Stent Implantation and Subsequent Dilatation for Pulmonary Vein Stenosis in Pediatric Patients

— Maximizing Effectiveness —

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The outcome of stent implantation and redilatation was investigated in 4 pediatric patients with 7 stenotic lesions of the pulmonary vein (PV), paying particular attention to late neointimal proliferation. The minimal diameter of the lesions increased from 0.8–3.6 (2.3±1.1) mm to 3.6–8.4 (5.1±1.6) mm immediately after stent implantation. Although the pressure gradient across the lesion was not measured in patient 4, in patients 1–3, it decreased from 4–34 (18±13) mmHg to 3–15 (7±4) mmHg. Except for case 4, who achieved a lesion diameter of 8.4 mm after initial stent dilatation, the other 6 lesions all restenosed within a few months, with an increasing pressure gradient. One patient with multiple PV stenoses associated with persistent severe pulmonary hypertension died suddenly. However, repeat dilatations were effective in all other lesions. Furthermore, in one lesion in patient 1, no serious restenosis developed for 20 months after the lesion was dilated up to 5.6 mm. Although further follow-up is mandatory, the final stent diameter within a vessel may determine long-term patency, and aggressive redilatation may be crucial for successful therapy of such a difficult disease. (*Circ J* 2003; 67: 187–190)

Key Words: Dilatation; Patency; Pulmonary vein; Stenosis; Stents

The prognosis for patients with congenital or acquired pulmonary vein (PV) stenosis is usually poor; to date neither surgery nor balloon dilatation has achieved a satisfactory outcome.^{1–7} Although implantation of stents is now widely used for various stenotic lesions in the great vessels,^{8–15} stent procedures for PV stenosis in children have been complicated by late restenosis associated with marked neointimal proliferation.^{10,16,17} We investigated the outcome of stent implantation and redilatation for pediatric PV stenosis, with particular attention to late neointimal proliferation.

Methods

We attempted stenting in 4 patients with 7 stenotic lesions of the PV. Cases 1 and 3, with total anomalous pulmonary venous connection (TAPVC), developed bilateral pulmonary vein occlusion and stenosis at 3 months and 1 month, respectively, after repair of TAPVC. In case 3, an atrial septal defect was created during surgical relief of stenosis to facilitate a transcatheter approach to the lesion. Despite surgical revision and several balloon dilatations, restenosis occurred each time and was complicated by severe lung edema. Consequently we decided to implant stents to improve the hypoxia associated with pulmonary edema.

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In cases 2 and 4, unilateral PV occlusion and stenosis were detected at 13 and 12 months, respectively, after surgery. Cardiac catheterization prior to surgery had not suggested any obstruction and we did not manipulate any of the PVs during surgery. Consequently we could not determine the cause of the obstruction. Although the definitive surgery for the cardiac defects of these patients would have been a Fontan type operation, we did not recommend this for these patients because of poor ventricular function, pulmonary venous obstruction, and pulmonary arteriovenous fistula. Instead we decided to implant stents as a palliative procedure to improve hypoxia (Table 1).

Stent Implantation

We implanted Palmaz stents (Johnson & Johnson Cordis, Miami, FL, USA) in cases 1 and 2, and in the left upper PV in case 3, from the groin through a 7 or 9Fr long sheath^{8–10} Because an acute and tortuous route made it difficult to implant the original Palmaz stent, we implanted Palmaz Corinthian stents (Johnson & Johnson Cordis) in the 2 lesions of case 3, and in case 4. The original Palmaz stents were manually crimped onto high pressure Cordis Power Flex or Opta balloons. The diameter of the balloon was equal to or 1 mm greater than the diameter of the reference vessel. Palmaz Corinthian stents, which were premounted on high-pressure Cordis Opta LP or Jupiter balloons, were implanted through 6Fr long sheath from the groin, except in the case of the right lower PV of patient 3 where we did not use a long sheath. After initial deployment, stents were further expanded as necessary with larger diameter or higher pressure balloons to leave minimal residual stenosis. We used several types of high-pressure balloons in the redilatation procedures (Table 2). Intensive anticoagulation therapy with dipyridamole and coumadin, and tranilast was

Table 1 Characteristics of the Subjects

Case no.	Age (months)	Weight (kg)	Gender	Diagnosis	Previous surgery
1	14	4.6	F	RISO, CAVC, DORV, TAPVC (mixed type), mild PS, bil SVC	CPV-LA anastomosis, rt PVO repair and CAVV plasty
2	29	9.2	F	TA, VSD, ASD, PS	BDG and VSD closure with fenestrated patch, ASD enlargement
3	20	5.2	M	TAPVC (Ia)	TAPVC repair, PVO repair
4	41	9.6	M	PA, unguarded tricuspid orifice, PDA	rt mBT, lt mBT, rt mBT ligation, and lt PVO repair

RISO, right isomerism; CAVC, common atrioventricular canal; DORV, double outlet right ventricle; TAPVC, total anomalous pulmonary venous connection; PS, pulmonary stenosis; bil SVC, bilateral superior vena cava; TA, tricuspid atresia; VSD, ventricular septal defect; ASD, atrial septal defect; PA, pulmonary atresia; PDA, persistent ductus arteriosus; CPV, common pulmonary vein; LA, left atrium; rt, right; PVO, pulmonary vein obstruction; CAVV, common atrioventricular valve; BDG, bidirectional Glenn; mBT, modified Blalock-Taussig shunt; lt, left; up, upper; low, lower.

Table 2 Stent Implantation and Redilatation

Case no.	Lesion	Implanted stents	Redilatation
1	Left upper Right lower	P154 on Opta 4mm, post dilatation with Power Flex 5mm + P154 on Power Flex 6mm P104 on Opta 4mm	Savvy 6mm, Opta 6mm, Blue Max 20 6mm Savvy 5mm, Opta 6mm, Blue Max 20 6mm Power Flex 7mm
2	Left lower	P188 on Power Flex 9mm	None
3	Left upper Right middle Right lower	P206 on Opta 6mm, post dilatation with Power Flex 7mm PQ154BLS + PQ156BLS PQ155BLS	Power Flex 7mm Power Flex 6mm Power Flex 6mm
4	Left lower	PQ185BJS	Power Flex 6mm

Fig 1. Changes in lesion diameter and pressure gradient.

given after the stenting.

Written informed consent for stent implantation and cardiac catheterization was obtained from the patient's

Fig 2. Selective angiograms of a left upper pulmonary vein in case 1. (a) Prior to implantation of a stent (arrow indicates stenosis). (b) After stent implantation. (c) F/U angiogram at 8 months (arrow indicates restenosis). (d) F/U angiogram at 29 months. Restenosis was trivial.

parents.

Data are expressed as mean $\pm$ SD. Statistical comparisons were done by paired t test using StatView 5.0 software (SAS Institute, Cary, NC, USA). A $p < 0.05$ was considered statistically significant.

Results

The minimal diameter of the lesions increased from 0.8–3.6 (2.3 ± 1.1) mm to 3.6–8.4 (5.1 ± 1.6) mm immediately after stent implantation ($p < 0.01$, Fig 1). We could not measure a pressure gradient across the lesion in case 4, but in cases 1–3, it decreased from 4–34 (18 ± 13) mmHg to 3–15 (7 ± 4) mmHg ($p < 0.05$, Fig 2). Although severe pulmonary hypertension persisted in cases 1 and 3, in whom bilateral pulmonary venous obstruction had existed more

<i>Pulmonary vein stenosis</i>
<i>rt up and lt low occlusion, rt low and lt up stenosis</i>
<i>lt up occlusion, lt low stenosis</i>
<i>rt up and lt low occlusion, rt middle, low, and lt low stenosis</i>
<i>lt up occlusion, lt low stenosis</i>

than 1 year prior to stent implantation, lung congestion was ameliorated in all other patients.

Except for case 4, whose lesion diameter increased to 8.4 mm (Fig 3), restenosis with an increasing pressure gradient occurred in the other 6 lesions, developing within a few months. Case 3 had persistent pulmonary hypertension 6 months after the last redilatation of the stent and died suddenly. However, repetitive redilatations were effective in all other lesions. Stent diameter increased in every redilatation from 4.2–6.8 (5.2 ± 0.9) mm to 4.4–6.9 (5.7 ± 1.0) mm, though the increase was not statistically significant. The intimal thickness significantly decreased from 0.1–3.7 (2.3 ± 1.1) mm to 0–1.5 (0.8 ± 0.6) mm ($p < 0.01$). In the left upper PV of case 1, there was no evidence of serious restenosis for 20 months after redilatation of the stent to 5.6 mm using an extra high pressure balloon at 8 months after the initial stent implantation (Figs 1,2).

Discussion

Pulmonary vein stenosis may occur as an isolated lesion in patients with an otherwise normal heart, but more frequently coexists with such congenital heart anomalies as TAPVC, transposition, and other anomalies.^{2,18–20} Although affecting a small number of patients, recurrent post repair PV stenosis may be lethal if it develops bilaterally.^{1,3,6,7,20} In patients with right isomerism, the presence of an obstructed PV is an independent risk factor for a poor prognosis.²¹

A previous study suggested that the presence of echocardiographically defined turbulence within the PVs after repair is associated with restenosis,²² and another study reported that the size of the individual PVs was an important determinant of outcome in patients with TAPVC.²³ Although pediatric data on the outcome of intravascular stent implantation for pulmonary artery and systemic vein stenosis suggests an exceptionally high patency rate, stent procedures in children with congenital or post repair PV stenosis are frequently complicated by restenosis with neointimal proliferation.^{10,16,17} Hosking et al reported that in swine there was no apparent difference in the proliferative responses of the normal systemic veins and the normal PV to the presence of an intravascular stent and they suggested that the final stent diameter within a vessel at the time of stent placement may determine the rate of reocclusion, particularly when the underlying substrate is abnormal with a tendency for neointimal proliferation.²⁴ We have found that, even in the pulmonary artery, a small vessel diameter is a risk factor for excessive late neointimal proliferation.²⁵

In the present study, although the acute results of stenting

Fig 3. Selective angiograms of a left lower pulmonary vein in case 2. (a) Prior to implantation of a stent (arrow indicates stenosis). (b) After stent implantation. (c) F/U angiogram at 5 months. No significant restenosis is documented.

the PVs were promising, restenosis was a major limitation, as reported previously.^{10,16,17} However, repeated redilatations were usually effective, following a slight increase in stent diameter and a striking decrease in the intimal thickness. Furthermore we achieved long-term patency in 2 lesions dilated up to 8.4 and 5.6 mm, respectively. Although further follow-up is mandatory, the final stent diameter within a vessel may be critical for long-term patency and we believe that aggressive redilatation may have a role in the therapy of this difficult disease.

The design of the stent strut may be another important determinant of late restenosis. We used 2 types of stent (ie, the original Palmaz and the Palmaz Corinthian), but we have not yet identified any difference between them because of the small number of lesions tested.

In conclusion, stenting acutely improves PV stenosis, but further investigations on effective measures to prevent restenosis are necessary. Medical treatment to prevent excessive intimal proliferation²⁶ and innovative stent design may be required, but redilatation to achieve an adequate internal diameter of the PV is another option.

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