Covered Stents in the Treatment of Pulmonary Arteriovenous Malformations

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ABSTRACT

Seven patients with pulmonary arteriovenous malformations (PAVMs) not well suited to coil and/or plug treatment were treated with expanded polytetrafluoroethylene–covered stents. Mean diameter of treated arteries was 6 mm. Complete technical success was achieved in 7 of 8 PAVMs, 6 using only covered stents and 1 using both a covered and a bare stent owing to endoleak. In 1 patient, the parent vessel was sacrificed after identification of additional feeding vessels following stent graft placement. In 6 patients with median imaging follow-up of 8 months (range, 1–121 months), all stent grafts were patent, and all treated PAVMs were completely excluded without persistence.

ABBREVIATION

PAVM = pulmonary arteriovenous malformation

Embolotherapy is the standard of care for treating pulmonary arteriovenous malformations (PAVMs). For embolotherapy to be used, the vessel being treated must be long enough to accommodate implantation of embolization devices. It is almost unavoidable that the lung tissues distal to the vessel receiving embolization are sacrificed when PAVM embolization procedures are performed, which ultimately results in small pulmonary infarcts. However, every attempt should be made to minimize the quantity of lung being sacrificed, as multiple embolization procedures are often needed by patients with PAVMs during their lifetime (1,2). For some PAVMs, the feeding vessels are sometimes of insufficient length for implantation of traditional embolization devices, such as coils and vascular occluders. For patients who cannot undergo embolotherapy with standard devices, sac embolization, a technique in which the sac is filled with coils, is commonly performed as an alternative (3–5). However, this approach is expensive; may negatively affect future imaging; and may increase the risk of recanalization, particularly if the mouth of the PAVM is left open as would be the case in short-neck PAVMs (4,5). Two separate cases of successful occlusion of PAVMs with covered stents have been previously published, 1 with follow-up data (6). This report describes 7 patients in whom covered stents were used to treat selected PAVMs not well suited to coil and/or plug treatment.

MATERIALS AND METHODS

Seven patients treated for PAVMs with covered stents between 2001 and 2017 were identified through a dedicated PAVM quality assurance database collected prospectively daily from the Interventional Radiology Division's comprehensive quality assurance program (HI-IQ; ConexSys, Lincoln, RI). One of these patients (#1) has been previously reported (7). The median age at presentation was 38 years (range, 15–59 y). Hereditary hemorrhagic telangiectasia was diagnosed in all patients. In 4 patients who had undergone previous embolization, imaging findings showed enlargement or persistence of previously treated PAVMs. Of the 4 patients, 3 had recanalized PAVM feeders, whereas 1 had a persistent PAVM owing to a previously untreated feeder. An example of a patient with a recanalized PAVM and feeder too short for further embolization is illustrated in **Figure 1a–g**. Eight PAVMs in 7 patients were treated by placing covered stents in the parent vessels, thereby preserving downstream

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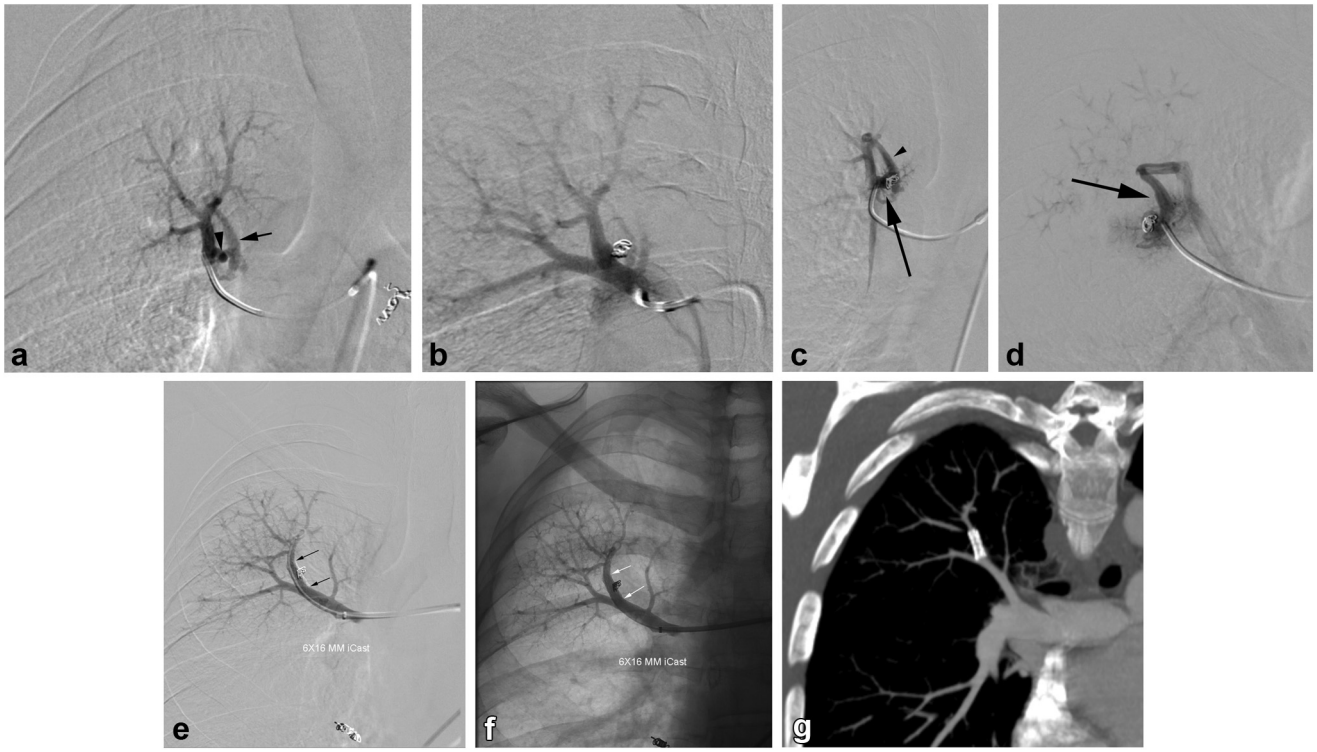

Figure 1. **(a)** Selective right upper lobe pulmonary arteriogram shows PAVM before initial treatment. Note very short communication (arrowhead) between the pulmonary artery (containing catheter) and draining vein (arrow). Note also the large normal pulmonary vascular bed distal to PAVM. **(b)** Selective right upper lobe pulmonary arteriogram after coil embolization shows occlusion of PAVM. **(c)** Selective right upper lobe pulmonary arteriogram obtained at follow-up shows recanalized PAVM with prompt arteriovenous shunting (arrowhead shows draining vein). Note very short remaining vessel between catheter tip and coil nest (arrow). **(d)** Oblique view with catheter tip in the vessel that previously received embolization again shows pronounced shunting with prompt filling of draining vein (arrow). Digitally subtracted **(e)** and native **(f)** images after placement of a covered stent (arrows) show good position and exclusion of the feeding artery with no further flow into PAVM. The parent vessel is well preserved. **(g)** Coronally reformatted image from computed tomography arteriogram obtained 55 months after the procedure shows a patent covered stent with resolution of PAVM.

flow to normal lung, while occluding the PAVM. This represents 1.1% (8 of 723) of all PAVMs treated in 229 patients at the host institution from 2001 to 2017. The principal decision to use a stent graft was based on the presence of (*a*) a short neck (approximately $\leq$ 5 mm long), (*b*) the inability to cross or enter an existing coil nest (using all available tools including microcatheters) in a way that additional coils or plugs could be safely deposited, and (*c*) a desire not to perform parent artery embolization to preserve a large normal downstream pulmonary vascular bed. The mean diameter of the arteries treated was 6 mm (range, 4–8 mm); the stent graft diameter was chosen to approximately match the diameter of the artery without undersizing. Because of the tapering nature of pulmonary arteries, once available, short self-expanding devices were preferred. A 7-F coaxial embolization set (White set; Cook, Inc, Bloomington, Indiana) was used for the embolization procedure. Because the stent grafts used (except JOSTENT Graftmaster; Abbott, Abbott Park, Illinois) were too large to fit through the guiding catheter, the guiding catheter was replaced with a 7-F or 8-F straight braided sheath (Flexor Shuttle; Cook, Inc, or Flexor Raabe; Cook, Inc) for the placement of the stent grafts and arteriography after stent placement. The shortest possible stent graft was used to minimize occlusion of normal side branches, which are usually not seen before embolization of PAVMs owing to competing flow. No antiplatelet or anticoagulant medication was given, as these agents are poorly tolerated in most patients with PAVMs because of epistaxis. All procedures were performed via a transfemoral approach by a board- and certificate of added qualification–certified attending interventional radiologist with $>$ 20 years of experience in PAVM embolotherapy (S.O.T.). Moderate sedation with intravenous midazolam and fentanyl was titrated to effect. Demographic and technical data are shown in the **Table**.

RESULTS

Complete technical success, defined as excluding the PAVM with a covered stent while maintaining patency of the parent vessel, was achieved in 7 of 8 PAVMs (87%), 6 using only covered stents and 1 using both a covered stent and a balloon-expandable stent. In this patient, arteriography performed after stent placement demonstrated persistent filling secondary to incomplete apposition of the proximal