

Endovascular stent implantation in congenital heart defects

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We report the immediate and short-term results of endovascular stent implantations from our center. We performed stent implantations in four patients (3, 12, 18 and 20 years old) with different stenoses or obstructions: right ventricular outflow conduit obstruction, left Blalock-Taussig obstruction, post-operative recoarctation and cavopulmonary anastomosis obstruction. Stent were implanted successfully. The mean diameters of stenoses were expanded from 4.5 ± 3.5 (2-7) mm to 9 ± 1.2 (8-10) mm, and the complaints of patients were improved significantly by stent implantation. There was no complication related to the procedures. All patients are living except one who died from cerebrovascular event unrelated to the stent implantation. The mean follow-up period of three living patients is 6.3 ± 5.5 (1-2) months. As of the last control, all have remained at the caliber achieved at original placement. In light of our limited experience and previous reported studies, we conclude that intravascular stents are safe and can be used effectively in selected patients with congenital heart defects.

Key words: stent implantation, children, congenital heart defects.

Stent implantation was first suggested and performed experimentally by Dotter¹ in the late 1960s. Stent technology and concept were developed in the early 1980s. Balloon-expandable and self-expanding stents have been used with increasing frequency in children with congenital heart defects since the late 1980s^{2,3}. Endovascular stents have been successfully performed in selected patients with various obstructive lesions^{2,4-9}. Almost all authors conclude that stent implantations are effective and safe in selected patients with congenital heart disease. Although this technique has been performed in many centers all over the world for more than 10 years, it has been used only recently in Turkey. For this reason we report the immediate and short-term results of stent implantations in four cases from our center.

Case Reports

Case 1

A 20-year-old female with isolated dextrocardia with double outlet right ventricle (DORV), atrioventricular discordans, transposition of

great arteries, pulmonary stenosis, and single functional ventricle initially presented at age one with cyanosis. She had cardiac catheterization and angiography at age three in 1981. She then underwent Blalock-Taussig shunt operation in 1982. In her follow-up, progressive cyanosis and hypoxia developed and cardiac catheterization in 1996 revealed partial obstruction and decreased flow in the shunt. Due to the complex cardiac pathology and difficult anatomic nature of her condition, a second right-side Blalock-Taussig (BT) shunt surgery was planned instead of corrective surgery. However, general anesthesia was contraindicated because of severe kyphoscoliosis and decreased lung capacity. For this reason balloon angioplasty and stent implantation were decided in order to maintain flow by widening of the shunt. Left BT shunt was reached retrogradely through the right femoral artery. Aortic injection showed an almost complete obstruction of the shunt that prevented even 0.025 inch guide wire insertion (Fig. 1). The 0.014 inch coronary guide wire was led through left BT shunt towards right pulmonary artery, and balloon angioplasty was

performed by coronary balloon catheter 2 mm in diameter and 2 cm in length. In a repeat catheterization procedure in 15 days, left BT shunt angioplasty was performed by Thysak balloon catheter 5 mm in diameter and 10 mm in length. Post procedure angiography revealed sufficient flow. Following this procedure, 7F (2.33 mm) Easy Wallstent Nom. 10-20 mm (fully open size) self-expandable stent was placed in left BT shunt. While oxygen saturation and diameter of obstructed region were 53.7 percent and 2 mm, respectively, they improved to 92.7 percent and 8 mm by stent implantation (Fig. 2). Heparine infusion (400 IU/kg/day) was continued for 48 hours following procedure and then acetylsalicylic acid was initiated as an antithrombotic agent. No complication related to catheter or stent implantation was noted. After one, six and 12 months, repeat Doppler echocardiographic examinations showed satisfactory shunt flow, and arterial oxygen saturation was 84 percent. During the one-year follow-up period the patient was improved, and we did not see a significant decrease in shunt flow with Doppler echocardiographic study. She also tolerated the Bruce protocol treadmill, testing up to seventh stage without significant reduction in arterial oxygen saturation, in her last control.

Case 2

A 12-year-old male with DORV, malposition of great arteries, ventricular septal defect (VSD),



Fig. 1. Left Blalock-Taussig shunt injection showing almost complete obstruction.

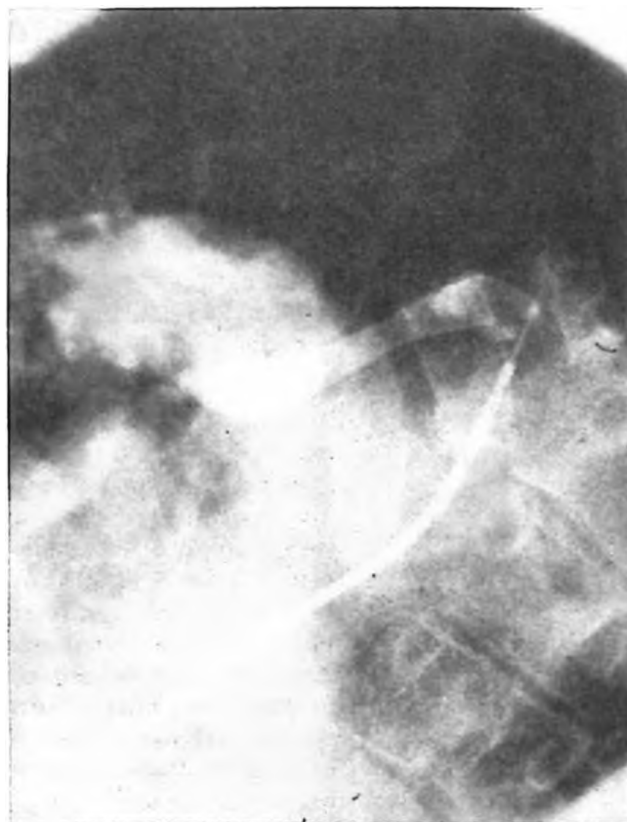


Fig. 2. Expanded left Blalock-Taussig shunt after the self-expandable stent implantation.

pulmonary stenosis and patent foramen ovale was initially brought to our center at age four with severe cyanosis and hypoxic spells. After echocardiographic study the diagnosis was confirmed by cardiac catheterization and angiographic study. He then underwent left BT shunt operation at age five in 1991 and Rastelli's operation at age nine in 1996. In his follow-up, progressive weariness, palpitation and exercise intolerance developed at age 12, and cardiac catheterization in 1999 demonstrated stenosis of the right ventricular conduit (Fig. 3). There was also 150 mmHg systolic flow gradient between the pulmonary arteries and right ventricle. Double balloon angioplasty with Thysak balloon catheter (12 mm in diameter and 4 cm in length) and Z-Med (B. Braun Medical Inc.) balloon catheter (10 mm in diameter and 4 cm in length) was performed to stenotic conduit. Dilatation of stenosis was possible but the stenosis did not remain expanded. Stent implantation was then decided in order to prolong the conduit life and to delay re-operation. The right ventricle was reached through the right femoral vein, and right ventricle injection showed stenosis of the

conduit 2.5 mm in diameter (Fig. 3). An 11F long sheath were advanced over the guide wire into position well across the narrowing. We loaded Palmaz-Schatz 308 balloon-expandable stent (Johnson and Johnson Interventional Systems, Warren NJ) on the balloon angioplasty catheter 10 mm in diameter and 4 cm in length. The balloon and stent were advanced over the wire and into the long sheath. When the stent was in place and centered at the stenosis, the sheath was gradually withdrawn. The balloon was inflated until the narrowing in the balloon disappeared. The stent remained expanded after balloon deflation. After stent implantation, the diameter of the stenosis expanded to 8 mm, and systolic flow gradient through the conduit decreased to 70 mmHg (Fig. 4). There was no complication related to catheterization or stent implantation. His complaints were improved. In his first control one month after procedure, echocardiographic study revealed no significant increase in Doppler gradient across right ventricular outflow tract.

Case 3

A.B. is an 18-year-old young female who presented to our center with fatigue and hypertension at age eight. Physical examination revealed a 2/6 continuous heart murmur, heard best in the posterior left scapular region, weak femoral arterial pulses and phenotype of William syndrome. Echocardiography demonstrated



Fig. 4. Expanded right ventricular conduit after the balloon-expandable stent implantation.

coarctation of aorta with an Doppler gradient of 50 mmHg. The diagnosis was confirmed by cardiac catheterization. Coarctation surgery (resection of coarctation segment and end to end anastomosis) was performed in 1988. During her post-operative follow-up, after 10 years, hypertension was detected. After echocardiography and cardiac catheterization, we found re-coarctation of aorta with a gradient of 40 mmHg through the re-coarctation. The diameter of coarctation was 7 mm and diameter of isthmic aorta was 12 mm. Stent implantation was decided. By using balloon angioplasty catheter (12 mm in diameter and 4 cm in length), Palmaz Schatz P308 (30 mm in length, 3.5 mm in nominal diameter), a balloon-expandable stent (Johnson and Johnson Interventional System, Sommerville, NJ) was placed in post-operative recoarcted segment using the standard method⁴. After the procedure, gradient was reduced to 20 mmHg. Because of residual gradient, repeat balloon dilatation of the stent was performed after two months and the coarcted segment was expanded to maximum of 10 mm and the gradient was reduced to 10 mmHg. There was no complication related to the procedure. Blood pressure was reduced from 160/120 mmHg to 125/85 mmHg. A follow-up period of six months after stent placement demonstrated 24-hour ambulatory blood pressure monitoring in the normal range and a stable Doppler gradient.

Case 4

A three-year-old boy with single ventricle had undergone a pulmonary banding operation at six months of age and a de-Leval operation at



Fig. 3. The stenotic right ventricular conduit.

18 months of age. He presented at age three with hypoxia, edema (especially in upper extremities), and bilateral hydrothorax and was immediately hospitalized in the intensive care unit. Cardiac catheterization revealed stenosis in the anastomosis between the vena cava superior and pulmonary artery. Through the anastomosis, mean gradient was 4 mmHg. Because of his severe symptoms and findings, general anesthesia and surgery were thought to be contraindicated for the patient, and stent implantation was decided. Palmaz Schatz P308 balloon-expandable stent was placed into the cavo-pulmonary anastomosis using Z-Med balloon angioplasty catheter (12 mm in diameter and 3 cm in length). The stent implantation procedure was as described previously by O'Laughlin et al.⁴. Stent implantation resulted in an immediate gradient reduction from 4 mmHg to 0 mmHg and the obstructed segment diameter increased from 5.5 mm to 10 mm. There was no complication related to the catheterization and stent implantation. The patient tolerated the procedure. Although there

Discussion

Endovascular stent implantation is mostly used in selected patients for the treatment of stenotic branch pulmonary arteries⁴, stenotic atriopulmonary and cavopulmonary anastomoses⁵, postoperative systemic venous and systemic venous baffle obstructions⁶, coarctation of aorta, especially segmentary, tortuous and with isthmic hypoplasia^{2,7}, obstructed right ventricular conduits⁸ and for maintenance of ductal patency in neonates and children⁹. We performed stent implantation in four different stenoses or obstructions: right ventricular outflow conduit obstruction, left Blalock-Taussig shunt obstruction, postoperative recoarctation and cavopulmonary anastomosis obstruction (Table 1). Many authors consider stent implantation to right ventricular outflow conduit obstructions, coarctation of aorta, stenotic aortopulmonary collaterals and obstruction of cavopulmonary anastomosis in selected patients a feasible and effective alternative to surgical therapy^{2,8,10-12}.

Table I. Patient Data 1

Name	Age (years)	W	Diagnosis	Stenosis	Stent type	Stent size
RP	20	50	DORV, VSD PS, L-BT shunt	L-BT shunt	Self exp.	8x27 mm
ET	12	33	DORV, VSD, PS, Rastelli op.	RV conduit	Balloon exp.	P308
SA	3	10	Single V, de-Leval op.	VCS-PA anastomosis	Balloon exp.	P308
AB	18	35	CA, surgery for CA	Post-op. recoarctation	Balloon exp.	P308

W : weight.
DORV : double outlet right ventricle.
PS : pulmonary stenosis.
V : ventricle.
PA : pulmonary artery.
exp : expandable.

L-BT : left Blalock-Taussig.
VSD : ventricular septal defect.
op : operation.
VCS : vena cava superior.
CA : coarctation of aorta.

was some decrease in edema, the patient died at the 24th hour after the procedure because of a cerebrovascular event unrelated to the stent implantation. No autopsy was allowed but postmortem study demonstrated the patency of the stent. Therefore, although stent embolization was not present, complications caused by the stent implantation cannot be clearly ruled out in this patient. However, due to placement of the stent in the cavopulmonary anastomosis, any possible embolization would have been pulmonary in nature, so we thus considered that there was no complication related to stent implantation in this patient.

If we look at the previous studies involved with stent implantation into right ventricular conduits, the mean reduction in the gradient across the conduits varies between 33 and 55 percent⁸. There was no significant mortality and morbidity in the previous studies. Authors are suggesting that the stent implantation into the right ventricular outflow tract can provide significant reduction in gradient, and reduction in the number of open heart procedures and conduit replacements⁸. In our patient with right ventricular outflow conduit obstruction, we demonstrated that the obstructed conduit could be expanded by balloon angioplasty, but it

returned to the predilation size after withdrawal of the balloon catheter; the reduction in gradient across outflow tract by stent implantation was 53 percent. So we thus managed a reduction similar in gradient to that seen in the literature. Although a significant reduction was achieved, the patient still has a gradient of 70 mmHg across the conduit (Table II). For this reason, we plan a second redilatation of the stent and, if necessary, a second stent implantation.

these advantages, arrival at the stenosis in an abnormal area is easier than with balloon expandable stents. After the implantation, arterial oxygen saturation and PO₂ improved significantly from 53 to 92 percent (Table II). Acetylsalicylic acid was started in the patient after the procedure and continued for six months. An effective palliation was provided by stent implantation in this patient. We have followed the patient with better exercise

Table II. Patient Data 2

Name	Gradient (before P)	Gradient (after P)	Diameter (before P)	Diameter (after P)	Follow-up	Result
RP	53%*	92%*	2 mm	8 mm	1 year	Alive
ET	150 mmHg	70 mmHg	2.5 mm	8 mm	1 month	Alive
SA	4 mmHg	0 mmHg	5.5 mm	10 mm	1 day	Died
AB	40 mmHg	10 mmHg	7 mm	10 mm	6 months	Alive

* Systemic arterial oxygen saturation.

P: procedure.

Many authors have shown the availability of self-expanding stent implantation to stenotic aortopulmonary collaterals in progressively hypoxemic patients and stenotic right and left lobe collaterals in a case with complex pulmonary atresia^{10,11}. For example, McLeod et al.¹¹ demonstrated an increase in arterial oxygen saturation from 78 to 85 percent by stenting of stenosed aortopulmonary collaterals. In our patient with left B-T shunt, because of deeper localization, surgical treatment was thought to be difficult. And decreased lung capacity resulting from severe progressive kyphoscoliosis contraindicated general anesthesia. We know that surgical results of patients with complex DORV have not been completely satisfactory. Sometimes patients are not suitable for corrective surgery. In such cases with pulmonary stenosis, in order to improve hypoxemia, an adequate aortopulmonary shunt is necessary. Some patients like ours may require a second surgery because of shunt stenosis. On the other hand, due to previous thoracotomy and increased risk of postoperative bleeding and atelectasis, a second surgery may not be favorable. Balloon angioplasty and stent implantation were thus decided in this patient as an alternative to surgery. We selected a self-expanding stent, because it and its delivery system have an advantage of flexibility compared with balloon-expandable stents. Furthermore, during delivery they do not require a stiff guiding long sheath. Given all

capacity and oxygen saturation (stable at 84%) for one year (Table II). There was no significant reduction in oxygen saturation during the follow-up period.

Authors suggest that stenting of aortic coarctation in selected patients is a feasible and effective alternative to surgical or balloon therapy^{2,12}. But the indications for stent implantation are not clearly defined. On the basis of limited experience, the indications are hypoplasia of isthmus or of transverse aortic arch and tortuous coarctation with malalignment of the proximal with the distal aortic segment, which are difficult to treat surgically². Recurrent aortic coarctation or small aneurysm after previous surgical or balloon therapy may be another indication for implantation of stents². If we give an example from the previous studies, Bülbül et al.¹³ reported stent implantation results of six patients with coarctation of aorta and demonstrated a reduction in the systolic pressure gradient from 36.7 ± 16.9 to 13.3 ± 23.2 mmHg. They also performed a successful further dilatation of a stent in one patient. A balloon angioplasty was first performed in our patient with postoperative re-coarctation, but it was unsuccessful, probably due to natural elastic recoil or resistance or remnant scar tissue due to previous surgery. Because of the surgical risks of reoperation, we chose stent implantation. At the time of stent implantation the systolic gradient decreased

from 40 mmHg to 20 mmHg. Because of this residual gradient, we made a further successful balloon dilation two months later and the gradient decreased to 10 mmHg. As a result of stent implantation and a further balloon dilatation, we achieved a good reduction in the systolic gradient (from 40 to 10 mmHg) similar to reported studies, and we could control the systolic blood pressure (Table II). The last control of the patient was done six months after the procedure, and Doppler echocardiographic study revealed no increase in gradient, and ambulatory blood pressure monitoring showed normal values.

In our patient with the obstruction of cavopulmonary anastomosis, there were symptoms related to the superior vena cava syndrome. Surgical relief of such obstruction generally requires cardiopulmonary bypass and often fails to satisfactorily relieve the obstruction⁶. Balloon dilatation may also provide only transient relief of such obstructions because of the elastic recoil of the obstructing tissue or because of restenosis⁶. In such cases Ward et al.⁶ showed a reduction of the systolic gradient from 12 ± 8.4 to 1.3 ± 1.4 mmHg by stent implantation. Given the severe clinical condition of our patient and high risks of reoperation, we decided to implant a stent after which the stenosis and gradient were completely resolved (from 4 to 0 mmHg) (Table II).

We did not see any complications related to the stent implantation during the procedure or follow-up, nor did we find evidence of stent compression or fracture or changing of stent position. One patient died 24 hours after the procedure but from causes unrelated to the stent implantation.

Based on our limited experience and previous reported studies, we conclude that intravascular stents are safe and can be used effectively in selected patients with congenital heart defects. Especially in patients with lesions that are difficult or impossible to treat surgically and in high risk patients, stent implantation can be an alternative and life-saving therapy, at least providing a significant reduction in the number of open heart surgeries.

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