Beyond typical cerebrovascular malformations including arteriovenous malformations (AVMs), developmental venous anomalies (DVAs), cavernous malformations, and capillary telangiectasia, the disease concept and the proper treatment plan for some rare vascular lesions have not yet been well established. A poorly defined arterial blush and an early venous drainage with a dilated medullary vein from the arterial or capillary phase is one of the rare vascular lesions. Such a vascular lesion can be distinguished from an AVM by the absence of a discrete nidus and poorly identifiable, enlarged feeding arteries, and distinguished from DVAs by the early venous drainage from the arterial or capillary phase. Various terminologies including arterialized DVA,15 mixed-type vascular malformation,6 venous angioma with arteriovenous (AV) shunt,10 atypical DVA with early venous filling, mixed venous and arteriovenous malformations, medullary venous malformation with an arterial component, or venous-predominant AVM (vp-AVM),8 which is referred to here, have been used to interpret the rare vascular anomalies, but still no definite terminology has been established.

OBJECTIVE  Treatment strategies for venous-predominant arteriovenous malformation (vp-AVM) remain unclear due to the limited number of cases and a lack of long-term outcomes. The purpose of this study was to report the authors' experience with treatment outcomes with a review of the pertinent literature in patients with vp-AVM.

METHODS  Medical and radiological data from 1998 to 2011 were retrospectively evaluated. The degree of the arteriovenous (AV) shunt was categorized into 2 groups, a high- and low-flow AV shunt based on the angiographic findings.

RESULTS  Sixteen patients with a mean age of 45.3 years (range 16–78 years) and a mean follow-up of 79.9 months (range 25–264 months) were examined. Symptomatic lesions were noted in 13 patients: intracranial hemorrhage (ICH) in 9, seizure in 1, and headache in 3. A high-flow shunt was observed on angiography in 13 patients. Among these 13 patients, 12 patients were symptomatic. Nine patients presenting with ICH underwent hematoma removal with additional Gamma Knife surgery (GKS; n = 4), GKS only (n = 2), or conservative treatment (n = 3). The 3 asymptomatic patients received conservative treatment, and 1 rebleeding episode was observed. Seven of 8 patients who underwent GKS as an initial or secondary treatment modality experienced a marked reduction in the AV shunt on follow-up angiography, but complete obliteration was not observed.

CONCLUSIONS  Poor lesion localization makes a vp-AVM challenging to treat. Symptomatic patients with a high-flow shunt are supposedly best treated with GKS, despite the fact that only 87.5% of the vp-AVMs treated this way showed a reduction in the malformation volume, and none were cured.

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KEY WORDS  arteriovenous malformation; developmental venous anomaly; intracranial hemorrhage; venous malformation; vascular disorders
Consensus on the treatment of vp-AVM remains controversial due to the different disease concepts as well as the limited number of cases and a lack of information on long-term outcomes. Pereira et al.\textsuperscript{10} believed that increased medullary blush represents a rapid transit time, not an AV shunt. Accordingly, an atypical DVA with early venous drainage did not become symptomatic. On the contrary, Im et al.\textsuperscript{8} reported that a vp-AVM more closely resembles an AVM because of its histological and clinical similarity. They believed that more aggressive treatment modalities such as resection or Gamma Knife surgery (GKS) can be used to prevent symptomatic vp-AVM or to treat intracranial hemorrhage (ICH) associated with a vp-AVM. Nevertheless, poorly localized abnormal lesions due to the absence of a definite nidus and enlarged feeding arteries as well as limited information on long-term treatment outcomes after GKS can make it difficult to select the appropriate treatment modality. The aim of this study was to report our experience with the long-term treatment outcomes of vp-AVMs as well as review the pertinent literature.

\section*{Methods}
\subsection*{Patient Population}
This study was approved by the institutional review board (1309–063–520) of Seoul National University College of Medicine. This retrospective analysis was performed in patients with a vp-AVM from 1998 to 2011 at a single center. A venous anomaly that had the following features on cerebral angiography was defined as a vp-AVM. First, a poorly defined arterial blush and an early venous drainage combined with dilated medullary veins noted during the arterial or capillary phase. Second, no definite nidus was noted.\textsuperscript{2,8} Vp-AVM was assessed by 2 factors, the presence of clinical symptoms relevant to vp-AVMs and the degree of the AV shunt at angiography. Symptomatic lesions included ICH, seizure, neurological deficits, and relevant clinical symptoms such as headache or dizziness. The degree of the AV shunt was categorized into 2 groups, a high- or low-flow AV shunt, based on the angiographic findings. A high-flow AV shunt was characterized by an abnormal prominent arterial blush and an early venous drainage from the arterial phase. A low-flow AV shunt was characterized by an arterial blush and an early venous drainage with a dilated medullary vein during the capillary phase (Fig. 1).

\subsection*{Data Collection}
Medical records including age, sex, hypertension, diabetes mellitus, smoking, presenting symptoms, treatment methods, and follow-up duration were reviewed. Radiological data such as location, presence of hemorrhage, arterial component dominance, and rebleeding events were examined. Follow-up radiological tests were performed with MRI or digital subtraction angiography according to parameters that were reported previously.\textsuperscript{8} Hematoma removal, GKS, or conservative treatments were performed. Hematoma removal was indicated for the management of increased intracranial pressure (ICP) refractory to medical treatment. GKS was considered for symptomatic patients primarily or secondarily. GKS was performed with the Leksell Gamma Knife (Elekta Instrument AB).\textsuperscript{4} The basic procedure for GKS was as follows. First, the abnormal vascular staining lesions were covered as much as possible, but not the main draining veins. Then, low-dose GKS was performed with a marginal dose of \( \leq 20 \text{ Gy} \) (50\% isodose).\textsuperscript{8,9}

MRI was performed at 6, 12, 24, and 36 months after diagnosis. Thereafter, continued MRI every 2 or 3 years was advised to determine the progression of the disease. If patients experienced new or worsened symptoms including seizure, headache, or neurological change, the MRI was checked. Specifically, for patients who presented with hemorrhage and underwent GKS, angiography was added to the MRI examination according to the clinical status of the patients. Repeated GKS was indicated for patients presenting with hemorrhage who did not show a reduction in vascularity or for patients who had worsened symptoms during the follow-up period.

The annual hemorrhage rate of vp-AVM before intervention was estimated as the number of hemorrhages divided by the patient-years at risk, assuming that the vp-AVM was present at birth. Concerning the annual hemorrhage rate after the intervention, none of our patients experienced hemorrhage after the intervention, therefore the postinterventional hemorrhage rate was estimated as the number of hemorrhage events divided by the patient risk-years from the diagnosis to the dates of last follow-up.

\section*{Results}
\subsection*{Clinical and Angiographic Features}
The demographic characteristics of the 16 patients are presented in Table 1. There were 9 male patients (56.3\%). The mean age of all patients in the study was 45.3 years (range 16–78 years) with a mean follow-up of 79.9 months (range 25–264 months). Symptomatic lesions were noted in 13 patients: ICH in 9, seizure in 1, and headache in 3. The presence of a high-flow shunt at angiography was observed in 13 patients. Among these 13 patients, 12 were symptomatic. The remaining 3 cases had low-flow shunts, and 2 cases were asymptomatic.

\subsection*{Long-Term Treatment Outcomes}
The annual hemorrhage rate of the patients with vp-AVMs before and after the intervention was 1.24\% and 0.94\%, respectively. A total of 13 symptomatic patients, including 9 patients with ICH presentation, underwent the following treatments: hematoma removal with additional GKS (n = 4), GKS only (n = 2), and conservative treatment (n = 3). Resection of the venous anomaly was performed due to a poorly demarcated lesion in the operative field.
Four symptomatic patients who had a seizure or headache received GKS (n = 2) or conservative treatment (n = 2). Three asymptomatic patients received conservative treatment. Seven of the 8 patients who underwent GKS primarily or secondarily experienced a marked reduction in the AV shunt on follow-up angiography. One remaining patient showed no change in the extent of the lesion for abnormal arterial and early venous drainage with a dilated medullary vein. A rebleeding event was observed in 1 of 3 conservatively treated patients initially presenting with ICH. Patients who underwent hematoma removal with additional GKS or GKS only did not experience any rebleeding events. Radiation-related complications such as radio-necrosis and brain edema were not noted in our study.

Review of the Pertinent Literature

Five previous studies were reviewed (Table 2). The number of patients in each study ranged from 3 to 15. The terminologies to describe a poorly defined arterial blush and an early venous drainage with a dilated medullary vein without a discrete nidus included mixed venous and arteriovenous malformation,1 venous malformation with arterial fistulization,14 venous angio ma with AV shunt,10 arterialized DVA,15 and vp-AVM. Two rebleeding events were reported after conservative treatment.8,15 The time interval between the first and second bleeding ranged from 1 to 85 months. Fatal complications due to incomplete resection of the venous anomaly and radiation necrosis were reported.

Illustrative Cases

Case 5

A 55-year-old man presented with ICH in the right frontal area. Right carotid angiography showed an abnormal vascular staining lesion in the insular area during the
midarterial phase and an early venous drainage of the sylvian vein with a dilated medullary vein during the capillary phase. The 3D reconstructed image revealed a caput medusa feature of the veins. GKS was performed to treat a vp-AVM. A follow-up angiogram obtained 24 months later showed a reduction of the vascular staining lesion and a decrease in early venous drainage (Fig. 2).

**Case 13**
A 27-year-old man visited a hospital due to a migraine headache with aura in the left temporal area. The brain MRI revealed multiple signal voids in the left posterior temporal lobe. Left vertebral angiography showed poorly marginated lesions of arterial blush and early venous drainage with a dilated medullary vein during the midarterial phase. The vp-AVM volume measured by MRI based on projections drawn from the angiography images was 5.2 ml, and the marginal dose was 18 Gy. A follow-up angiogram obtained 24 months after GKS showed a reduction of the extent of the arterial blush in the lesion and nearly the disappearance of the early venous drainage. Moreover, the patient’s headache had improved (Fig. 3).

### Discussion
Atypical venous anomaly consisting of an abnormal arterial blush and early venous drainage with a dilated medullary vein from the arterial or capillary phase, without a definite nidus, has been noted using various terminologies, including vp-AVM. Treatment strategies for vp-AVM remain unclear because of the limited number of cases and a lack of information on long-term outcomes. Accordingly, selection of treatment modalities is usually conducted according to the physician’s disease concept and experience. Pereira et al. suggested that an increased medullary blush concomitant with an early venous drainage implicates a rapid transit time by an enlarged collector vein. They believed that medullary blush was not related to true AV shunting and rarely was symptomatic. Komiyama et al. recommended initial conservative treatment for a venous angioma irrespective of the combination with an AV shunt, due to their benign prognosis. Lasjaunias et al. and Goulao et al. reported that a DVA is a normal variant of the venous drainage pattern that occurs as a compensatory drainage system. Accordingly, a dilated vein concomitant

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**TABLE 2. Literature review of studies on abnormal arterial blush and early venous drainage with a dilated medullary vein from the arterial or capillary phase without a discrete nidus**

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Pts (males)</th>
<th>Mean Age (range)</th>
<th>Terminology Used to Describe Diagnosis</th>
<th>Treatment</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awad et al., 1993</td>
<td>3</td>
<td></td>
<td>Mixed VM &amp; AVM</td>
<td>Gyrectomy (n = 2), HR + GKS (n = 1)</td>
<td></td>
</tr>
<tr>
<td>Mullan et al., 1996</td>
<td>3</td>
<td>24 yrs (22–26)</td>
<td>VM + arterial fistulization</td>
<td>Not stated</td>
<td></td>
</tr>
<tr>
<td>Komiyama et al., 1999</td>
<td>3 (2)</td>
<td>24 yrs (22–26)</td>
<td>Venous angioma with AV shunt</td>
<td>Conservative (n = 3)</td>
<td>None</td>
</tr>
<tr>
<td>Im et al., 2008</td>
<td>15 (9)</td>
<td>27.4 yrs (8–71)</td>
<td>vp-AVM (n = 15)</td>
<td>Conservative (n = 6), GKS (n = 4), HR + GKS (n = 2), resection of venous anomaly (n = 3)</td>
<td>Rebleeding (n = 1), fatal (n = 1) due to incomplete resection</td>
</tr>
<tr>
<td>Oran et al., 2009</td>
<td>7 (4)</td>
<td>25.6 yrs (6–51)</td>
<td>Arterialized DVA (n = 4), arterialized DVA + AVM (n = 3)</td>
<td>Conservative (n = 2), GKS (n = 2), decompression (n = 1), EE + GKS (n = 1), EE + DVA resection (n = 1)</td>
<td>Rebleeding (n = 1), radiation necrosis (n = 1), EE + DVA resection (n = 1)</td>
</tr>
<tr>
<td>Present series, 2014</td>
<td>16 (9)</td>
<td>45.3 yrs (16–78)</td>
<td>vp-AVM (n = 16)</td>
<td>Conservative (n = 6), HR + GKS (n = 4), GKS (n = 4)</td>
<td>Rebleeding (n = 1)</td>
</tr>
</tbody>
</table>

EE = endovascular embolization; Pts = patients; VM = venous malformation.

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**FIG. 2.** Case 5. A 55-year-old man presented with ICH in the right frontal area. **A** and **B**: Abnormal arterial blush in the insular area (arrows) during the midarterial phase and an early venous drainage of the sylvian vein (arrow) with a dilated medullary vein during the capillary phase were observed. **C** and **D**: A follow-up angiogram obtained 24 months later after GKS revealed a reduction of the arterial blush and early venous drainage.
with a venous anomaly may represent fragile vessel walls that are susceptible to hemodynamic compromise by an inadequate response to hemodynamic stress. However, Hirata et al. and Im et al. believed that an atypical venous anomaly (described as mixed venous and arteriovenous malformation, and vp-AVM, respectively) resembles a true AVM based on histological and clinical similarity. In our study, we divided vp-AVMs into 2 groups: high- and low-flow AV shunts. Twelve of our 13 cases with vp-AVMs and a high-flow AV shunt were symptomatic, and 1 of 3 cases with a vp-AVM and low-flow shunt was symptomatic. Accordingly, the presence of symptoms appears to be associated with the severity of the shunt flow.

Treatment modalities included conservative, open surgical, GKS, and endovascular intervention. Conservative treatment was performed under the rationale that patients with vp-AVMs experienced benign clinical behavior such as DVAs. However, vp-AVMs showed histological features similar to AVMs, and 2 cases of rebleeding have been reported previously. We also experienced 1 case of a rebleeding episode among the patients who underwent conservative treatment. Accordingly, physicians should be aware of the possibility of hemorrhagic presentation in patients with vp-AVMs. Open surgery has been performed in vp-AVMs that manifested massive or repetitive bleeding. However, poor lesion localization due to the absence of a definite nidus and nonidentifiable enlarged feeding arteries can be challenging for complete resection. Incomplete resection can lead to catastrophic hematoma, venous infarction, and severe brain swelling. Im et al. reported a fatal complication after an incomplete resection of a vp-AVM. Moreover, lesions located in the eloquent area or deep in the brain are also challenging for resection. Accordingly, resection should be performed only in patients who present with a recurrent hematoma or epilepsy.

GKS has been used to treat vp-AVMs. A general principle of GKS is to cover the extent of the staining area during the arterial phase without harming the main drainage vein to avoid possible venous infarction or hemorrhage. Good treatment outcomes have been reported for venous anomalies, but complete obliteration has not yet been reported in patients with vp-AVMs. Because the absence of a discrete nidus makes dosimetry and defining the margin difficult, it can be hard to target the lesions. In
our cohort, we had 7 cases (87.5%) with a marked reduction in AV shunting and early venous drainage, but none were cured. Radiation-induced complications are a concern after GKS. Oran et al. reported a case of fatal radiosclerosis after GKS. Although no adverse events associated with GKS were observed in our case series, further study is required to better define the optimal parameters for the radiation dose, patient selection, and treatment strategy for radiation-resistant vp-AVM. Endovascular interventions can also be considered. In particular, a vp-AVM with an identifiable and prominently enlarged feeding artery could be feasible for selective embolization. However, most vp-AVM cases have shown a diffuse and undefined arterial feeding artery; thus, endovascular intervention appears to have limited use in patients with vp-AVMs. Based on our experience and review of the pertinent literature, we believed that symptomatic vp-AVMs with a high-flow shunt could be considered for GKS treatment. Except in those cases with massive or repetitive bleeding, GKS appears to reduce hemodynamic stress in the main drainage system with a dilated vein by decreasing the shunt flow, although it did not reach complete obliteration. Asymptomatic vp-AVMs with or without a high-flow shunt can be treated conservatively.

The differential diagnosis between a vp-AVM and a true AVM with medullary components is important because a true AVM with medullary components resulted in a higher bleeding rate and poor neurological outcome. AVMs with medullary components are more likely to have enlarged feeding arteries with an edge shape and a streaming pattern for the medullary vein; moreover, a discrete nidus is observed.

Two concerns remain regarding a GKS indication for patients with vp-AVMs presenting with headache and proper radiation dose. In our study, 3 patients complained of migraine headaches with auras. In addition, the headaches developed ipsilateral to the vp-AVMs. Although cluster headaches, chronic paroxysmal hemicranias, and short-lasting unilateral neuralgiform headaches with conjunctival injection and tearing can also be associated with AVMs, those are atypical features. After consultation with a neurologist, and according to the International Classification of Headache Disorder, 3rd edition criteria, we believed that headache was associated with vp-AVMs. During the follow-up period, 2 patients who had undergone GKS showed reduction of the vascularity, and their migraine headaches were greatly lessened. In a review of the literature, detailed information on the GKS parameters for vp-AVMs has not been well described. We tried to include all abnormal vascular staining lesions in the GKS planning; however, normal brain tissue in the targeted lesions could also be included to a greater extent and affected by the radiation more than that of the AVM, which has a tightly packed nidus. Inoue reported that low-dose GKS (≤ 20-Gy margin dose) was feasible for the treatment of AVMs and could decrease the long-term adverse effects to surrounding tissue. Accordingly, we chose a low radiation dose targeted to the vp-AVM.

Our study has several distinctive features. First, our study included the largest sample size of patients with vp-AVMs to date (n = 16). Second, these patients with vp-VMs have been followed for a mean of 79.9 months. Although no direct comparative test among the treatment modalities was conducted due to the small number of cases, information on long-term treatment outcomes would be beneficial when selecting the treatment modality.

Conclusions

Poor lesion localization of vp-AVMs makes them challenging to treat. Symptomatic patients with a high-flow shunt are supposedly best treated with GKS, despite the fact that only 87.5% of the vp-AVMs treated this way showed a reduction in the malformation volume, and none were cured.

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Venous-predominant arteriovenous malformation


**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

**Author Contributions**

Conception and design: JE Kim. Acquisition of data: Ahn, WS Cho, Kang, Chung. Analysis and interpretation of data: JE Kim, Jeon, Sohn, YD Cho, Chung, DG Kim. Drafting the article: Jeon. Critically revising the article: Son, Bang, Oh.

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