Follow-up of percutaneous transcatheter closure of pulmonary arteriovenous fistulas

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To the Editor: Pulmonary arteriovenous fistula (PAVF) is abnormally dilated vessels that bypass the lung capillary bed, providing a direct right-to-left shunt. The clinical manifestations of PAVF can vary from asymptomatic to dyspnea on exertion, fatigueability, cyanosis, and neurological complications. Patients with congenital PAVF are often associated with hereditary hemorrhagic telangiectasia (HHT) and congenital heart disease. The primary aim of treatment through transcatheter techniques or surgery is to reduce or abrogate abnormal shunt and to prevent severe complications. The development of medical apparatus and instruments has expanded the indications of interventional closure of PAVF. However, data on the efficacy and safety of transcatheter closure of PAVFs is still lacking.

This retrospective study included 13 patients (seven males, six females) aged 1 to 59 years with a diagnosis of PAVF who underwent heart catheterization and/or transcatheter closure of PAVF at Guangdong Cardiovascular Institute (Guangdong, China) between April 2006 and September 2016. All patients were diagnosed with a PAVF through contrast-enhanced cardiac computed tomography. The case records, test results, and data collected via a telephone follow-up were obtained. These records were reviewed. Written informed consent was obtained from the patients or their guardians. The study protocol was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of Guangdong General Hospital.

All patients underwent a complete examination before surgery. The patients who underwent interventional procedures during general anesthesia received an intravenous heparin bolus (100 U/kg). Access was obtained through femoral venous or femoral arterial catheters. After heart catheterization (HC), selected left or/and right pulmonary artery angiography was performed based on preoperative examinations to determine the anatomy, location, type, feeding artery, and drainage site of the PAVF. During the procedure when diffuse fistulas could not be confirmed by selective angiography, agitated saline with air was injected into the specific pulmonary artery under monitoring by transesophageal echocardiography. If the PAVF was not diffuse and had the indications for transcatheter occlusion, attempted transcatheter occlusion of the PAVF was performed in available cases. Briefly, 5F or 6F multipurpose catheters or a right coronary guidewire and a 0.32 inch x 260 mm guidewire and a 0.035 inch x 260 mm super stiff straight tip were used to access the feeding artery and/or fistula and a delivery system was created. Occlusion devices, such as coils, an Amplatzer vascular plug, or a Lifetech vascular plug, were deployed through a delivery sheath. The oxygen saturation, 12-lead electrocardiography, blood pressure, and clinical manifestations were monitored for 15 to 20 min after device deployment. Selective pulmonary artery angiography was performed to evaluate and confirm the blood supply of nearby lung tissue. In our center, acute success of a transcatheter occlusion is defined as an increase in postoperative arterial oxygen saturation to over 90%.

Occlusion devices were chosen based on the size and anatomic features of the feeding artery. The devices utilized included the following: Lifetech vascular plug (LVP) (Lifetech Scientific, Shenzhen, China), Amplatzer vascular plug I/plug II (AGA Medical Corporation, MN, USA), and Cook coils (William Cook Europe, Bjaeverskov, Denmark).

The age of the 13 patients at the time of the procedure ranged from 1 to 55 years, with a median of 25 (10, 28). Their body weight ranged from 9 kg to 72 kg. Five patients (5/13) were asymptomatic, seven patients (7/13) had cyanosis and polypnea, and one (1/13) was hospitalized due to hemoptysis. Based on clinical symptoms and family
history, three patients were diagnosed with HHT before the procedure (1/13) and during the follow-up (2/13). Electrocardiographic examination before the procedure showed left ventricular super voltage in two patients (2/13), Wolff-Parkinson-White syndrome (WPW) type B in one patient (1/13), frequent premature ventricular beats in one patient (1/13), and sinus tachycardia in one patient (1/13). On echocardiography, both the left atrium (LA) and left ventricle (LV) were dilated in one patient (1/13). LV dilation was detected in three patients (3/13) and patent foramen ovale (PFO) was detected in one patient (1/13).

Thirteen patients had accepted HC and 10 (10/13) of them were successfully treated by transcatheter occlusion. However, three patients were not accepted for attempted transcatheter occlusion due to diffuse or multi-lobar lesions. PAVF characteristics, procedural data, and the devices used are presented in Table 1. The pulmonary to systemic blood flow ratio (Qp/Qs) was calculated based on the oxygen saturation at a different location to estimate left to right shunting. Available Qp/Qs ratios revealed an average shunt ratio of (1.72 ± 0.20): 1 (range from 1.23:1 to 2.13:1). The anatomical morphology of the PAVFs was presented completely before occlusion by selective and repeated angiography. The results showed that four patients (4/13) had a single feeding artery, five patients (5/13) had double feeding arteries, one patient (1/13) had triple feeding arteries, one patient (1/13) had multiple feeding arteries, and two (2/13) had diffuse fistulas on the first procedure. The mean diameter of the feeding arteries was 4.99 ± 1.92 mm (range from 2.7 mm to 8.1 mm) (n = 14). Two patients (2/10) underwent re-intervention for occlusion of new-onset PAVF. This was performed once for one patient and twice for the other patient. One patient (1/10) underwent lobectomy for recanalization of the PAVF. Three patients, two with a diffuse fistula and one with multiple fistulas, with no indications for interventional or surgical procedures, suffered severe PH, heart failure, and even death during the follow-up; this subgroup had the worst prognosis.

The occluder devices used in this study were analyzed retrospectively. The results show that the LVP was deployed in eight cases, coils were deployed in two procedures, the Amplatzer vascular plug II (AVP II) was deployed in two procedures, and the AVP I was deployed in two procedures. Only four patients (4/10) were treated successfully with one occluder. Six (6/10) patients were treated with more than one occluder and two patients had more than one type of device (LVP combined with coil) implanted. There were no serious complications, such as thrombopoiesis, fistula rupture, or occluder detachment, etc., during the procedure and perioperative period.

All 13 patients were available for follow-up after HC and (or) transcatheter occlusion and the mean follow-up period was 7.1 ± 2.7 years (range: 3–12 years). Three patients (3/10), one at 5 months, one at 5 months, and one at 11 months after the first transcatheter occlusion, presented with cyanosis. Two patients were confirmed with recanalization of the fistula and another one with abnormal collateral vessels between the descending thoracic aorta and the pulmonary artery 5 months after the first procedure. The patients with recanalization of their fistula underwent the procedure again: one underwent lobectomy and two underwent re-intervention for the fistula or collateral vessel. Two patients were diagnosed with HHT during the follow-up. Two patients developed CNS complications; one had a diffuse fistula and PFO and developed cerebral infarction in the ninth year of follow-up, and the other with multiple fistulas who had no indication for intervention or lobectomy developed heart failure and cerebral infarction 4 years after HC.

Three patients developed pulmonary artery hypertension (PAH). Among those patients, one was confirmed with mild PAH immediately after the first procedure but had no progression or specific drugs during the 4-year follow-up. Another one who had undergone transcatheter occlusion for a fistula and collateral vessel was found with PAH immediately after the last procedure and developed to severe PAH with high risk. The third patient with a diffuse fistula presented with increased pulmonary artery pressure 3 years after HC and developed to severe PAH. According to the guidelines for pediatric pulmonary hypertension, PAH-targeted therapy in patients with lower-risk PAH is recommended.[11] Of the two patients who had accepted standardized anti-PAH-specific medicines, one patient with a diffuse fistula died from heart failure 4 years after the first HC and another developed severe PH with high risk at the time of data collection.

Percutaneous transcatheter closure is the preferred treatment for PAVF. The surgical success and prognosis are related to the locations and types of fistulas. Briefly, isolated PAVF has a better prognosis than multiple and diffuse PAVFs. In this study, two patients with a diffuse fistula and one patient with multiple fistulas could not accept occlusion or lobectomy. They were all complicated by severe hypoxemia and hyperhemoglobinemia.

In patients with PAVF, more than 50% were associated with hereditary hemorrhagic telangiectasia (HHT), while in HHT, about 15% to 35% were associated with PAVF.[2] HHT is an autosomal dominant disorder characterized by mucocutaneous and visceral vascular malformations that may occur in multiple organs.[3] A diagnosis of HHT is based on at least three of the four following symptoms: spontaneous epistaxis, cutaneous telangiectasia, arteriovenous malformations in internal organs, and a positive family history.[4] In this study, only one was confirmed before the first operation due to recurrent hemorrhina. HHT is always difficult to detect due to the lack of specific symptoms and physical signs during childhood and the prepubertal period. PAVFs associated with HHT probably carry more risk factors than simple PAVFs. Recanalization was found and treated in three cases of PAVF (3/10), two of which were diagnosed with HHT. Furthermore, other complications such as paradoxical embolism, stroke, and hemorrhage also need more attention to PAVFs associated with HHT.

PAVF's and PH with different pathophysiological causes, but some studies reminded that PH associated with PAVFs is worthy of attention. First, some pathogenic mutations in genes are involved in PH and HHT. Second, gastrointestinal-
nal vascular malformation induces the disorders of vasoactive substances of pulmonary vasculature. There were three patients (3/13) developed PH during the follow-up, two of whom had onset after transcatheter occlusion for PAVF and one developed PH 3 years after HC. The true characteristics and causes of PH secondary to PAVF occlusion are still unclear. Firstly, the relative overload of pulmonary circulation after occlusion or lobectomy may be the trigger of PAH. Secondly, the abnormal development of pulmonary vasculature during embryonic period is the root of PAVF and PH.

The most prominent disorders and complications of PAVF are hypoxemia and neurological paradoxical embolism. The incidence rate of neurological complications is more than 38% in PAVF.[5] We also found that PFO can coexist with PAVF and it is often misdiagnosed.

Transcatheter closure is an effective therapy for PAVF. However, more prudent treatment and more rigorous follow-ups are needed, especially in cases where PAVF is associated with HHT.

**Declaration of patient consent**

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due

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**Table 1: Clinical characteristics and procedural data from the cardiac catheterizations and (or not) transcatheter closure of PAVFs.**

| Patient number | Age (years) | Sex | Presentation | Location | FA (mm) |
|----------------|-------------|-----|--------------|----------|---------|
| 1              | 2.5         | Male| Asymptomatic | RLL      | 6.0     |
| 2              | 2.5         | Male| Asymptomatic | LLL      | 8.0+5.0 |
| 3              | 17          | Male| Cyanosis     | BL       | Diffuse |
| 4              | 22          | Female| Asymptomatic | LLL      | 4.4+2.8+2.7 |
| 5              | 30          | Female| Hemoptysis   | RML_RUL  | 2.0+4.0 |
| 6              | 5           | Male| Cyanosis     | LLL      | Multiple |
| 7              | 15          | Female| Polypnea and Cyanosis | LUL+RUL | 6.5+4.5 |
| 8              | 2.5         | Male| Asymptomatic | LUL      | 8.0+3.0 |
| 9              | 1           | Male| Cyanosis     | LUL+LLL  | 5.3+2.0 |
| 10             | 2.5         | Male| Asymptomatic | BL       | 5.2+6.0+4.0 |
| 11             | 59          | Female| Polypnea and Cyanosis | LUL+LLL | Diffuse |
| 12             | 1           | Female| Cyanosis     | LLL      | 8.0     |
| 13             | 32          | Female| Cyanosis     | LLL+RML  | 6.2+4.6 |

| Patient number | Qp/Qs | SaO2 pre-op | SaO2 po-op | Devices (size) | Ending event | HHT |
|----------------|-------|-------------|-------------|----------------|--------------|-----|
| 1              | 1.63  | 84%         | 97%         | AVP (12 mm)    | No           | No  |
| 2              | 2.07  | 81%         | 99%         | AVP (12 mm+8 mm) | No           | No  |
| 3              | 1.47  | 86%         |             | CI             | No           | No  |
| 4              | 2.13  | 79%         | 96%         | LVP (10 mm+6 mm) | No           | No  |
| 5              | 1.47  | 89%         | 98%         | Coils (2 3×3+2 5×5) | RC           | Yes |
| 6              | 1.62  | 72%         | 95%         | LVP (24 mm)    | No           | No  |
| 7              | 1.74  | 73%         | 92%         | LVP (14 mm+12 mm) | RC+PH        | Yes |
| 8              | 1.23  | 86%         | 94%         | LVP (8 mm)     | No           | No  |
| 9              | 1.53  | 82%         | 95%         | LVP (14 mm)    | No           | No  |
| 10             | 1.99  | 79%         | 93%         | AVP II (10 mm) | RC+PH        | Yes |
| 11             | 1.74  | 82%         |             | CI             | No           | No  |
| 12             | 1.61  | 83%         |             | Death          | No           | No  |
| 13             | 1.89  | 70%         | 96%         | AVPII (14 mm)  | No           | No  |
| 14             | 1.76  | 87%         | 95%         | LVP (10 mm+8 mm) | GH+PH        | Yes |

AVP: Amplatz vascular plug; BL: bilateral lung; CI: cerebral infarction; DAO: descending aorta; GH: gastrointestinal hemorrhage; HHT: hereditary hemorrhagic telangiectasia; LLL: left lower lobe; LUL: left upper lobe; LVP: Leftech vascular plug; PAVF: pulmonary arteriovenous fistula; PH: pulmonary hypertension; Po-op: postoperative; Qp/Qs: pulmonary to systemic blood flow ratio; RC: recanalization; RLL: right lower lobe; RML: right middle lobe; RUL: right upper lobe; SaO2: oxygen saturation; FA: feeding artery; po-op: post operation.
efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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**Conflicts of interest**

None.

**References**

1. Abman SH, Hansmann G, Archer SL, Ivy DD, Adatia I, Chung WK, et al. Pediatric pulmonary hypertension: guidelines from the American heart association and american thoracic society. Circulation 2015;132 21:2037–2099. doi: 10.1161/CIR.0000000000000329.
2. Shovlin CL. Pulmonary arteriovenous malformations. Am J Respir Crit Care Med 2014;190 11:1217–1228. doi: 10.1164/rccm.201407-1254CL.
3. Lacout A, Pelage JP, Lesur G, Chinet T, Beauchet A, Roume J, et al. Pancreatic involvement in hereditary hemorrhagic telangiectasia: assessment with multidetector helical CT. Radiology 2010;254:479–484. doi: 10.1148/radiol.09090096.
4. Saboo SS, Chamarthy M, Bhalla S, Park H, Sutphin P, Kay F, et al. Pulmonary arteriovenous malformations: diagnosis. Cardiovasc Diagn Ther 2018;8:325–337. doi: 10.21037/cdt.2018.06.01.
5. Palagallo GJ, McWilliams SR, Sekarski LA, Sharma A, Goyal MS, White AJ. The prevalence of malformations of cortical development in a pediatric hereditary hemorrhagic telangiectasia population. AJNR Am J Neuroradiol 2017;38:383–386. doi: 10.3174/ajnr.A4980.

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