

# MVP™ Micro Vascular Plug Systems for the Treatment of Pulmonary Arteriovenous Malformations

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## Abstract

**Purpose** To describe our institutional experience with MVP™ micro vascular plug systems for the treatment of pulmonary arteriovenous malformations (PAVMs).

**Materials and Methods** We performed a retrospective medical record review of 52 patients with 119 PAVMs treated exclusively with MVP™ systems (69 procedures/153 MVP™ systems) between July 2014 and July 2018. All patients had PAVMs with feeding artery diameters  $\geq 2$  mm. MVP™ systems were deployed according to physician preference. We collected patient demographic information; procedural data (including size of feeding artery, size and number of embolics used per PAVM, fluoroscopy time, contrast administration), technical success rates, complications, and persistence. Persistence was assessed using computed tomography angiography (CTA) performed 1–3 months and 3–5 years after embolization per clinical protocol.

**Results** All procedures were technically successful without major complications. Mean feeding artery diameter was  $3.3 \pm 1.2$  mm. Mean fluoroscopy time per procedure and

contrast volume administered per procedure were  $35 \pm 16$  min and  $217 \pm 101$  mL, respectively. A mean of  $1.3 \pm 0.8$  MVP™ systems was used per PAVM. There were no instances of persistence during a mean follow-up time of  $328 \pm 258$  days (range 26 to 914 days).

**Conclusions** For PAVMs with feeding artery diameters of 2 to 7.9 mm (mean  $3.3 \pm 1.2$  mm), MVP™ systems are safe and effective given their high technical success rates and lack of persistence. Further prospective work will be required to elucidate the advantages and disadvantages of these MVP™ systems for PAVM embolization.

**Level of Evidence** Level III.

**Keywords** Computed tomography angiography · Hemorrhagic hereditary telangiectasia · MVP™ micro vascular plug system · Pulmonary arteriovenous malformation · Persistence

## Abbreviations

CT	computed tomography
CTA	computed tomography angiography
DSA	digital subtraction angiography
HHT	hemorrhagic hereditary telangiectasia
MVP™ system	MVP™ micro vascular plug system
PAVM	pulmonary arteriovenous malformation

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## Introduction

A pulmonary arteriovenous malformation (PAVM) is an anomalous connection between a pulmonary artery and a pulmonary vein that lacks an intervening capillary bed. PAVMs may be congenital or acquired, but they are most common in patients with hemorrhagic hereditary telangiectasia (HHT) [1]. The most common symptoms of PAVM are dyspnea, exercise intolerance, migraine headache, stroke or transient ischemic attack, brain abscess, and lung hemorrhage [1, 2].

Original guidelines recommended treating only those PAVMs with feeding arteries of 3-mm diameter or greater [3, 4] on the basis of studies reporting stroke in patients with such PAVMs. It was thought that PAVMs with feeding arteries smaller than 3 mm posed no risk of paradoxical embolization. However, investigations have since shown that PAVMs with feeding arteries smaller than 3 mm can lead to paradoxical embolization, and that this risk is independent of feeding artery size [4]. Thus, current practice is to treat PAVMs with feeding arteries less than 3 mm to prevent paradoxical embolization, aneurysm rupture, and chronic hypoxemia secondary to shunting [5, 6] in patients who lack contraindications to treatment (e.g., severe pulmonary hypertension, renal failure, early pregnancy) [3, 4, 7, 8].

The treatment of choice is transcatheter embolization using coils or plugs to occlude the malformation [4]. Coils are the most widely used embolic device. However, coil embolization is associated with long procedure time, necessity of using numerous coils to occlude a single PAVM, and persistence rates of 4% to 57% [2, 9–13]. An alternative is the Amplatzer vascular plug (AVP) (St. Jude Medical, Plymouth, MN), a re-sheathable embolic device that achieves occlusion with quick delivery of a single plug [6, 13, 14] with persistence rates of 1% to 29% [6, 13–15]. However, AVPs cannot be delivered through microcatheters, which limit their utility in smaller, more tortuous feeding arteries.

A new device for PAVM occlusion is the MVP™ micro vascular plug system (Medtronic, Minneapolis, MN), which combines the benefits of coil and AVP embolization. Unlike coils and other vascular plugs, which can take as long as 20 min to show occlusion on angiography [16], MVP™ systems can occlude a vessel immediately [16]. Like microcoils, MVP™ systems have the added benefit of microcatheter delivery, allowing them to be navigated into small, distal, and very tortuous vessels [16–20]. There is a paucity of data regarding persistence rates for MVP™ systems for PAVM embolization. In fact, the number of publications reporting the use of MVP™ systems in general is limited, and most studies report only short- to mid-

term follow-up. Our goal was to describe our institutional experience with MVP™ systems for the treatment of pulmonary arteriovenous malformations (PAVMs) by collecting and analyzing patient demographic characteristics, specific procedural data (including size of feeding artery, size and number of embolics used per PAVM, fluoroscopy time, contrast administration), technical success rates, complications, and persistence.

## Methods

### Data Collection

We performed an institutional review board–approved review of PAVM embolization with MVP™ systems. A radiology information system search was performed to find all patients treated at our facility using MVP™ systems for PAVM embolization between July 2014 and July 2018. (All patients with PAVM feeding arteries  $\geq 2$  mm on computed tomography angiography (CTA) are offered embolization at our institution). We included patients who had a PAVM that was treated with MVP™ systems alone. Keywords used for the search were “pulmonary arteriovenous malformation (PAVM)” and “micro vascular plug (MVP).”

### Patient Characteristics

Fifty-two patients with 119 PAVMs (86% simple) were included (mean  $\pm$  standard deviation age,  $41 \pm 21$  years). Forty-five patients (87%) were diagnosed with HHT. Fifty-eight percent of PAVMs were discovered during PAVM screening for HHT workup. Forty-eight percent of patients were symptomatic at the time of presentation to our institution from their PAVMs, and most reported dyspnea (both at rest and with exertion) and hemoptysis. Twenty-nine percent of our population had previous PAVM treatment (embolization or resection) (Table 1).

### Outcomes

#### Procedural Data

We used the radiology information system to obtain data on the size and number of MVP™ systems deployed, fluoroscopy time, and volume of administered contrast agent. Feeding artery size (vessel cross-sectional diameter) was measured on CTA and confirmed with the use of pulmonary digital subtraction angiography (DSA) (0.014-inch ATW Marker Wire, Cordis, USA). One hundred and nineteen PAVMs were embolized with 153 MVP™

**Table 1** Patient demographic characteristics

(N = 52)	
Age [mean (SD)]	41 years ± 21
HHT (%)	86
Female (%)	69
Race/ethnicity	Caucasian 47 Black 3 Hispanic 2
Simple PAVM (%)	86
Symptomatic (%)	48
PAVM discovered as part of HHT workup (%)	58
Other previously treated PAVMs (%)	29
Other visceral AVMs	35

systems (113 MVP-3 devices, 36 MVP-5 devices, 3 MVP-7 devices, 1 MVP-9 device).

### *Embolization Technique*

The procedure, risks, benefits, and alternatives were explained to the patient, and written informed consent was obtained. The patient was placed supine on the fluoroscopy table. In most cases, midazolam and fentanyl were used for conscious sedation; however, in pediatric patients and in patients who were unable to tolerate sedation, general anesthesia was used. The groin was prepared and draped in usual sterile fashion. The common femoral vein was accessed, usually on the right, with a micropuncture set (Cook Inc, Bloomington, IN) under fluoroscopic and ultrasonographic guidance. A Bentson wire (Cook Inc, Bloomington, IN) was advanced into the inferior vena cava, and the 5-Fr micropuncture sheath was exchanged for a 9-Fr sheath (Cook Inc, Bloomington, IN). A 7-Fr Van Aman or Grollman catheter (Cook Inc, Bloomington, IN) was advanced over the wire into the right atrium, right ventricle, and main pulmonary artery with the assistance of a 0.038-inch tip-deflecting wire (Cook Inc, Bloomington, IN).

Next, the Van Aman catheter (Cook Inc, Bloomington, IN) was advanced into the target pulmonary artery, and unilateral pulmonary angiography was performed in multiple projections, depending on the location of the target PAVM. An AP view was obtained in all patients. For lower lobe PAVMs, a contralateral oblique angiogram was obtained. For upper lobe PAVMs, an ipsilateral oblique angiogram was performed. A 0.035-inch Rosen exchange length wire (Cook Inc, Bloomington, IN) was advanced through the catheter, and the Van Aman catheter was exchanged over the wire for a coaxial Lumax white set which consists of an 8-Fr guide catheter and a 7-Fr MPA (Cook Inc, Bloomington, IN). The Lumax white set was advanced into the target pulmonary artery, and an arteriogram was obtained with hand injection. The feeding artery

of the AVM was selected with the Lumax white set, and hand contrast injection was performed to confirm tip location. The Lumax white set was maneuvered into the more distal aspect of the AVM feeding artery past the normal pulmonary branches. A 0.014-inch ATW marker wire (Cordis, Baar, Switzerland) was advanced through the White set, and the diameter of the AVM feeding artery was determined. The AVM feeding artery was embolized through the Lumax white set. A 0.021- or 0.027-inch microcatheter (traditionally we use Renegade and Hi-Flo Renegade microcatheters (Boston Scientific, Marlborough, MA)) was advanced into the distal target feeding artery. These microcatheters are used for MVP-3 device and MVP-5 device deployment. The MVP-7 device or MVP-9 device was deployed through a minimum of a 4- or 5-Fr diagnostic catheter, respectively. Hand contrast injection was performed to confirm complete embolization of the AVM feeding artery immediately after deployment of the MVP™ system. Then, a unilateral pulmonary angiogram was obtained. Catheters were removed, and pressure was held until venous hemostasis was achieved. A sterile dressing was then applied.

### *Device Selection and Description*

The MVP™ system device consists of a nitinol cage that is covered by a polytetrafluoroethylene (PTFE) membrane with radiopaque markers at the proximal and distal tips of the device. The device has a proprietary mechanical detachment mechanism that allows for re-sheathing and re-positioning before final deployment. There are four MVP™ system types available, MVP-3 devices, MVP-5 devices, MVP-7 devices, and MVP-9 devices. The MVP-3 devices and MVP-5 devices are delivered through microcatheters with diameters of at least 0.021 and 0.027 inches, respectively, and the MVP-7 devices and MVP-9 devices are delivered through diagnostic catheters that are a minimum of 4 or 5 Fr, respectively.

Device selection was determined by the operating physicians (CRW, SM, KH), who have more than 50 years of combined experience (minimum, > 10 y). Four sizes of MVP™ system were used. The MVP-3 devices were used for feeding arteries measuring 1.5–4 mm, and the MVP-5 devices were used for feeding arteries measuring 3–5 mm. The MVP-7 devices and MVP-9 devices were used for feeding arteries measuring 5–7 mm and 7–9 mm, respectively. In the final year of this study period, we began to use the larger MVP-7 devices and MVP-9 devices (indicated for feeding arteries 5–7 mm and 7–9 mm, respectively). Of note, we did not oversize these devices because the PTFE covering of the plug needs to open fully to occlude blood flow. This represents a significant deviation from oversizing that is used for other embolic devices for PAVMs.

### Technical Success

Technical success was defined as complete occlusion of the feeding artery within 1 cm of the PAVM without evidence of residual blood flow on post-deployment DSA and confirmed on the final pulmonary angiogram. All procedural angiograms were reviewed by 2 study authors (CRW and CRB) to confirm technical success.

### Persistence Rates

Persistence was defined as continued perfusion of the PAVM sac on CTA or DSA [21]. As described by Woodward et al. [21], persistence patterns include: recanalization, defined as vascular flow through or around an embolic device (i.e., coil pack); pulmonary-to-pulmonary reperfusion, in which the embolized feeding artery is occluded but small adjacent feeding arteries remain; incomplete primary treatment, involving incomplete treatment of a complex PAVM; and systemic-to-pulmonary reperfusion, in which a PAVM continues to be perfused by systemic feeding arteries. In our practice, patients routinely receive CTA ~ 1–3 months after PAVM embolization, followed by periodic CTA follow-up if recurrent symptoms, including hypoxia, cerebrovascular event, brain abscess occurred. Asymptomatic patients with HHT were evaluated with CTA 3–5 years after the procedure if PAVMs were simple and the patient remained asymptomatic. In all patients who had persistence seen on CTA, or who had need for embolization of other PAVMs, pulmonary DSA was performed (Fig. 1).

All CTAs and, if performed, pulmonary DSAs were reviewed by 2 study authors (CRW and CRB) to determine whether there was persistence. Reperfusion could not be determined for all patients because of the variable duration of follow-up. For example, some patients present only for embolization and then return to providers outside our institution for follow-up. In these cases, follow-up CT scans were unavailable (Fig. 2).

### CTA Protocol

When performed at our institution, images were acquired with inspiratory breath hold. Deep inspiration was avoided because it can reduce pulmonary arterial enhancement by causing disproportionate influx of unenhanced blood from the inferior vena cava. A high-pitch dual-source scanning technique that reduces scan time was used to reduce respiratory motion artifact. Specific technical parameters included a kVp of 100–120 depending on patient size, care dose reference mAs 170, time (rotation) 0.28 s, acquisition time of 1–2 s (average), collimation  $128 \times 0.6$  mm, a pitch value of 2.2, and a craniocaudal scan direction.

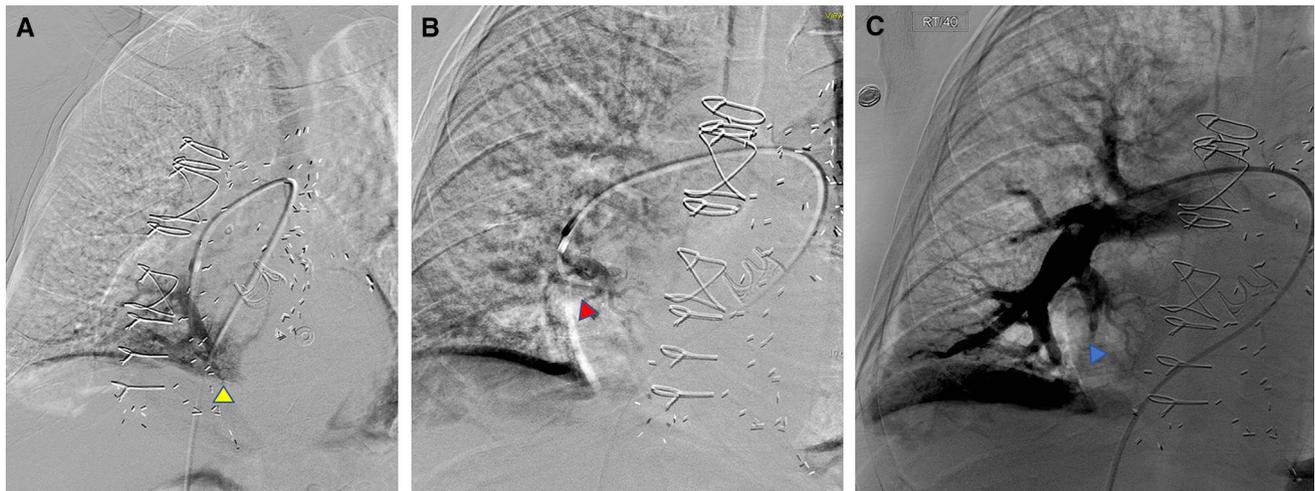


**Fig. 1** MVP™ micro vascular plug system (Medtronic, Minneapolis, MN). Image available at <http://www.medtronic.com/us-en/healthcare-professionals/products/cardiovascular/peripheral-embolization/mvp.html>

Acquisition was timed via contrast bolus tracking. Specifically, a region of interest drawn in the main pulmonary artery triggers acquisition when internal enhancement reaches 150–200 HU. Pulmonary angiography CT technique does not use gating. A high iodine delivery rate is important for high image quality (infusion rate of  $\geq 5$  mL/sec). Specific contrast parameters include use of a nonionic contrast material, an approximate contrast administration volume of 100 mL, and an injection rate of 5–6 mL/sec. Critical to our imaging protocol is thin 0.75-mm slices with a reconstruction spacing of 0.5 mm. Standard 3-mm slices are also obtained for soft tissue and lungs. Window widths and levels for soft tissue, thin sections, and lung are 410/10, 410/10, and 1600/500, respectively (Fig. 3).

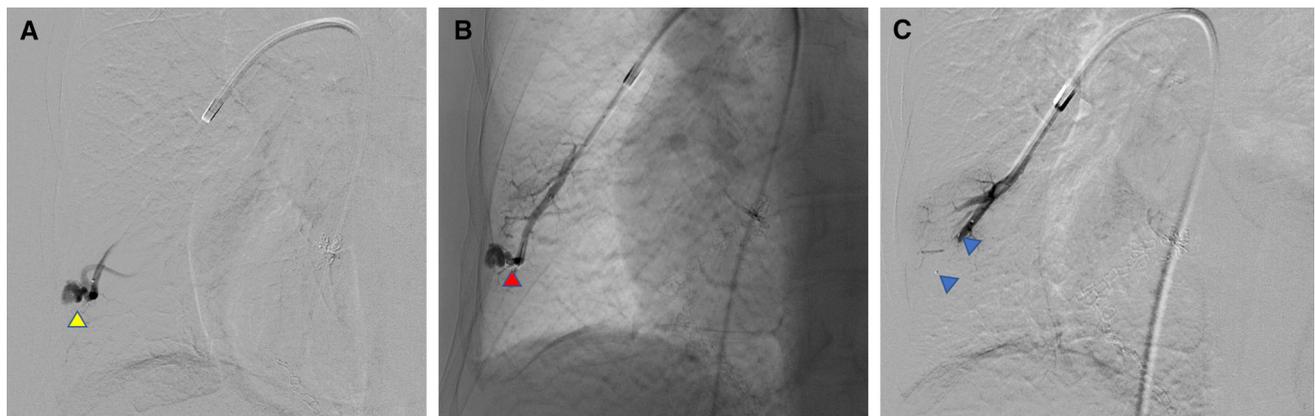
### Complications

We searched medical records for post-procedure complications and classified them by the Society for Interventional Radiology classification system [26]. Complications that required no therapy with no long-term consequence or nominal therapy with no long-term consequence were classified as minor (e.g., pleurisy, minor infection requiring outpatient therapy). Complications that required hospitalization for therapy lasting < 48 h, involved an increase in level of care, required hospitalization of > 48 h, or caused permanent adverse sequelae or death were classified as



**Fig. 2** Embolization of simple pulmonary arteriovenous malformation (PAVM) using a single MVP™ micro vascular plug system, MVP-5 device, **A** pre-treatment angiogram demonstrating a simple PAVM (yellow arrow head) with single feeding artery measuring

5 mm, **B** deployment of MVP-5 device (red arrow head), **C** post-treatment angiogram demonstrating successful occlusion with MVP-5 device (blue arrow head)



**Fig. 3** Embolization of simple pulmonary arteriovenous malformation (PAVM) using a single MVP™ micro vascular plug system, MVP-3 device, **A** pre-treatment angiogram demonstrating simple PAVM with single 2.5-mm feeding artery (yellow arrow head),

**B** deployment of MVP-3 device (red arrow head), **C** post-treatment angiogram demonstrating successful occlusion (blue arrow heads denote radiopaque markers at the proximal and distal ends of the MVP-3 device)

major (e.g., stroke, nontarget embolization, hemorrhage, infection requiring inpatient treatment).

#### Statistical Methods

Clinical and demographic data were tabulated and summarized. Means and standard deviations were calculated for all variables (Table 1).

#### Results

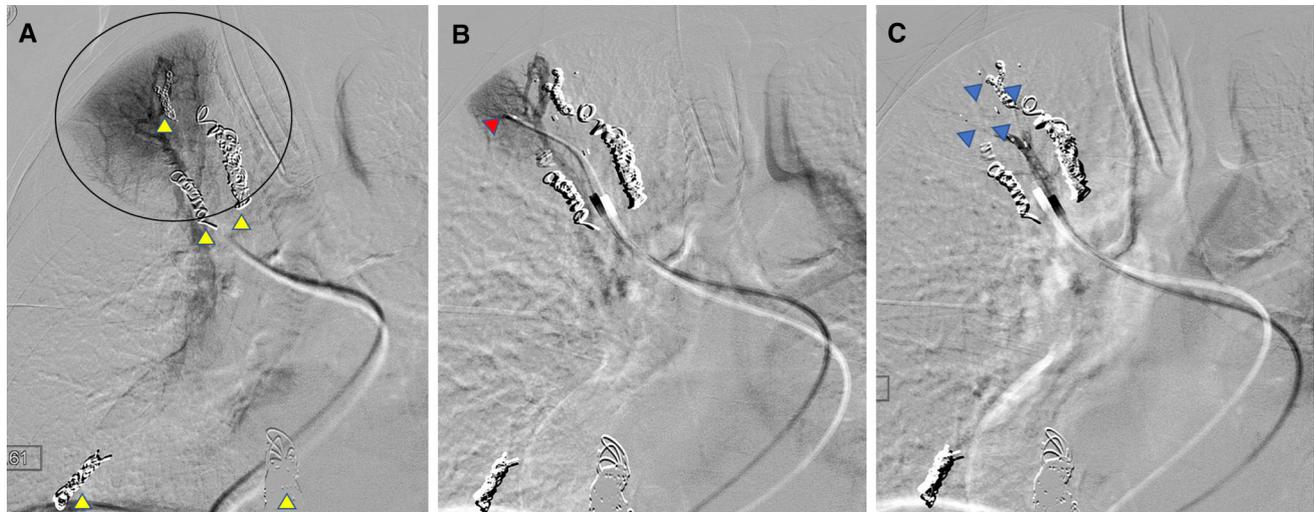
All procedures were technically successful. Mean feeding artery diameter for our study sample was  $3.3 \pm 1.2$  mm (range 2 to 7.9 mm). Eighty-six percent of PAVMs were

simple. Average fluoroscopy time per procedure and contrast volume administered per procedure were  $35 \pm 16$  min and  $217 \pm 101$  mL, respectively. A mean of  $1.3 \pm 0.8$  MVP™ systems was used per PAVM (Table 2).

Ninety-three of 119 PAVMs had follow-up CTA or pulmonary angiography. Eighty-five percent of these PAVMs with follow-up CTA were simple PAVMs. There were no instances of persistence (specifically no recanalization, pulmonary-to-pulmonary reperfusion, incomplete primary treatment, or systemic-to-pulmonary reperfusion) at a mean follow-up time of  $328 \pm 258$  days (range 26 to 914 days). There were no major and 1 minor complication(s): 1 case of post-procedural pleurisy that resolved without intervention (Fig. 4).

**Table 2** Summary of procedural characteristics (119 PAVMs treated with 153 MVP™ systems in 69 procedures)

	Mean	Standard deviation	Range
Feeding artery diameter, mm	3.3	1.2	2–7.9
Fluoroscopy time, min	35	16	10.7–71.3
Contrast volume, mL	217	101	40–440
Number of MVP™ systems per PAVM	1.3	0.8	1–7
Follow-up duration, days	328	258	26–914



**Fig. 4** Embolization of a complex pulmonary arteriovenous malformation (PAVM) using multiple MVP™ micro vascular plug system, 3 MVP-3 devices and 1 MVP-5 device. **A** pre-treatment angiogram demonstrating PAVM with 4 feeding arteries. Note the patient has multiple PAVMs treated with coils (yellow arrow heads),

**B** deployment of MVP-3 devices (red arrow head), **C** post-treatment angiogram demonstrating successful occlusion of 4 feeding arteries with 4 MVP™ systems (blue arrow heads) (3 MVP-3 devices and 1 MVP-5 device)

## Discussion

At our institution, we have found MVP™ systems to be both safe and effective for the treatment of PAVMs. Our dataset over the past 4 years demonstrates that treatment of PAVMs with MVP™ systems produces a high technical success rate with no major complications and no evidence of persistence.

MVP™ systems were primarily used for PAVMs measuring 2 to 7.9 mm (mean  $3.3 \pm 1.2$  mm). It is highly likely that this range will shift over time to include larger vessels. Given that, for most of the study period, the MVP-7 devices and MVP-9 devices were unavailable. In fact, only within the final year of this study period were the largest MVP™ systems (MVP-7 devices and MVP-9 devices) available at our institution. Future research is necessary to determine the safety and efficacy of MVP-7 devices and MVP-9 devices and how they compare with AVPs for PAVMs with larger feeding arteries.

The lack of persistence is consistent with smaller studies of PAVM embolization with MVP™ systems [19]. Our study and the current literature demonstrate that MVP™

systems have considerably lower persistence rates compared with published data for AVPs [1–29%] [6, 13–15] and for coils [4–57%] [2, 9–11, 13]. The lack of persistence when using MVP™ systems for PAVM embolization is likely attributable to its design, featuring a nitinol scaffolding with a polytetrafluoroethylene covering that provides instantaneous occlusion (compared with AVPs, which take 2–5 min for occlusion [24]).

Although MVP™ systems are still the most expensive solid embolic device on the market today, typically only 1 device is required to occlude a PAVM (mean 1.3 MVP™ system per PAVM) compared with coil embolization, which usually requires multiple coils [25]. Because numerous coils are required to occlude a typical PAVM, coils tend to be a more expensive method of embolization in our practice. Although this cost could be mitigated by using less expensive, nondetachable coils, the use of detachable devices is standard in our practice to achieve a dense coil pack [22], as well as to prevent embolic migration and to reduce the risk of paradoxical embolism [23]. In addition, the lack of persistence in the MVP™ system group may mitigate the need for retreatment, which

would make it a more affordable option over time when compared with coils and AVPs, which have higher persistence rates. A controlled cost analysis will be required to fully address this question and would greatly aid interventionalists in their decision-making process.

Our study has limitations, including its retrospective design, small sample size, and variable CTA follow-up regime. Analysis of persistence rates was limited because of the rarity of persistence and variable duration of follow-up in this sample.

In summary, for PAVMs with feeding arteries in the range of 2 to 7.9 mm (mean  $3.3 \pm 1.2$  mm), MVP™ systems are safe and effective given their high technical success rates and lack of persistence. Further prospective work will be required to elucidate the advantages and disadvantages of these MVP™ systems for PAVM embolization in terms of cost and procedural efficiency.

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#### Compliance with Ethical Standards

**Conflict of interest** Dr. Weiss has received research grants from Medtronic, Siemens Healthcare, Merit Medical, and BTG, and he is a consultant for BTG and Medtronic. Medtronic has provided grant support for this study. A study investigator has received research grants from Siemens Healthcare, Merit Medical, and BTG, and he or she is a consultant for BTG and Medtronic.

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