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Double-Barrel Stent With Side-Cell Crush Technique for the Management of Complex Pulmonary Vein Stenosis

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Primary pulmonary vein stenosis is a severe and unrelenting disease often characterized by the development of multivessel obstruction. Endovascular stents have proven to be an effective intervention,[1,2] but as the disease extends to previously healthy vessels over time, treatment is obligatorily piecemeal, and de novo lesions often develop near a preexisting stent. This is a particular challenge in patients with pulmonary vein anatomic subtypes involving common or adjacent venoatrial connections. In such cases, any intervention on the new lesion runs the risk of obstructing access to or damaging the previously placed stent.

To address this challenge, stents can be deployed using a "double barrel" orientation. When a preexisting stent is adjacent to a de novo lesion, the second stent is implanted while a balloon is inflated within the first stent, thus ensuring the de novo wire has not crossed through a side-cell and that the new stent does not crush or obstruct the adjacent vessel. Alternatively, if adjacent lesions are being addressed during the same case, simultaneous stents can be deployed after accessing each individual vessel. This yields immediately satisfactory results with a double-barrel stent orientation, but with subsequent interventions, it can be technically challenging to pass a wire through the true central lumens of each stent. To mitigate this problem, we have modified techniques used to address coronary artery bifurcation lesions.[3] Herein we describe our first instance of using the double-barrel stent side-cell crush technique to address complex pulmonary vein anatomy.

The patient is a singleton male born at 28 weeks gestation with comorbidities including pulmonary hypertension and bronchopulmonary dysplasia requiring tracheostomy and ventilator dependence. At 5 months of age, he underwent his first intervention with a 3.5 × 8 mm Resolute Onyx drug-eluting stent (Medtronic) placed in a recanalized atretic right upper pulmonary vein and balloon angioplasty of a second lesion involving the left upper pulmonary vein (LUPV) venoatrial junction. He then manifested severe progression of disease; at 8 months of age, disease recurred in the LUPV (Figure 1A), which was treated with a 5 × 12 Synergy drug-eluting stent (Boston Scientific) (S^1). At 10 months of age, the disease extended to the proximal left lower pulmonary vein (LLPV) (Figure 1B) which was addressed with a 6 × 12 mm Formula 418 bare metal stent (Cook Medical) (S^2). The left upper and lower pulmonary veins shared a common origin from the left atrium, so the left upper and lower pulmonary vein stents were deployed in a double-barrel orientation (Figure 1C). At 13 months of age, he presented for ongoing rehabilitation with distal extension of disease in the LLPV; at this point, the orientation of his left vein stents became a technical challenge.

Using a 6.5F Destino steerable sheath (Oscar Inc), a 0.014" guide wire was placed through the central lumen of the stent with the greatest potential diameter, in this case S^2 in the LLPV (Figure 1D). Next, using a microcatheter placed within the long sheath, apart from the LLPV wire, the side-cells of both stents were crossed, and distal wire position was established through S^1. Starting with a 2 mm coronary balloon the side-cells are dilated to the target diameter appropriate for upper vein rehabilitation (Figure 1E). This leaves a proximal gap between the 2 stents (Figure 1F). Leaving the upper wire in position, a second balloon is advanced into the lower vein, which is then rehabilitated as indicated. In this case, disease progressed and an additional stent was placed peripherally in the LLPV. Finally, to create a common origin at the venoatrial junction, both LUPV and LLPV balloons are aligned with the proximal edge of the stents and simultaneously inflated to effectively crush the proximal portion of S^1 and dilate the proximal portion of S^2 to create a stented "Y" at the vein bifurcation (Figure 1G). Retrograde pulmonary vein angiogram demonstrates patency of both vessels and a single functional orifice relative to the left atrium (Figure 1H). The final position of each stent is illustrated in the image (Figure 1I). In the 2.5 years since stent modification, the patient has undergone 4 additional interventional procedures with access to the primary vessel and distal branches preserved (Figure 1J). His most recent computed tomography angiography performed at 3.5 years of age demonstrates preserved left vein patency with no extension of disease.

Stents are an essential tool in the treatment of pulmonary vein stenosis, but they have several well-known limitations. As illustrated in this case, disease progression is unpredictable, and previously placed

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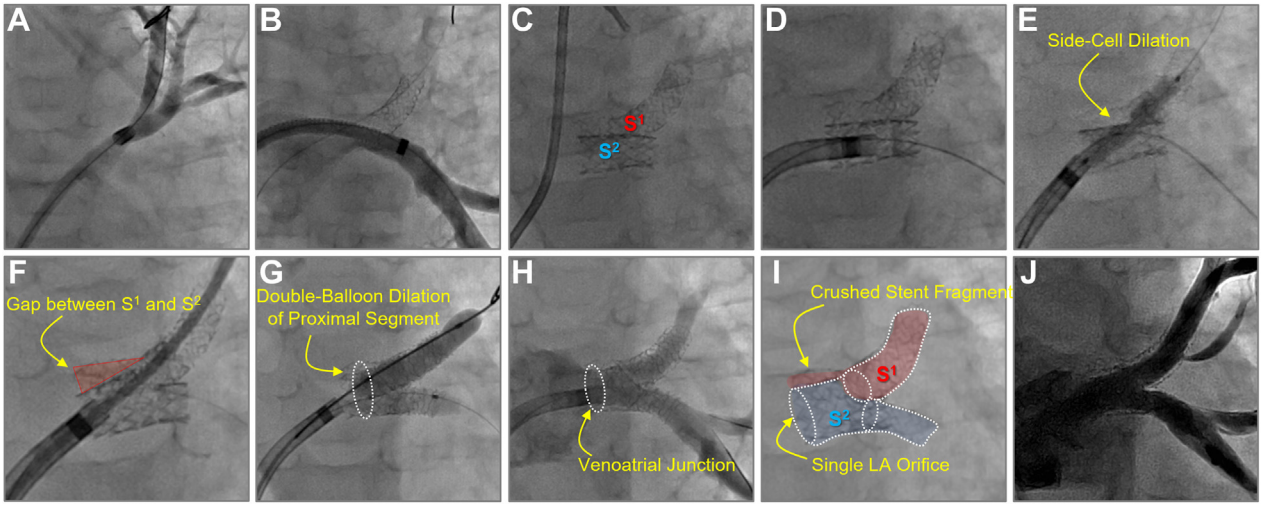

Figure 1.

Stepwise demonstration of the side-cell crush technique. Native lesions in the left upper pulmonary vein (LUPV) and left lower pulmonary vein at the time of stenting are demonstrated in panels (**A**) and (**B**), respectively. (**C**) Stents have previously been deployed in a double-barrel orientation. S^1 in the LUPV and S^2 in the left lower pulmonary vein. (**D**) A guide wire is positioned in S^2, the stent with the greatest potential diameter. (**E**) A second guide wire crosses both stents and terminates in the LUPV; the side-cells are dilated. (**F**) A gap between S^1 and S^2 remains at the venoatrial junction. (**G**) Simultaneous balloon dilation of S^1 and S^2 to crush the proximal portion of S^1 against the vessel wall. (**H**) Angiogram demonstrating the "Y" stent conformation with a single origin at the venoatrial junction. (**I**) Annotated and color-coded demonstration of final stent configuration. (**J**) Repeat angiogram 2.5 years later demonstrating preserved patency. LA, left atrium.

stents can render future interventions more challenging. The side-cell crush technique can be used to simplify pulmonary vein access in the setting of multivessel disease with a common venoatrial origin.

Declaration of competing interest

Paul Tannous is a consultant for Ascend Cardiovascular. Conor P. O'Halloran, Matthew Cornicelli, and Amanda Hauck reported no financial interests.

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Ethics statement and patient consent

This manuscript was prepared in adherence to good clinical practice guidelines and the Declaration of Helsinki. This study was deemed exempt by our local institutional review board.

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