



# Persistence in Coil-Embolized Pulmonary Arteriovenous Malformations with Feeding Artery Diameters of 3 mm or Less: A Retrospective Single-Center Observational Study

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## ABSTRACT

**Purpose:** To assess persistence in coil-embolized pulmonary arteriovenous malformations (PAVMs) with feeding artery diameters  $\leq 3$  mm.

**Materials and Methods:** Fifty-eight patients (21 male, 37 female; mean age, 43 y; range, 13–71 y) with 141 simple-type PAVMs treated from 2004 to 2014 were analyzed retrospectively. Inclusion criteria were one or more PAVMs with feeding artery diameters  $\leq 3$  mm (“small PAVMs”), treatment with coil embolization, and presence of a follow-up chest computed tomographic (CT) angiogram at approximately 6 months. Feeding artery diameter, total coil length, and coil nest-to-PAVM sac distance were measured on arteriographic images. Coil packing density was estimated. Persistence was defined as less than 70% reduction in PAVM sac size and was assessed for each PAVM with respect to previous arteriogram or CT angiogram. Each variable was statistically tested for association with persistence.

**Results:** On follow-up CT arteriography, 111 of 141 PAVMs (79%) showed a 70% or greater reduction in size of the sac and were deemed not persistent. The remaining 30 (21%) with unchanged or minimally reduced sac sizes were classified as persistent. Feeding artery diameter, coil size, quantity of coils, shape of coils, coil nest length, compaction, and visible packing density did not affect persistence, but coil nest-to-sac distance was directly correlated with persistence ( $P < .006$ ). This result held true even with nest-to-sac distances of less than 1 cm.

**Conclusions:** Small PAVMs have a high persistence rate after coil embolotherapy. Most previously described risk factors for PAVM persistence do not seem to apply to these PAVMs, with the exception of coil nest-to-sac distance.

## ABBREVIATIONS

ACT = activated clotting time, HHT = hereditary hemorrhagic telangiectasia, PAVM = pulmonary arteriovenous malformation

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For decades, pulmonary arteriovenous malformations (PAVMs) have been treated by embolotherapy (1). PAVMs are treated to avert a number of serious sequelae. Adverse outcomes from these right-to-left shunts include stroke, transient ischemic attack, abscess in the brain or other organ, myocardial infarction, angina, cyanosis, or exercise intolerance (2,3). Until relatively recently, PAVMs with feeding arteries smaller than 3 mm in diameter (herein “small PAVMs”) were not treated (4). Although it is true that the caliber of feeding arteries of small PAVMs is insufficient to cause desaturation, it has been demonstrated that paradoxical emboli, brain abscess, and stroke are possible even with feeding arteries smaller than 3 mm in diameter (4–7). Consequently, the “3-mm rule” has been supplanted by a recommendation that PAVMs with feeding arteries 2–3 mm in diameter may be treated (8).

The treatment of small PAVMs is complicated by the limited selection of appropriately sized coils (and, until recently, vascular occluders) for this vessel size. As a result, until recently, most small PAVMs could not be treated by using the approaches for which the lowest persistence rates have been reported; namely, deployment of vascular occluders with or without additional coils (4,5). Although the relative deficiency of treatment options for small PAVMs may be improved by the recent introduction of microcatheter-compatible plugs, these devices are far costlier than microcoils. In addition, long-term data regarding their persistence rates have yet to be published.

Despite the hereditary hemorrhagic telangiectasia (HHT) community’s increasing treatment of small PAVMs, there is currently a lack of evidence to assess the success of treatment of these PAVMs, even in the intermediate term. In an effort to address this question, the present retrospective study was performed to investigate the persistence rate of small PAVMs treated with coils alone. Our hypothesis was that variability in the persistence

of small PAVMs in the intermediate follow-up period could be explained by one or more of the following variables: distance of the coil nest to the sac, tightness of the coil nest, appropriateness of the chosen coil diameter for the target vessel, or coil type (shaped vs nonshaped).

## MATERIALS AND METHODS

Institutional review board approval was obtained for this retrospective study, which was carried out in full compliance with the Health Information Portability and Accountability Act.

Fourteen years (2002–2015) of previously recorded PAVM treatment data from a dedicated quality-assurance database were analyzed and filtered for patients who received coil embolization of at least one PAVM with a single feeding artery less than or equal to 3 mm in diameter, which was defined as a small PAVM. Fifty-eight patients (21 male, 37 female) with a mean age of 43 years (range, 13–71 y) were studied. Feeding arteries were measured by using pulmonary arteriographic images with the guiding catheter, catheter, or microcatheter serving as an internal reference. Only “simple-type” small PAVMs were included in this study to reduce the quantity of variables that may confound persistence. Simple-type PAVMs are those that have only one feeding artery and one draining vein (3). To be included in the study, patients were required to have had a follow-up computed tomographic (CT) angiogram at approximately 6 months after primary embolotherapy. Patients were consecutive within the context of the selection criteria. No patient in the study had a coagulopathy or was taking anticoagulation therapy. Use of antiplatelet therapy was not specifically captured but is very rare in the HHT population as a result of exacerbation of epistaxis. Any PAVMs with feeding arteries larger than 3 mm were excluded from the analysis.

**Table 1.** Overview of Microcoil Characteristics

Coil Type	Diameter in Vessel (mm)			Coil Wire Diameter (in)	Extended Length (cm)	No. Deployed (%)
	Complex Shaped	Proximal	Distal			
3/2-mm MicroTornado	Yes	3	2	0.018	1.5	2 (1.4)
4/2-mm MicroTornado	Yes	4	2	0.018	3	1 (0.7)
3/5-mm Tornado	Yes	5	3	0.035	3.6	21 (14.9)
2-mm MicroNester	No	2	2	0.018	7	19 (13.5)
2-mm MicroNester	No	2	2	0.018	14	1 (0.7)
3-mm MicroNester	No	3	3	0.018	7	1 (0.7)
3-mm MicroNester	No	3	3	0.018	14	25 (17.7)
4-mm Nester	No	4	4	0.035	14	11 (7.8)
3-mm VortX	Yes	3	2.5	0.018	3	1 (0.7)
2-mm Hilal	No	2	2	0.018	2	23 (16.3)
Mixed types*	–	–	–	–	–	42 (29.8)

PAVM = pulmonary arteriovenous malformation.

\*Denotes instances in which different coil types were mixed in the treatment of a PAVM.

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