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Bifurcating stents in the pulmonary arteries: a novel technique to relieve bilateral branch pulmonary artery obstruction

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Abstract

Balloon angioplasty and stent placement in close proximity to the bifurcation of the branch pulmonary arteries can be challenging. Multiple approaches have been previously described, though none of these approaches both treats bilateral proximal branch pulmonary artery stenosis and provides an anchor for a transcatheter pulmonary valve replacement. We report a novel approach that involves serial stent placement and balloon dilation through the struts of the stent in each pulmonary artery, along with balloon expansion of the proximal portion of the stents to the diameter of the main pulmonary artery. In the two cases we describe, this strategy resulted in significant relief of branch pulmonary artery obstruction without compromising the anatomy of the main pulmonary artery segment. This technique can be an effective way to alleviate stenoses of the bilateral proximal branch pulmonary arteries and provide a landing zone for a future transcatheter pulmonary valve.

Indexing Words

tetralogy of Fallot; stenosis; pulmonary valve insufficiency; transcatheter pulmonary valve replacement; melody valve

Introduction

Endovascular stenting is a well-established procedure for treatment of pulmonary artery stenosis.¹ In many cases, stent placement is also required to anchor a transcatheter pulmonary valve replacement.^{2,3} However, stent therapy for stenosis involving the distal main and branch pulmonary artery ostia poses challenges. Several strategies have been

described. The traditional technique involves simultaneous expansion of two stents, one in each pulmonary artery (“kissing” stents).⁴ A second technique involves expansion of one stent in the distal main pulmonary artery (MPA) over one or two balloons with guidewires positioned in each distal branch pulmonary artery (“double-wire” technique).^{5, 6} A more recently described strategy involves expansion of one stent from the distal MPA to a proximal stenotic branch pulmonary artery thereby jailing the other branch pulmonary artery, and then subsequently dilating the jailed vessel with a balloon advanced through the struts of the stent.^{7, 8} While each of these strategies may be useful, none address bilateral branch pulmonary artery stenoses while also permitting subsequent placement of a transcatheter valve. Here we describe a technique designed to accomplish these goals.

Case 1

A 37 year-old man with tetralogy of Fallot had undergone a Waterston shunt at 2 years of age, complete repair with a transannular patch at 7 years of age, and a surgical pulmonary arterioplasty at 10 years of age. Recent non-invasive imaging demonstrated pulmonic stenosis with insufficiency; the patient was referred for cardiac catheterization due to the recent onset of exercise limitation.

Initial hemodynamic assessment demonstrated a right ventricular pressure of 56/7 mmHg with a 21 mmHg gradient across the right ventricular outflow tract. Angiography demonstrated moderate pulmonic regurgitation along with moderate right ventricular dilation and mild dysfunction. There was narrowing of the distal MPA to 12 mm and long-segment proximal right pulmonary artery (RPA) stenosis with a minimum diameter of 9 mm. The left pulmonary artery (LPA) was of adequate size (Fig. 1A). The coronary arteries were distant from the right ventricular outflow tract.

A 20 mm ZMED II balloon (NuMed, Hopkinton, NY) was inflated within the main pulmonary artery and there was an 18 mm central waist at peak inflation. A 26 mm long IntraStent LD Max stent (EV3, Plymouth, MN) was expanded on a 20 mm BiB (NuMED, Hopkinton, NY), traversing the distal MPA to the proximal LPA, thereby bridging the RPA (Fig. 1B). An 8 mm Diamond balloon (Boston Scientific, Natick, MA) was advanced through the struts of the stent over a wire positioned in the RPA and inflated, thereby expanding a cell of the stent. Progressively larger balloons were used to dilate the cell of the stent (Fig. 1C). A 20 mm Atlas balloon (BARD Peripheral Vascular, Tempe, AZ) was advanced to the distal MPA within the LD max stent over a stiff wire positioned in the LPA. The MPA was post-dilated with this balloon and subsequently the RPA was further dilated and the stent strut fractured inferiorly with a 14 mm Atlas balloon.

Next, a Palmaz Genesis PG2510B stent (Cordis, Bridgewater, NJ) was expanded on a 14 mm BiB in the proximal RPA (Fig. 1D). Balloon dilation with a 20 mm Atlas balloon extending from the distal MPA to the proximal LPA was performed (Fig 1E). This dilation improved alignment of the RPA stent with the pulmonary artery bifurcation. Finally, a Melody valve (Medtronic, Minneapolis, MN) was deployed on a 22 mm Ensemble (Medtronic, Minneapolis, MN) delivery system within the previously placed LD Max stent.

After intervention, the right ventricular pressure was reduced to 33/9 mmHg. There was a 5 mmHg gradient between the right ventricle and the LPA and a 10 mmHg gradient between the right ventricle and the RPA. Angiographically, the bifurcating stents were in appropriate position extending from the MPA to the proximal branch pulmonary arteries. There was relief of main and branch pulmonary artery obstruction and trivial insufficiency through the center of the Melody valve (Fig. 1F).

Case 2

A 15 year-old boy with a history of tetralogy of Fallot with pulmonary atresia and transannular homograft patch augmentation of the right ventricular outflow tract was referred for cardiac catheterization due to concern for worsening right ventricular outflow tract obstruction on non-invasive imaging. At one year of age, LPA stenosis had been treated with a Palmaz P188 stent (Cordis, Bridgewater, NJ).

Hemodynamic assessment demonstrated systemic right ventricular pressure of 77/14 mmHg. There was a 54 mmHg gradient from the MPA to the RPA and a 47 mmHg gradient from the MPA to the LPA. Angiography demonstrated normal biventricular function, no significant right ventricular outflow tract obstruction, severe pulmonic insufficiency, and severe bilateral proximal branch pulmonary artery obstruction. The previously placed LPA stent was fractured and overhanging the origin of the RPA (Fig. 2A). The diameters of the proximal RPA, proximal LPA, and distal MPA measured 5 mm, 8 mm, and 15 mm respectively.

Simultaneous balloon dilations of the branch pulmonary arteries were performed with Diamond 12 mm balloons and next with Atlas 14 mm balloons, thereby apposing the proximal portion of the in-situ stent to the pulmonary arterial wall (Fig 2B). Next, an Intrastent LD Max 36 mm long stent was expanded over a 14 mm BiB in the distal MPA and proximal LPA, intentionally jailing the RPA (Fig. 2C). A guidewire was advanced through the struts of the LPA stent into the RPA. The RPA was dilated with progressively larger balloons, the largest being an Atlas Gold 12mm balloon (BARD Peripheral Vascular, Tempe, AZ), widening the struts and opening up the cell of stent (Fig 2D). Subsequently, a 14 mm BiB was advanced to the distal MPA over the wire positioned in the distal LPA and a Diamond 12 mm balloon advanced into the RPA. These balloons were dilated simultaneously in order to expand the proximal portion of the stent to the diameter of the distal MPA (Fig 2E).

Next, another 36 mm long Intrastent LD Max stent was advanced through the dilated struts of the previously placed stent and expanded over a 14 mm BiB, traversing the distal MPA to the proximal RPA, thereby jailing the LPA (Fig. 2F). A guidewire was advanced through the struts of this newly placed RPA stent into the LPA. The LPA was dilated through the struts of the stent with progressively larger balloons, the largest of which was an Atlas Gold 12 mm balloon (Fig. 2G). Finally, a simultaneous dilation was performed with a 14 mm balloon in the RPA and a 12 mm balloon in the LPA (Fig. 2H).

After the interventions, the right ventricular pressure was reduced to 28/12 mmHg, with a 4 mmHg gradient from the right ventricle to the MPA and another 6 mmHg gradient from the

MPA to the RPA. Angiographically, there were bifurcating stents appropriately sized and positioned in each branch pulmonary artery with, effectively, a double-layer of stent fully expanded to the MPA diameter. There was unobstructed flow through the MPA and both branch pulmonary arteries (Fig. 2I).

Discussion

Stent treatment of bifurcation stenoses can be challenging. Several innovative strategies have been described, but none is effective in relieving bilateral obstruction while preserving or creating a landing zone for subsequent transcatheter valve deployment.^{4–8} Boujemline et al (2012) and Violini et al (2013) described an approach to placing a stent in the MPA that would serve as an anchor for a transcatheter pulmonary valve replacement in which one of the branch pulmonary arteries was intentionally jailed and then recovered via balloon dilation through the struts of the stent.^{7, 8} We propose a similar strategy but with modifications to treat bilateral proximal branch pulmonary artery stenosis.

In the two cases we report, there was effective relief of obstruction. Additionally, in both cases the newly stented portion of the distal MPA created a suitable landing zone for a transcatheter Melody valve. In one case the valve was implanted at the same procedure, while in the other the patient did not meet clinical criteria for concurrent valve placement.

An important concern when performing this procedure is that it involves dilating a cell of the stent, which alters its intended geometry. This alteration could potentially weaken the structural integrity of the stent and predispose to stent fracture. While there is no way to quantify this risk in the clinical setting, it should be considered before undertaking this procedure and further studies including long-term follow-up are warranted.

Conclusion

Stenosis in close proximity to the bifurcation of the pulmonary arteries is a challenging problem for which multiple strategies have been described. We report a novel approach that results in relief of all obstructions, creates an appropriate landing zone for transcatheter valve placement, and avoids pulmonary artery jailing. The procedure was successful in both patients for whom this technique was utilized and there were no early complications. The long-term outcome of this extensive stenting procedure remains unknown.

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Figure 1.

A: Angiogram demonstrating discrete distal MPA and long-segment proximal RPA stenosis.

B: MPA-LPA stent (IntraStent LD Max). C: RPA dilation (8 mm Diamond balloon) through

the struts of the stent. D: RPA stent (Palmaz Genesis PG2510B). E: LPA dilation (20 mm

Atlas balloon). F: Angiogram after Melody valve placement demonstrating relief of all obstructions and trivial pulmonary insufficiency.

Figure 2.

A: Angiogram demonstrating severe bilateral proximal branch pulmonary artery stenoses and a fractured in situ LPA stent. B: Simultaneous RPA and LPA dilations (12 mm Diamond balloons). C: MPA-LPA stent (Intrastent LD Max). D: RPA dilation [4 mm Dura Star balloon (Cordis, Bridgewater, NJ)] through the struts of the new LPA stent. E: Simultaneous RPA (12 mm Diamond balloon) and LPA (14 mm BiB) dilations. F: MPA-RPA stent (Intrastent LD Max). G: LPA dilation [8 mm Sterling balloon (Boston Scientific, Natick, MA)] through the struts of the RPA stent. H: Simultaneous RPA (14 mm BiB) and LPA (12 mm Atlas balloon) dilations. I: Angiogram after intervention demonstrating unobstructed pulmonary arteries.