Pediatric Interventions

Stent Implantation to Create Interatrial Communications in Patients With Complex Congenital Heart Disease

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A restrictive interatrial communication can complicate the management of complex congenital heart disease. The purpose of this report is to present a new technique to achieve a patent and reliable interatrial communication by using an endovascular stent. A stent was successfully implanted across a fenestrated extracardiac conduit in two patients with low cardiac output after Fontan operations and across the interatrial septum in a patient with double inlet left ventricle and severe left atrioventricular stenosis. The procedures were uncomplicated and all patients showed immediate hemodynamic improvement. Cathet. Cardiovasc. Intervent. 47:310–313, 1999. © 1999 Wiley-Liss, Inc.

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INTRODUCTION

A restrictive interatrial communication complicates the management of complex congenital heart lesions with the development of atrial hypertension and reduced cardiac output [1,2]. The opening or creation of an interatrial communication may be achieved by balloon or blade septostomy and static balloon dilatation [1] and may offer hemodynamic benefit to the patient following single ventricle palliation [3,4].

Intravascular stents have been successfully employed in patients with various obstructive lesions such as branch pulmonary artery and venous stenosis with excellent anatomic and hemodynamic relief [5]. There are few studies, however, addressing the use of these devices to create or maintain an effective interatrial communication in complex heart lesions [4,6,7]. In this report we describe a new technique for stent implantation in the native atrial septum or Fontan conduit.

CASE REPORTS

Case 1

A 39-month-old boy, weighing 14 kg, had undergone staged palliation for hypoplastic left heart syndrome. A modified Fontan operation with a fenestrated (4 mm) extracardiac conduit (21-mm aortic homograft) and left pulmonary arterioplasty was performed. On the second postoperative day, due to increased right-sided pressures (mean right atrial pressure, 20 mm Hg), high arterial saturations (>90%), and low cardiac output, a cardiac catheterization was performed.

Stenosis at the origin of the right pulmonary artery with a mean gradient of 2 mm Hg was noted and no right-to-left atrial shunt was demonstrated from an angiogram within the atrial conduit. An endovascular stent (Palmaz P204, Johnson & Johnson Interventional, Warren, NJ) was implanted successfully in the right pulmonary artery using standard techniques [5]. The collapsed fenestration was crossed with a wire, and dilated with a 5 mm \( \times \) 2 cm long balloon followed by a 7 mm \( \times \) 2 cm long balloon (Cordis, Miami, FL) with immediate increase in angiographic right-to-left shunting. Right atrial pressure and systemic arterial saturation fell to 18 mm Hg and to 88%, respectively. Nevertheless, the child continued to display signs of low cardiac output and increasing arterial saturation. A transesophageal echocardiogram the Department of Pediatrics, Division of Cardiology, and the Variety Club Catheterization Laboratories, the Hospital for Sick Children, University of Toronto Faculty of Medicine, Toronto, Ontario, Canada

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following day revealed mildly reduced ventricular function and significant ventricular hypertrophy, with almost no shunting across the fenestration. On the fifth postoperative day the child underwent a second catheterization with a view to stent the fenestration. Significant findings included a mean atrial conduit pressure of 20 mm Hg, mean left atrial pressure of 12 mm Hg, systemic arterial saturation of 95% (\(\text{FiO}_2 = 0.65\)), and no angiographic right-to-left shunt through the fenestration.

The general technique of stent delivery was similar to that described for other stent implantations [6]. Heparin sulfate was administered (150 IU/kg) and the fenestration was crossed using a 5 Fr right coronary catheter (Judkins type, Cook, Bloomington, IN) and advanced into the pulmonary venous atrium. A 0.035” exchange guidewire (Cook) was positioned in the pulmonary venous atrium and a long 10 Fr sheath (Cook) with a side port and dilator were advanced through the defect. A stent (Palmaz P204, Johnson & Johnson) was preinflated over a 5-mm balloon. The stent was encircled at its midportion with a 4-0 suture (Dexon, Johnson & Johnson) and secured to a strut. This was tightened so as to achieve a circumference of 5 mm. The prepared stent was hand-crimped over a 12 mm × 2 cm balloon (Cordis) and advanced through the long sheath. The sheath was retracted and the stent exposed across the fenestration. The balloon was inflated allowing both ends of the stent to flare simultaneously on either side of the conduit atrial communication, with the center being restrained to 5 mm by the suture material. After proper stent placement was confirmed by hand injection through the side arm of the sheath, the catheter and wire were carefully removed. There was immediate pressure equalization in the pulmonary and systemic venous atria (mean = 16 mm Hg), the systemic arterial saturation fell to 88% and angiography demonstrated a 5-mm patent fenestration. No immediate complications occurred. A continuous infusion of heparin sulfate (10 IU/kg/hr) was administered after the procedure. Despite the initial favorable hemodynamic results and stent patency confirmed echocardiographically, the child progressed with multigorgan failure and died on the seventh postoperative day. Permission for autopsy was declined.

**Case 2**

The second patient was a 27-month-old boy, weighing 8.9 kg, with a univentricular atrioventricular connection of left ventricular type, ventriculoarterial discordance, severe stenosis of the left AV valve, moderate subpulmonary stenosis, and a ventricular septal defect. Balloon and blade atrial septostomy were performed at 5 days and 5 months of age, respectively, in attempt to enlarge a restrictive atrial septal defect. Subsequently, the child developed progressive subaortic stenosis, massive ventricular hypertrophy, and diastolic dysfunction due to reduction in the ventricular septal defect diameter. Considered unsuitable for a further univentricular palliation (Fontan operation), a cardiac transplantation was declined.

With the development of progressive heart failure, a cardiac catheterization was undertaken with a view to stent the atrial septum as a palliative procedure. The mean left atrial pressure was 22 mm Hg, mean right atrial pressure 12 mm Hg, and systemic arterial saturation 75% with an angiographically restrictive atrial septal defect. Using a Brockenbrough needle (Cook), the atrial septum was marked with 2 ml of contrast (Isovue, Bracco, Princeton, N.J.) and an 8 Fr long sheath subsequently placed in the superior portion of the left atrium using transseptal needle puncture technique. Utilizing a similar technique as described above, a stent (Palmaz, P204, Johnson & Johnson) was mounted over an 8-mm balloon and its circumference limited to 8 mm with a suture. After systemic heparinization, this was positioned across the contrast marked atrial septum using a 12 mm × 2 cm balloon (Cordis), again to flare ends of the stent. The central portion of the stent was limited to 8 mm by the previously placed suture. There was an immediate increase in the systemic arterial saturation to 85% (\(\text{FiO}_2 0.25\)), an increase in the mean right atrial pressure to 13 mm Hg and a drop in the mean left atrial pressure to 18 mm Hg. No immediate complications occurred. Dramatic improvement in congestive signs and symptoms was observed and the child was able to be discharged home on the following day on low-dose acetylsalicylic acid (5 mg/kg/d). Coumadin was not used because of poor compliance. Although repeat echocardiograms demonstrated patency of the stent, the child died 6 months after the procedure due to ongoing cardiac failure. No autopsy was allowed.

**Case 3**

The third patient was a 4.5-year-old boy, weighing 13.5 kg, with right atrial isomerism, an unbalanced atrioventricular septal defect with hypoplastic left ventricle, common atrium, pulmonary atresia with hypoplastic pulmonary arteries and bilateral superior caval veins. The child had undergone an extracardiac fenestrated (4 mm) Fontan operation (23-mm aortic homograft conduit) and left pulmonary arterioplasty after earlier staged palliation. Intraoperative transesophageal echocardiogram revealed ventricular hypertrophy, preservation of systolic function, and spontaneous contrast formation within the Fontan circuit.

After difficulty weaning from cardiopulmonary bypass, the child developed low cardiac output syndrome with high systemic arterial saturations (>90%), increasing serum lactate levels, and high volume of drainage from a peritoneal dialysis catheter. On the first postopera-
tive day cardiac catheterization demonstrated a mean conduit pressure of 15 mm Hg, mean left atrial pressure of 8 mm Hg, stenosis of the right bidirectional cavopulmonary connection, mild narrowing of the inferior caval vein-conduit junction, and a restrictive fenestration (measuring 2 mm). After systemic heparinization, a stent (P154, Palmaz, Johnson & Johnson) was implanted over a 12 mm × 2 cm balloon (Cordis) in the right superior caval vein–right pulmonary artery junction with good anatomic result. Subsequently, another stent (P204, Palmaz, Johnson & Johnson) was inflated over a 5-mm balloon with a suture tied around the circumference at its midportion to 5 mm. This was implanted across the conduit using an 8 mm × 2 cm balloon (Cordis) through an 8 Fr long sheath as described above (Fig. 1).

The fenestration diameter increased to 4 mm and the systemic arterial saturation decreased from 95% to 85%. The procedure was uncomplicated and the child was maintained on continuous heparin sulfate infusion (10 IU/kg/hr). Despite initial hemodynamic improvement, significant peritoneal drainage persisted and the conduit was removed on the following day. At surgery, the stent was widely patent with a diameter of 4 mm and securely placed across the fenestration. No clots were observed within the stent lumen. Although a central shunt was created, the child developed multigener failure and died on the sixth postoperative day. No autopsy was allowed.

**DISCUSSION**

Transcatheter creation or enlargement of a communication between the atria is usually achieved through balloon or blade septostomy and/or static balloon dilation of the interatrial septum [1]. Although these procedures provide adequate immediate palliation, they are usually of only temporary impact as noted by Perry et al. [2] after balloon or blade septostomy in patients with complex lesions associated with left atrioventricular valve stenosis or atresia. Studying a different subset of patients, Kreutzer et al. [4] have recently reported transcatheter creation or enlargement of Fontan fenestrations with balloon dilatation in a small series of postoperative symptomatic patients, with hemodynamic improvement in most, but not all.

Intravascular stents have been used to treat a broad spectrum of stenotic lesions associated with congenital heart disease by preventing vessel elastic recoil and providing long-term patency of the affected vessel [5]. The application of this concept to create a patent and reliable communication between the atrial chambers is attractive. Stent migration and embolization, however, are a significant concern. To enhance the stability of the device within the atrial septum or conduit wall, we created a restricted circumference within its midportion, to a predetermined diameter with suture material, allowing the ends to flare with balloon expansion.

Management of the symptomatic patient after a failed Fontan operation continues to be challenging, difficult, and controversial. Current therapeutic options include surgical takedown and cardiac transplantation [4]. Transcatheter creation or enlargement of fenestration with stent implantation can achieve a reliable communication between the atrial chambers. However, its role in the...
management of these patients remains speculative. Unfortunately, even with an adequate interatrial communication, our two Fontan patients died of low cardiac output due to ongoing failed total cavopulmonary physiology, in part related to diastolic ventricular dysfunction secondary to ventricular hypertrophy. In the series by Kreutzer et al. [4], there was one case of stent implantation across the Fontan baffle with good early term palliation, although no details of the stent implantation technique were described. Miga et al. [6] also reported two patients who developed multiorgan failure after a modified Fontan operation and showed immediate improvement after late stent placement (7 days and 3 months, respectively) into the hemi-Fontan baffles. Both patients died of persistent low cardiac output, despite the presence of fully functional fenestrations. These authors speculated that early intervention in such patients might have led to improved outcome. Late stent placement across an extracardiac Fontan conduit has also been described for the treatment of protein losing enteropathy [7].

Stent implantation in the atrial septum in patient 2 provided a reliable and sustained communication between the atrial chambers with acute relief of pulmonary venous congestion. This type of palliation may have a role as a bridging procedure for patients waiting for cardiac transplantation. This is particularly true in patients with hypoplastic left heart syndrome [8], who can benefit from this technique by attaining a controlled interatrial communication [1].

The possibility of thrombus forming upon the stent struts is a concern, especially in patients after a Fontan operation who, due to low baffle flow, are naturally at risk for this type of complication [9]. Therefore, we feel that anticoagulation should be maintained in patients after this form of palliative procedure.

This report demonstrates the feasibility of stent implantation across the atrial septum or fenestration in patients with complex congenital heart disease in which an adequate interatrial communication is crucial for survival. We describe a new technique for stent implantation that allows for a controlled diameter to be achieved with flaring of the ends of the stent to minimize the risks of inadvertent migration. Further experience and follow-up studies are needed to evaluate the outcome of this palliative procedure.

REFERENCES