, access routes, embolization materials, and pulmonary artery pressure during ethanol embolization. The therapeutic results evaluated were the overall clinical response, complications, and sequelae.

The overall clinical responses were separated into five categories based on the final angiographic findings, symptomatic improvements, and posttreatment sequelae. Cure was defined as complete disappearance or devascularization of more than 90% of AVMs on the last angiography, with a complete loss of initial symptoms and no significant sequelae or discomfort after the treatment. Partial response was defined as disappearance of 50%–89% of the AVMs on the last angiography, with partially improved symptoms and no sequelae or discomfort in everyday living. No response was defined as disappearance of less than 50% of the AVMs on the last angiography, with persistent clinical symptoms. Treatment failure was noted in any of the following three settings: (i) lesion inaccessible by direct puncture or intravascular routes, (ii) terminated treatment schedule as a result of an expected complication that was too serious to be offset by clinical gains, or (iii) no further therapeutic effect despite treatment. Aggravation was defined by (i) sclerotherapy resulting in permanent complications that made further treatment impossible or (ii) symptoms that were aggravated after sclerotherapy. Complications were classified according to Society of Interventional Radiology criteria (15) as minor or major.

**Statistical Analysis**

Statistical analysis was performed with SAS software (version 9.1.3; SAS, Cary, North Carolina). Univariate analysis was performed by using the $\chi^2$ and Fisher exact tests. Multivariate analysis was performed with logistic regression by using the cumulative logit model. Post-hoc analyses of interactions between factors and overall clinical responses were performed with logistic regression using Bonferroni correction to verify whether the “markedly improved” cases were significantly different from the “no-change” cases and whether the no-change cases had a
specific poor prognostic factor compared with the markedly improved or “improved” cases.

RESULTS

The angiographic classifications and number of patients within each classification are listed in Table 1. The overall clinical response was a cure in 68 patients (39%), a partial response in 91 patients (52%), no response in nine patients (5%), treatment failure in seven patients (4%), and aggravation in one patient (1%). The treatment failures (n = 7) included four patients who underwent amputation as a result of persistent AVMs and symptoms despite uncomplicated sclerotherapy. In one patient, further ethanol sclerotherapy failed as a result of persistent pulmonary arterial hypertension during the initial ethanol sclerotherapy, and one patient showed continuous progression of joint destruction and contracture despite sclerotherapy. Sclerotherapy failed in one patient as a result of high risk of skin necrosis from diffuse microfistulous arteriovenular shunting involving subcutaneous and skin areas. Follow-up periods ranged from 1 to 120 months (mean, 30.3 mo).

Univariate analysis showed that AVM location, AVM extent, angiographic classification, and complications had P values lower than .05 (Table 3). By multivariate statistical analysis, AVM extent (P = .002) and angiographic classification (P = .001) were statistically significant factors that influenced the overall clinical outcome (Table 4). When the extent of AVMs was diffuse, the probability of a good overall clinical response (ie, cure) decreased (odds ratio, 0.224).

Post-hoc analysis with logistic regression using Bonferroni correction showed that AVM extent and angiographic classification had a significant positive influence on the markedly improved cases. The receiver operating characteristic curve in this model had good predictive power, with an area under the curve of 0.819, indicating that localized AVMs (odds ratio, 0.199) and type I and II AVMs (odds ratio, 0.162) have a high probability for an overall response of marked improvement. AVM extent also had a significant influence on the no-change group. When other variables were constant, the probability that AVMs with a diffuse extent led to an overall clinical response of no change was significantly increased (odds ratio, 3.279). This model showed moderate predictive power on receiver operating characteristic curve analysis, with an area under the curve of 0.785.

Table 3. Results of Univariate Analysis for All Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>χ² Test</th>
<th>Fisher Exact Test</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.504</td>
<td>0.492</td>
<td></td>
</tr>
<tr>
<td>Previous treatment</td>
<td>0.209</td>
<td>0.199</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>0.004</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Extent</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Skin involvement</td>
<td>0.003</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Bone involvement</td>
<td>0.067</td>
<td>0.087</td>
<td></td>
</tr>
<tr>
<td>Draining vein</td>
<td>0.892</td>
<td>0.919</td>
<td></td>
</tr>
<tr>
<td>No. of feeding arteries</td>
<td>0.076</td>
<td>0.083</td>
<td></td>
</tr>
<tr>
<td>Type of classification</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Treatment methods</td>
<td>0.122</td>
<td>0.127</td>
<td></td>
</tr>
<tr>
<td>AVM features</td>
<td>0.504</td>
<td>0.585</td>
<td></td>
</tr>
<tr>
<td>No. of treatment sessions</td>
<td>0.240</td>
<td>0.177</td>
<td></td>
</tr>
<tr>
<td>Treatment access</td>
<td>0.763</td>
<td>0.741</td>
<td></td>
</tr>
<tr>
<td>Clinical presentation</td>
<td>0.147</td>
<td>0.153</td>
<td></td>
</tr>
<tr>
<td>PAP increase during procedure</td>
<td>0.512</td>
<td>0.720</td>
<td></td>
</tr>
<tr>
<td>Complications</td>
<td>0.001</td>
<td>0.008</td>
<td></td>
</tr>
</tbody>
</table>

AVM = arteriovenous malformation, PAP = pulmonary artery pressure.

Table 4. Multivariate Analysis of Factors for Effects and Maximum Likelihood Estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>SE</th>
<th>P Value</th>
<th>OR</th>
<th>95% Wald CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.332</td>
<td>.342</td>
<td>1.371</td>
<td>0.715–2.627</td>
</tr>
<tr>
<td>Previous treatment</td>
<td>0.374</td>
<td>.607</td>
<td>0.825</td>
<td>0.396–1.718</td>
</tr>
<tr>
<td>Location</td>
<td>0.349</td>
<td>.216</td>
<td>0.640</td>
<td>0.327–1.287</td>
</tr>
<tr>
<td>Extent</td>
<td>0.383</td>
<td>.002</td>
<td>0.301</td>
<td>0.142–0.638</td>
</tr>
<tr>
<td>Skin involvement</td>
<td>0.412</td>
<td>.104</td>
<td>1.954</td>
<td>0.871–4.384</td>
</tr>
<tr>
<td>Bone involvement</td>
<td>0.515</td>
<td>.942</td>
<td>0.902</td>
<td>0.329–2.477</td>
</tr>
<tr>
<td>Draining vein</td>
<td>0.360</td>
<td>.533</td>
<td>0.789</td>
<td>0.395–1.617</td>
</tr>
<tr>
<td>No. of feeding arteries</td>
<td>0.810</td>
<td>.246</td>
<td>0.391</td>
<td>0.080–1.912</td>
</tr>
<tr>
<td>Type of classification</td>
<td>0.559</td>
<td>.001</td>
<td>0.146</td>
<td>0.049–0.437</td>
</tr>
<tr>
<td>Treatment methods</td>
<td>0.408</td>
<td>.569</td>
<td>1.261</td>
<td>0.567–2.805</td>
</tr>
<tr>
<td>AVM features</td>
<td>0.805</td>
<td>.878</td>
<td>1.132</td>
<td>0.234–5.485</td>
</tr>
<tr>
<td>No. of treatment sessions</td>
<td>0.532</td>
<td>.195</td>
<td>0.502</td>
<td>0.177–1.423</td>
</tr>
<tr>
<td>Treatment access</td>
<td>0.350</td>
<td>.574</td>
<td>1.218</td>
<td>0.613–2.419</td>
</tr>
<tr>
<td>Clinical presentation</td>
<td>0.375</td>
<td>.966</td>
<td>1.016</td>
<td>0.487–2.117</td>
</tr>
<tr>
<td>PAP increase during procedure</td>
<td>1.008</td>
<td>.662</td>
<td>1.555</td>
<td>0.216–11.222</td>
</tr>
<tr>
<td>Complications</td>
<td>0.345</td>
<td>.348</td>
<td>0.723</td>
<td>0.368–1.422</td>
</tr>
</tbody>
</table>

AVM = arteriovenous malformation, CI = confidence interval, OR = odds ratio, PAP = pulmonary artery pressure, SE = standard error.
The overall complication rate was 45% (79 of 176 patients). Minor complications occurred in 35% of patients (62 of 176 patients). Ten patients had skin blisters and reddish discoloration. Thirty-six patients had isolated skin necrosis that healed spontaneously with conservative dressing. Skin necrosis with transient nerve palsy was observed in four patients, and isolated transient nerve palsy occurred in eight patients. Two patients had asymptomatic deep vein thrombosis after sclerotherapy that resolved during follow-up ultrasonography without further management. Two patients had stiffness in finger joints that recovered with exercise.

Seventeen major complications developed in 17 of 176 patients (10%). Skin necrosis required skin grafts in two patients and escharectomy in three patients. Three patients underwent a scheduled amputation for tissue necrosis after sclerotherapy. One patient had skin and tissue necrosis after sclerotherapy that led to amputation. Three patients underwent thrombolysis for distal arterial embolization after sclerotherapy and showed a complete recovery. Permanent nerve injury occurred in one patient. One patient had a surgical coil removed as a result of extrusion through the skin, and one patient had a coil mass infection that led to bacterial endocarditis. One patient had acute pancreatitis from ethanol use immediate after sclerotherapy and recovered completely with conservative management for 2 weeks. One patient with acute renal failure as a result of rhabdomyolysis after sclerotherapy had a prolonged hospital stay for 22 days but also recovered completely without specific treatment.

**DISCUSSION**

There are abundant data on peripheral AVMs related to initial presentation, including subjective symptoms, objective clinical findings, and imaging findings. Although there are data from several clinical studies regarding the results of ethanol embolization treatment for AVMs (16–20), little information is known regarding significant clinical factors before treatment that could predict its results. Although a large number of patients with peripheral AVMs require staged therapy with multiple embolization sessions, minor and major complications are not infrequent in AVM sclerotherapy. Therefore, predictive factors for the treatment of AVM will help patients prepare mentally and physically for multiple treatment sessions. Positive predictive factors can also help to establish effective treatment plans.

According to the present study, peripheral AVM extent was a significant predictive factor related to overall clinical response. AVMs are progressive, and the diffuse lesions are prone to recur and persist, even after surgery or embolization (21). Unless a sufficient area of the AVM is completely treated, residual AVMs can easily expand over time or during the treatment interval, despite embolization. If the AVM extent is small or localized, the fraction of the AVMs treated in each session might be larger than in diffuse or extensive AVMs. A previous report (22) showed that AVMs involving the finger or both the palm and finger had higher complication rates and showed fewer therapeutic benefits. This result agrees with our result that shows that localized AVMs not involving the finger and toe had a good overall clinical response. AVMs located in the extremities and extending over two adjacent joints usually tend to be extensive and involve the whole limb, so repeated and staged embolization is limited in reaching a certain therapeutic goal.

Angiographic classification was also a statistically significant predictive factor for overall clinical outcome in the present study. This result coincides with a previous report (12) that showed that type II AVMs were associated with higher cure rates than other AVM types. In the present study, patients with type I or II AVMs had excellent final outcomes compared with patients with type III or combined AVMs. Generally, the most important clinical determinants for treatment of AVMs are the subjective symptoms. However, any AVMs left untreated may undergo severe progression that may make them impossible to be treated at all in the future. Therefore, if the initial angiographic images shows type I or II AVMs, the chance of a complete cure can be high, the patient can be assured a good clinical outcome, and an active treatment plan should be considered. Treating a type IIIa lesion is difficult with an intraarterial or direct puncture approach. Type IIIa AVMs usually have so many arteriovenous communications in the lesion that it is difficult to achieve favorable results from sclerotherapy even after repeated treatment sessions. Therefore, in our institution, patients with type IIIa AVMs are usually informed that they have a high likelihood of poor clinical outcome or even failure of treatment because small-diameter arterioles and venules are very difficult to successfully access by intraarterial or direct puncture. A type IIIb lesion is also difficult to control, in that hypertrophied and engorged feeder vessels and draining veins are less susceptible to the sclerosing effect of ethanol as a result of dilution by the massive flow volume and velocity. However, although outcomes are not as good as those in type I or II AVMs, certain hemodynamic features of type IIIb AVMs allow favorable outcomes after multiple sessions of treatment. Although treatment is not easy, type IIIb AVMs treated at regular intervals, with targeted removal of as many AVMs as possible at each session of sclerotherapy, could be partially or completely cured. In our institution, relative to the onset of AVM treatment, the incidence of complications and the number of treatment sessions are decreasing with time. Treatment strategy evolved from dedicated intraarterial ethanol embolization to more complex methods with a combined approach. This implies that the complete cure rate can improve in the future with the further understanding of hemodynamic features and vascular anatomy of AVMs.
Peripheral AVMs with skin or bone involvement might appear more severe and difficult to treat on initial evaluation. Despite the appearance of these AVMs, however, skin or bone involvement did not significantly correlate with clinical outcomes. Although bone AVMs appear to be severe and complex on CT angiography and conventional angiography, we saw efficacy rates as high as 82% for ethanol embolization of AVMs with bone involvement (23). Avoiding skin necrosis during ethanol embolization is difficult in patients with skin involvement. Diluting the ethanol to 70% can be an alternative for this type of AVM. Less toxic agents, such as ethylene vinyl alcohol copolymer (eg, Onyx 18 LES; ev3, Irvine, California), can also be considered for this type of AVMs. Even in cerebral AVMs, however, Onyx embolization completely obliterates only approximately 50% of AVMs, and 1.1% of these recanalize despite initial complete obliteration (24). Several reports of Onyx use in peripheral AVMs demonstrated that most high-flow AVMs showed incomplete embolization and were cured less frequently than expected with ethanol treatment (25,26). Onyx is very expensive in large volumes, and the recurrence rate and long-term results in peripheral AVMs have not been reported. In addition, there are no reliable data about the effect of Onyx on skin damage. Glue has a mass effect after sclerosis, and delayed washout with recurrence of AVMs has been reported (27,28). Therefore, glue use should be restricted to limited AVMs.

Reported complication rates of ethanol embolization range from 10% to 61% (2). In the present study, the complication rate was 44%; however, 82% of complications were minor (64 of 78). Therefore, 162 patients (92%) had no posttreatment sequelae after the clinical follow-up period.

The present study has several limitations. First, the results of ethanol embolization were assessed retrospectively. AVMs are rare, and the treatment process is so complex that a prospective study would be difficult to conduct. Second, the study had a relatively short follow-up period compared with other studies (9,16). Long-term follow-up would be desirable to define ultimate quality of life and disease recurrence. In the present study, however, a significant number of patients showed marked improvement, including cure, after few or even one session of treatment. Therefore, the overall follow-up period was shortened. Third, factors such increased elevated pulmonary artery pressure during the procedure had a one-sided distribution. Compared with the whole patient population, only a few patients had significantly increased pulmonary artery pressure during the procedure; therefore, some factors in the data are somewhat biased.

In conclusion, the most significant predictive factors for AVM embolization were AVM extent and angiographic classification. Therefore, thoroughly evaluating the anatomic extent of the lesion and precisely interpreting baseline angiographic findings before deciding on a treatment plan for AVMs are important. Patients can be informed of the expected results based on these predictive factors.

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REFERENCES

CME TEST QUESTIONS: NOVEMBER 2012

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The CME questions in the November issue are derived from the article “Predictive Factors for Response of Peripheral Arteriovenous Malformations to Embolization Therapy: Analysis of Clinical Data and Imaging Findings” by Park et al.

1. Among those patients treated for extremity and trunk arteriovenous malformations (AVMs):
   a) Lesions with more than three feeding arteries were uncommon.
   b) Nearly all lesions were mixed AVMs.
   c) Diffuse AVMs were about twice as common as localized ones.
   d) There was equal distribution of lesions with hand or foot or major organ involvement and those without.

2. In the current study, with regard to overall clinical success of AVM treatment:
   a) Half had a complete cure.
   b) More than 90% had at least a partial response.
   c) Almost 1 in 10 patients was a frank treatment failure.
   d) No patients worsened after treatment.

3. Regarding the clinical response of AVMs in the study, all of the following are true EXCEPT:
   a) Type I and II AVMs had a high probability of being “markedly improved”.
   b) Diffuse AVMs had an increased probability of “no change”.
   c) Presence of skin or bone involvement did not correlate with clinical outcome.
   d) Type IIIa AVMs are more likely to be at least partially cured than type IIIb AVMs.

4. In evaluating complications of AVM treatment:
   a) Skin injury was the most common complication among both minor and major complications.
   b) Some type of complication occurred in more than half of patients.
   c) Most complications resulted in permanent sequelae.
   d) No complications lead to amputation.