Cardiology in the Young

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Transcatheter balloon angioplasty of internal pulmonary artery bands to improve pulmonary blood flow: a case series

Ashwin Srivatsav[1], Lindsay Eilers[2], Asra Khan[2] and Gary Stapleton[3]

[1]Pediatrics, Baylor College of Medicine, Houston, TX, USA; [2]Pediatric Cardiology, Texas Children's Hospital, Houston, TX, USA and [3]Pediatric Cardiology, Medical City Children's Hospital, Dallas, TX, USA

Brief Report

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Corresponding author:
A. Srivatsav; Email: ar.srivatsav@gmail.com

Abstract

Pulmonary artery banding (PAB) is used to restrict pulmonary blood flow in select patients with large left-to-right intracardiac shunts or unrestrictive pulmonary blood flow prior to eventual surgical repair or palliation. More recently, surgical placement of an internal or intraluminal PAB (IPAB) has been used to restrict pulmonary circulation. Here we present two patients who underwent balloon angioplasty of the IPAB to treat cyanosis and improve pulmonary blood flow.

Background

Pulmonary artery banding (PAB) may be used to restrict pulmonary blood flow in select patients with large left-to-right intracardiac shunts or with univentricular hearts and unrestrictive pulmonary blood flow prior to eventual surgical repair or palliation. PAB can be performed by placement of an external band on the main or branch pulmonary arteries (PA) or by surgical placement of an internal or intraluminal PAB (IPAB), the latter of which involves placement of a small fenestrated patch inside the main pulmonary artery (MPA) (Fig. 1). Transcatheter balloon angioplasty (BA) of external PA bands in patients who develop cyanosis can be performed to prolong the time before definitive surgical repair or further palliation. However, there are limited published reports describing BA of an IPAB. Here we present two patients who underwent BA of the IPAB to treat cyanosis and improve pulmonary blood flow.

Case reports

Case 1

An 8-day-old full-term male infant presented in cardiogenic shock with severe multi-organ dysfunction and was diagnosed with critical coarctation of the aorta and a large muscular ventricular septal defect (VSD). He was admitted to the cardiac ICU and started on a continuous prostaglandin infusion (PGE). At 2 weeks of life, he underwent arch advancement and IPAB placement using a bovine pericardial patch with a 4-millimeter (mm) fenestration via an MPA incision at the level of the sino-tubular junction. At 4 weeks of life, he had progressive desaturations and hypoxaemia requiring supplemental oxygen via nasal cannula. Transthoracic echocardiogram demonstrated right ventricular (RV) systolic dysfunction, supra-systemic RV pressures, and increased gradient across the IPAB (Fig. 2). He was taken to the catheterisation lab where baseline arterial saturation on 100% F_iO_2 was 90%. Access was obtained via the right femoral vein, and the PAB was crossed using a 0.014" Choice Floppy Guidewire (Boston Scientific, Marlborough, MA) through a 4F Angled Glidecath (Terumo Medical, Somerset, NJ). Serial IPAB dilation was performed starting with a 4-mm diameter Emerge balloon (Boston Scientific) and then increased by 1-mm diameter increments up to a 7-mm Sterling balloon (Boston Scientific) (Fig. 3). Following dilation, there was an improvement in systemic saturations and the RV pressure decreased to equal that of the systemic circulation. The patient was extubated, weaned to room air, and discharged home 3 days later. A CT scan done for pre-surgical planning at 6 months of age showed a 4.8-mm IPAB fenestration (Fig. 4). All follow-up imaging prior to IPAB removal demonstrated normal branch PA calibre. He subsequently underwent IPAB removal and surgical VSD closure at 7 months of life.

Case 2

A full-term male infant with double outlet right ventricle with D-malposed great arteries and aortic arch hypoplasia was admitted on PGE. At 6 days of life, he underwent aortic arch advancement and IPAB using a bovine pericardial patch with a 4-mm fenestration via a main PA transverse incision. The next day following delayed sternal closure, he became acutely hypoxaemic and required both intubation and escalation of inotropic support. Colour Doppler

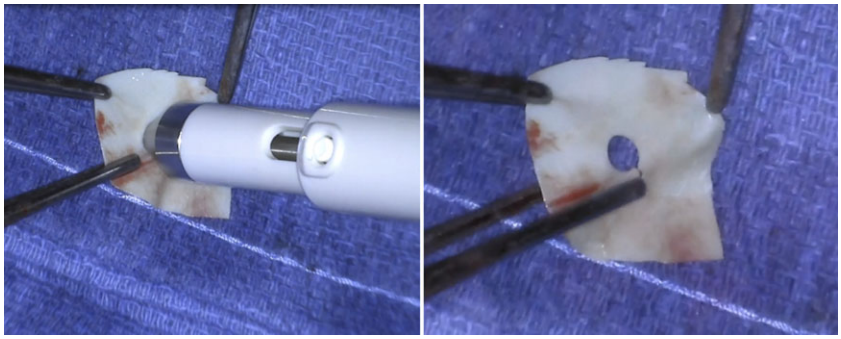

Figure 1. Punch used to create a 4-mm fenestration in a glutaraldehydepreserved bovine pericardial patch.

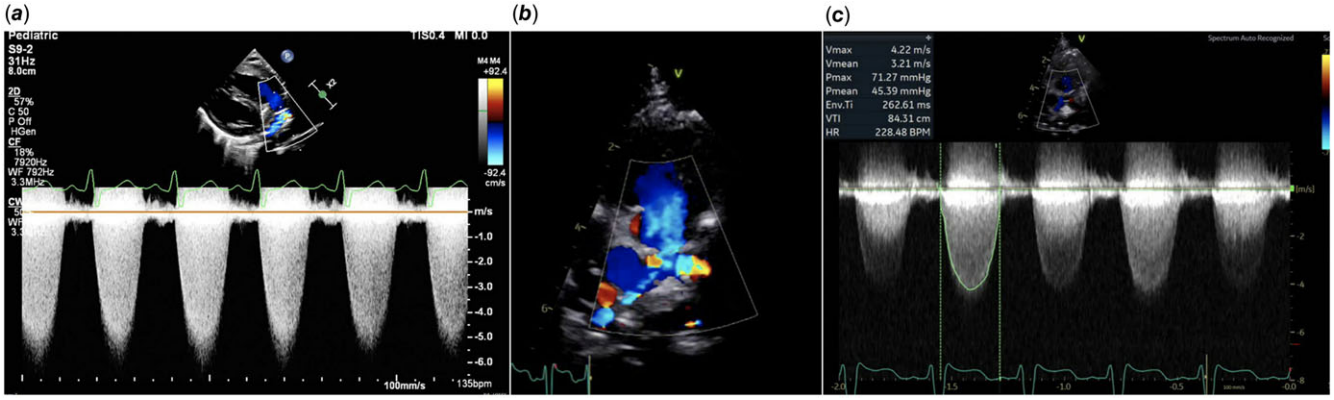

Figure 2. Transthoracic echocardiogram performed for patient 1. (***a***) Pre-balloon angioplasty Doppler of IPAB with peak velocity > 5 m/sec. (***b***) Parasternal short axis view with colour Doppler performed the day following balloon angioplasty of IPAB. (***c***) Post-balloon angioplasty Doppler with peak velocity 4.2 m/sec. IPAB = internal or intraluminal pulmonary artery banding.

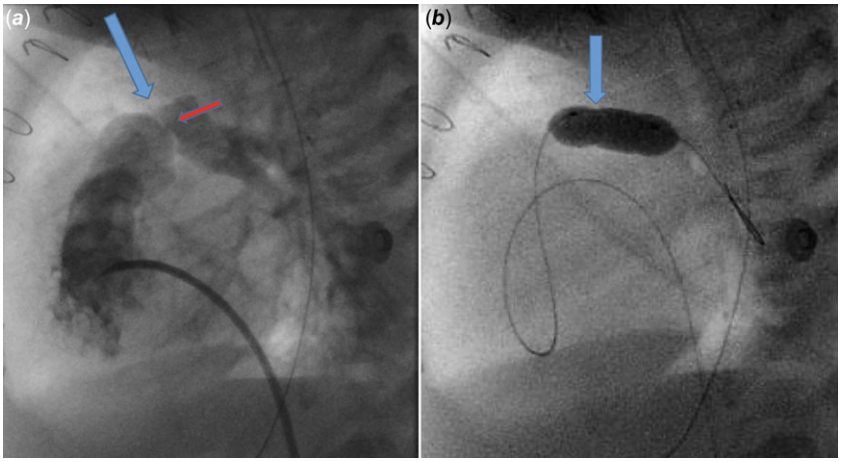

Figure 3. Angiograms for patient 1: (***a***) Lateral projection of RV angiogram showing the IPAB (blue arrow) with narrow, faint contrast jet (red arrow) coming through the fenestration. (***b***) Balloon angioplasty of IPAB using a 7-mm balloon with slight waist seen at full inflation (blue arrow). RV = right ventricular; IPAB = internal or intraluminal pulmonary artery banding.

imaging by transthoracic echocardiogram demonstrated limited flow across the IPAB. He was taken emergently for cardiac catheterisation with an arterial saturation of 69% on 100% F_iO_2. The IPAB was crossed with a 0.014" Choice wire via right femoral venous access, and serial dilation of the IPAB was performed with a 5-mm Emerge balloon, followed by 6-mm and 7-mm Sterling balloons. Systemic saturations improved to 80% with 30% F_iO_2. He was discharged home 3 weeks later; however, at 3 months of age, he presented again with hypoxaemia. He was again referred to the catheterisation laboratory where a repeat BA of the IPAB was performed with a 7-mm Sterling balloon. This was again followed by improvement in his systemic saturations, and he subsequently had an uncomplicated course through bi-directional cavopulmonary anastomosis and IPAB removal (with an approximately 5-mm fenestration) at 5 months of life. Follow-up echocardiograms demonstrated a widely patent Glenn anastomosis and right pulmonary artery but a mildly hypoplastic left pulmonary artery.

Discussion

Surgical PAB was first reported in 1952 and has since been used for palliation of select patients with large left-to-right shunts or with univentricular hearts and unprotected pulmonary blood flows.[1] PAB band placement minimises pulmonary overcirculation,

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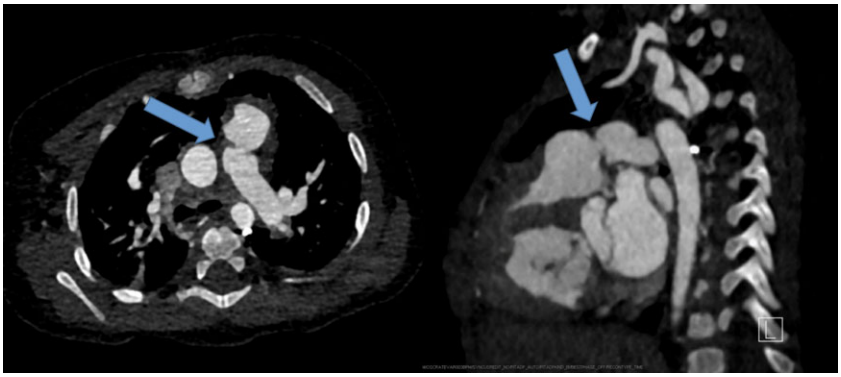

Figure 4. Axial and sagittal view from computed tomography angiography for patient 1 obtained 5 months after BA of IPAB demonstrating a patent fenestration (blue arrows) measuring 4.8 mm. BA = balloon angioplasty; IPAB = internal or intraluminal pulmonary artery banding.

protects the pulmonary vascular bed, and reduces the risks of both vascular remodelling and development of pulmonary hypertension.[2] Historically, PAB involved the placement of an external band on the main or branch PA. While highly effective, associated complications include stenosis of the main or branch PA, PA pseudoaneurysm formation, increased risk of haemolysis or thrombosis, and local infection.[2] More recently, surgical placement of IPAB has been used by placing a bovine or porcine pericardial patch with a small fenestration inside the main PA resulting in effective restriction of pulmonary blood flow by creating a known luminal diameter within the PAs.[3–7] As such, IPAB offers an alternative option for patients requiring cardiopulmonary bypass (CPB). Similarly, microvascular plugs have been used as a percutaneous option to deliver endoluminal pulmonary flow restrictors.[8]

Following PAB, the need for adjustment due to cyanosis or prolongation of the palliative period prior to surgery is common. While early adjustments for fixed PAB required repeat surgical intervention, the development and increasing use of new techniques and adjustable PAB have allowed for safe, percutaneous adjustments and decreased the need for multiple re-operations.[9–14] Percutaneous balloon dilation has also been explored as a way to loosen external PA bands without re-operation. El-Said et al. reported the successful use of catheter-based balloon dilation of external PAB with an expected increase in pulmonary blood flow in all cases.[12] Similarly, Brown et al. reported effective and safe balloon dilation of both main and bilateral branch external PA bands.[15] Successful BA of novel external PAB techniques is continuing to be reported in the current literature.[16–18]

The literature describing transcatheter BA of IPAB is more limited. To our knowledge, there are only two reports of BA of IPAB to date. Piluiko et al. described the use of percutaneous BA in two patients with internal PAB to treat low arterial saturations.[7] Both patients saw improvement in arterial saturations and were later able to undergo hemi-Fontan procedures. Sandrio et al. also reported the successful use of BA of internal PAB in four patients with a decreasing pressure gradient across the band; however, no significant saturation changes were observed following the procedure.[19]

Our cases describe the third report of successful BA of IPAB to increase pulmonary blood flow. In all three procedures, the IPAB was crossed using a floppy tip coronary guide wire. For the two index procedures, the initial balloon diameter was equal to or 1 mm larger than the initial surgical fenestration in the IPAB. Serial dilation was then performed increasing the balloon diameter by 1 mm until the desired increase was saturation and hemodynamic changes were observed. Our second patient represents the first known report of repeat BA of an IPAB to prolong the period of palliation, increase the time to surgery, and provide further time for patient growth. Given that both patients had ductal-dependent systemic circulation and required aortic arch and pulmonary artery exposure, IPAB provides an effective method of restricting pulmonary blood flow in patients whose surgical approach necessitates CPB.

Conclusion

Transcatheter BA of an IPAB can be used to stretch the fenestration in the IPAB patch, allowing for methodical, serial dilations that reduce resistance across the fenestration and increase pulmonary blood flow, thereby improving systemic saturations. This technique can prolong the time to definitive surgical repair or further palliation, thereby allowing for further patient growth before their next surgical procedure. Further evaluation of this technique in a larger patient population is needed.

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