CardioVascular and Interventional Radiology

Cardiovasc Intervent Radiol (1999) 22:210–213

Venous Sac Embolization of Pulmonary Arteriovenous Malformation: Preliminary Experience Using Interlocking Detachable Coils

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Abstract

Purpose: To evaluate the indication and advantages of venous sac embolization of pulmonary arteriovenous malformations (PAVMs) using interlocking detachable coils (IDCs).
Methods: We performed percutaneous embolization in 12 PAVMs in four patients using IDCs, initially placed in the venous sac or at the feeding artery to prevent systemic migration of additional coils. We placed the IDCs in the venous sac in PAVMs with the following vascular architecture: the draining vein was larger than the feeding arteries and both vessels were interposed with the venous sac or there were short feeding arteries.
Results: Complete occlusion was achieved in all 12 PAVMs without significant complications. We deployed IDCs in the venous sac in eight PAVMs and in the feeding artery in four.
Conclusion: Venous sac embolization may be beneficial in PAVMs with large out-flow vessels or short feeding arteries. IDCs are suitable for this procedure.

Key words: Lung—Arteriovenous malformations—Arteries, therapeutic blockade

Pulmonary arteriovenous malformations (PAVMs) are rare congenital anomalies of the pulmonary vessels and are occasionally seen as a manifestation of hereditary hemorrhagic telangiectasia (Rendo-Osler-Weber syndrome), especially in patients with multiple lesions [1]. Since PAVMs are frequently associated with paradoxical embolization, resulting in several neurological deficits including stroke, transient ischemic attack, and brain abscess, embolotherapy is advocated, especially in cases where the feeding arteries exceed 3 mm in diameter [2–4]. Percutaneous embolization, which has become the treatment of choice for PAVMs, is performed using a coil or detachable balloon. With either approach, the more distal embolization of the afferent arteries close to the venous sac is considered to be appropriate to prevent infarction of the adjacent normal lung tissue, and venous sac embolization has been avoided for fear of rupture and thrombus dislodgement during the procedure [5, 6]. However, we believe that venous sac embolization is occasionally useful to resolve the technical difficulties and to reduce the risk of migration of embolic materials in embolotherapy of PAVMs.

We successfully performed venous sac embolization using an interlocking detachable coil (IDC; Boston Scientific Corporation, Natick, MA, USA) in eight PAVMs in four patients. We describe the indication for venous sac embolization of PAVMs and the advantages of IDCs over other standard coils in this procedure.

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Materials and Methods

Patients

We performed percutaneous embolization in 12 PAVMs in four patients (3 women, 1 man; aged 16–66 years, mean 40 years) using IDCs. Two PAVMs were present in three patients and six in one patient. PAVMs were incidentally detected on chest radiograph in

Table 1. Results of embolization of 12 pulmonary arteriovenous malformations

Patient no. Age (years)/Sex	PAVM no.	Size of venous sac (mm)	Diameter of feeding artery (mm)	Diameter of draining vein (mm)	Site of embolization	Number of coils used		Other factors
						IDC	FPC	
1/44/F	1	11	5	6	Venous sac	3	6	
	2	8	3	4	Venous sac	2	4	
2/16/M	3	13	3	5	Venous sac	9	12	
	4	10	3	4	Venous sac	3	0	Short feeding artery
3/66/F	5	20	4	8	Venous sac + feeding artery	8	8	
	6	—	4	4	Feeding artery	2	2	
	7	6	4	4	Feeding artery	2	1	
	8	15	5	5	Feeding artery	3	1	
	9	10	4	7	Venous sac	3	1	Short feeding artery
	10	8	5	5	Feeding artery	3	2	
4/63/F	11	12	4	6	Venous sac + feeding artery	7	28	
	12	10	4	5	Venous sac + feeding artery	3	5	

PAVM = pulmonary arteriovenous malformation; IDC = interlocking detachable coil; FPC = fibered platinum coil

three patients with no clinical symptoms. In the remaining patient with six PAVMs, clinical history of previous frequent cerebral infarctions and dyspnea on excursion raised the suspicion of PAVM.

The diagnosis of PAVMs was established based on the findings of thoracic computed tomography (CT) and pulmonary angiography. All 12 PAVMs were a simple type consisting of one afferent pulmonary artery and one draining vein. The PAVMs were located in the right upper lobe in 1, right middle lobe in 3, right lower lobe in 3, left lingular segment in 4, and left lower lobe in 1. Eleven of 12 PAVMs had venous sacs ranging in size from 6 to 20 mm (mean 11.2 mm) and the remaining PAVM revealed direct communication with an afferent artery and a draining vein without an intervening venous sac. The diameters of the afferent arteries of all PAVMs ranged from 3 to 5 mm (mean 4.0 mm) and that of the draining veins from 4 to 8 mm (mean 5.3 mm). The diameter of the draining vein was larger than that of the feeding artery in eight PAVMs. Two PAVMs with venous sacs had a short afferent artery.

Embolization Technique

A 6–7 Fr wedge-pressure balloon catheter was selectively placed at the lobar pulmonary arteries, and diagnostic angiography was initially performed using digital subtraction angiography (DSA) to confirm the location, number, size, and branching pattern of the feeding artery and the size of both the venous sac and the draining vein. A Tracker 18 catheter (Boston Scientific) with two radiopaque-tip markers was introduced coaxillary over a 0.016-inch microguidewire. The microcatheter was advanced to the afferent artery or into the venous sac of the PAVMs and DSA images were obtained to confirm its location.

In the embolization, we used a 0.018-inch IDC and a 0.018-inch fibered platinum coil (FPC; Boston Scientific). During embolization the balloon was inflated to interrupt blood flow in the feeding artery in order to prevent migration of the coil or thrombus.

In the IDC system, the coil and coil pusher are interposed within the catheter by two interlocking cylinders so that the cylinder attached to the coil is not capable of traveling or escaping beyond the cylinder attached to the coil pusher until the device is pushed out of the catheter, effecting separation. The IDC is released when the coil pusher is advanced until the radiopaque marker on its distal end is superimposed on the proximal marker of the microcatheter. When necessary, the coil can be easily retrieved before the two markers are superimposed, and may be pushed forward again.

We initially placed the IDC either in the venous sac or at the feeding artery to prevent systemic migration of additional coils. Unless the IDC is detached, the coil can easily be retrieved and repositioned repeatedly and its size changed. We chose an IDC with a diameter 10% larger than the size of the structure to be embolized. When the size or the arrangement of the IDC was not thought to be optimal for the venous sac or arteries, the coil was retrieved and redeployed or changed in size until the best fit for the IDC in the lesion was obtained. Available IDC sizes ranged from 2 to 14 mm in diameter and 4 to 20 mm in length. After placement of the IDCs we additionally used FPCs until we confirmed complete obstruction of PAVMs.

As a rule we placed the IDC at the feeding artery, as close to the neck of the venous sac as possible, to avoid occlusion of normal lung vessels. However, we placed the IDC at the venous sac in PAVMs with the following two particular vascular architectures. The first situation was in PAVMs where the draining vein was larger than the feeding artery and both vessels were interposed with the venous sac. In this case, coils adjusted to the size of the feeding artery are likely to migrate if their sizes are not appropriate to fit and fix their positions. We thought we could reduce the risk of migration by placing an IDC that was larger than the outflow vessels in the venous sac. The second situation was in PAVMs with very short feeding arteries. Embolization of such short afferent arteries is technically difficult without significant risk of sacrificing large normal pulmonary arteries.

Results

On pulmonary angiography obtained after embolization, complete occlusion was seen in all 12 PAVMs (Table 1). The procedure was completed without significant complications in all patients. We deployed the IDCs in the venous sac in eight PAVMs and in the feeding artery in four; additional FPC deployment was performed in 11. The mean increase in PaO_2 after embolization was 17.8 mmHg. No significant deterioration of PaO_2 was identified in these patients during

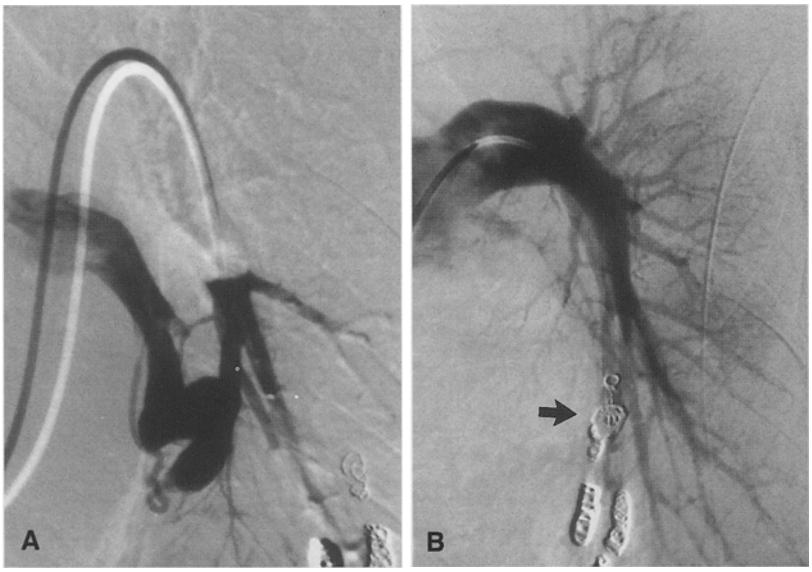

Fig. 1. Venous sac embolization in a PAVM with a short feeding artery. **A** Selective left lower lobe pulmonary arteriography reveals a pulmonary arteriovenous malformation with a short afferent artery. Embolization at the afferent artery was considered to be technically difficult. The venous sac was 10 mm in diameter. **B** We performed venous sac embolization using three IDCs: 12 mm × 20 cm; 10 mm × 20 cm; and 6 mm × 20 cm and one FPC. Pulmonary arteriography after the procedure revealed complete occlusion of the pulmonary AVM (arrow).

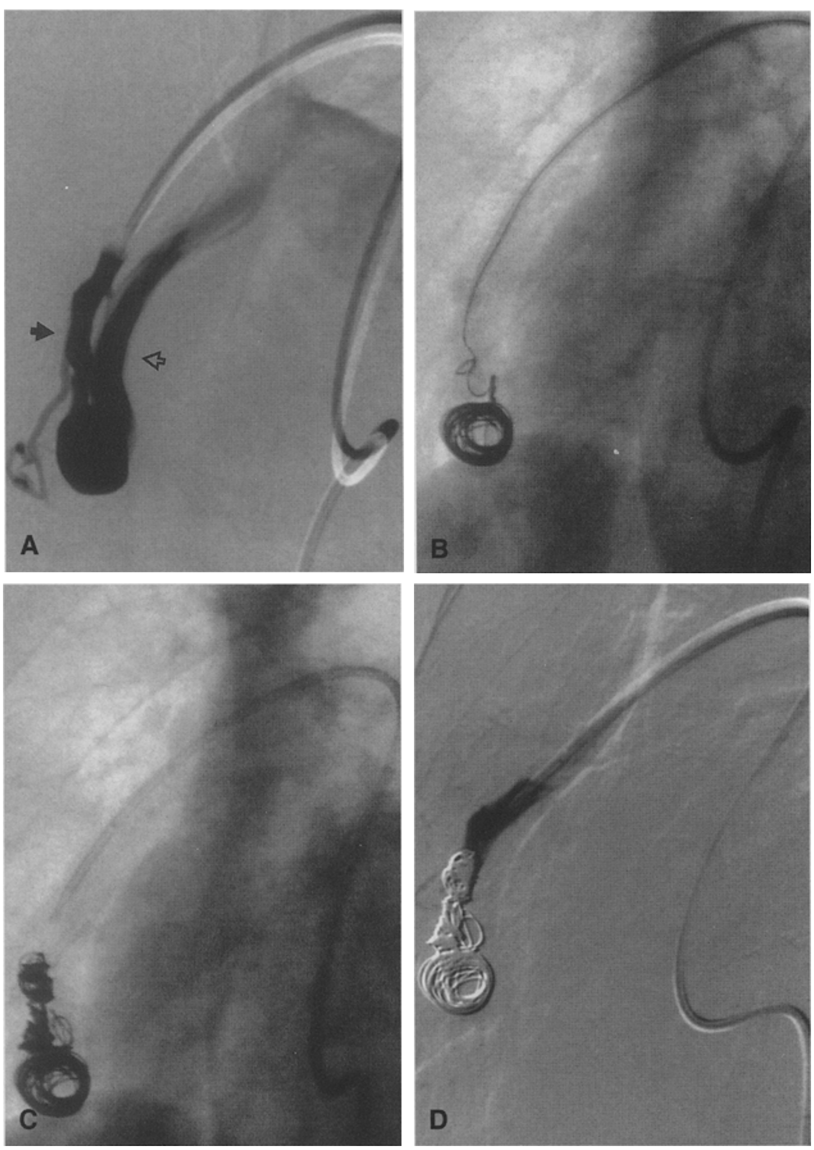

Fig. 2. Venous sac embolization in a PAVM with a large draining vein. **A** Selective pulmonary arteriography of right segment 5 reveals a large pulmonary arteriovenous malformation with a venous sac 20 mm in diameter. The diameters of the afferent artery (arrow) and draining vein (open arrow) are 4 mm and 8 mm, respectively. **B** The venous sac was embolized with six IDCs: one at 14 mm × 20 cm; two at 12 mm × 20 cm; one at 10 mm × 20 cm; one at 9 mm × 20 cm; and one at 6 mm × 20 cm; total length 120 cm). **C** Additional embolization using two IDCs (one at 6 mm × 20 cm, one at 5 mm × 15 cm) and eight FPCs was performed at the afferent artery just proximal to the venous sac. **D** Pulmonary arteriography after embolization reveals complete occlusion of the PAVM.

the follow-up period which ranged from 8 to 44 months (mean 28.0 months).

Venous Sac Embolization

We placed the IDCs in the venous sac in the following eight PAVMs: 2 PAVMs with short feeding arteries (less than 1.5 cm; Fig. 1) and 6 with outflow vessels (mean 5.7 mm, range, 4–8 mm) larger than the feeding arteries (mean 3.8 mm, range 3–5 mm; Fig. 2). The mean diameter of the venous sacs of these eight PAVMs was 11.8 mm (range 8–20 mm). The mean number of IDCs used in the embolization of these venous sacs was 5 (range 2–9). After placement of the IDC, we deployed FPCs in the remaining portion of the venous sac in four PAVMs and in that of the venous sac and feeding artery in three until complete obstruction was obtained. The mean number of FPCs used in the embolization was eight (range 0–28).

Afferent Artery Embolization

An embolization coil was deployed in the feeding artery in four PAVMs in which the risk of paradoxical migration of coil was not considered to be significant. In these four PAVMs (three with venous sac and one without), the sizes of the outflow vessels were approximately the same as those of afferent arteries. The mean diameter of the afferent artery of these four PAVMs was 4.5 mm (range, 4–5 mm). The mean number of IDCs used in the embolization of these afferent arteries was 3 (range 2–3). Additionally, deployment of FPCs was performed in all four lesions. The mean number of FPCs used in the embolization was 2 (range 1–2).

Discussion

In the treatment of PAVMs, transcatheter embolization with a coil or detachable balloon to improve pulmonary gas exchange and lung function and to decrease right to left shunting has been proven to be safe and effective. Most of the complications associated with embolization, including pleuritic chest pain, arrhythmia, hyperventilation, confusion, and air emboli, were transient and required no treatment. However, systemic embolization of a coil or detachable balloon was considered to be a serious complication and its incidence was reported in 0.7%–2% of procedures [2–4]. Paradoxical migration of a coil was likely to occur in PAVMs with high blood flow through dilated afferent and outflow vessels [3]. Especially in PAVMs with larger outflow vessels, coils adjusted to the size of small feeding arteries migrate easily to systemic circulation when they are detached. In six such PAVMs with a larger outflow vessel, we could deploy IDCs larger than the outflow vessels by placing the coil in the venous sac instead of the feeding artery. By using retrievable IDCs in the procedure, the ideal size and exact positioning of the coil within the venous sac was easily determined. The softness and compliant nature of the IDC allowed us to safely place multiple coils to form a complex IDC mass [6, 7]. Interruption of blood flow by inflation of the proximal balloon catheter is another effective method for preventing migration of the coil during the procedure.

We believe that PAVMs with short afferent arteries are also suitable for venous sac embolization. Haitjema et al. [3] described a PAVM with a very short feeding vessel that precluded safe coil placement and that was surgically treated. Coley and Jackson [5], on the other hand, reported successful venous sac coil embolization in two PAVMs with short feeding vessels. We believe IDCs provide some previously mentioned advantages in venous sac embolization in such cases.

We do not advocate routine placement of coils in the venous sac, and in the remaining four PAVMs we deployed the coil in the feeding artery. Coley and Jackson [5] described several reasons that may preclude venous sac embolization: the risk of sac rupture; thrombus formation in the coil and its dislodgement; and impaired pulmonary venous drainage by the coil protruding from the venous sac. Another disadvantage of venous sac coil embolization is that this procedure needs many more coils for packing the venous sac compared with those needed to embolize the feeding artery. In our results, the mean number of coils used in the venous sac tended to be larger than that in the feeding artery embolization. However, in PAVMs in which venous sac embolization is indicated to prevent coil migration, we believe loose venous sac embolization by a smaller number of IDCs instead of complete packing may be sufficient and then we can safely embolize the proximal afferent arteries.

Despite our limited experience, we conclude that venous sac embolization may be beneficial in PAVMs with large outflow vessels and very short feeding arteries, and IDCs are suitable for this procedure.

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