Hybrid Intraoperative Pulmonary Artery Stent Placement for Congenital Heart Disease

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Percutaneous branch pulmonary artery (PA) stenting can be challenging, especially in patients with stenosis of the right ventricular (RV) outflow tract or tortuous PA branches. In these cases, a hybrid procedure deploying PA stent(s) during cardiac surgery provides an alternative to relieve branch PA stenosis. The Mayo Clinic Congenital Cardiac surgical database was used to identify all patients having hybrid PA stent procedures. Retrospective analysis of clinical data, procedural details, and outcomes was performed. Between January 1997 and November 2006, 24 patients (15 females), median age 15 years (range 3 to 67 years), had hybrid PA stent procedures. A total of 27 stents were deployed. A left PA stent was placed in 13, right PA stent in 8; 3 patients had bilateral PA stents. Primary cardiac diagnoses were pulmonary atresia (9), tetralogy of Fallot (7), tricuspid atresia (2), and others (6). Maximum balloon diameters ranged from 8 to 16 mm (median = 12 mm). Concomitant surgical procedures performed were RV to PA conduit replacement or RV outflow tract reconstruction (14), pulmonary valve replacement (7), and others (3). Two procedures were performed following complications of percutaneous procedure. There were no deaths or PA damage. There were 2 cases of distal stent migration. Repeat stent dilations within 6 months were performed in 3 patients. In conclusion, hybrid PA stenting can play an important role in the management of congenital heart disease with complex branch PA anatomy. It also can be used as an emergency rescue procedure following complications of percutaneous transcatheter procedures, such as stent embolization. Hybrid procedures were safe and effective in most patients, although stent positioning remains critical. Intraoperative fluoroscopy and active suture fixation of the proximal stent may reduce the need for late re-intervention. © 2008 Elsevier Inc. All rights reserved. (Am J Cardiol 2008;102:1737–1741)

Percutaneous stenting is now an established treatment modality for older children and adults with branch pulmonary artery (PA) stenosis.\textsuperscript{1,2} However, percutaneous stenting can be challenging, especially in patients with stenosis of the right ventricular (RV) outflow tract or tortuous PA branches. In these cases, deploying PA stent(s) during cardiac surgery as a hybrid procedure provides an alternative for relief of branch PA stenosis.\textsuperscript{2–4} Additionally, intraoperative stenting may be the only available alternative in patients with difficult vascular access. Percutaneous stenting is well described in literature, but data regarding the outcomes of intraoperative stenting have been limited.

Methods and Results

The Mayo Clinic Congenital Cardiac surgical database was reviewed to identify all patients having hybrid PA stent procedures. Retrospective analysis of clinical data, procedural details, and outcomes was performed. The study was approved by the Mayo Clinic Institutional Review Board.

All intraoperative stenting was performed by surgeons with expertise in congenital heart disease, assisted by pediatric interventional cardiologists. All procedures were performed under hypothermic cardiopulmonary bypass. No patient required circulatory arrest. All patients had previous angiography to define the size, area, and length of PA stenosis. The stent and delivery balloon size were determined based on angiographic data and calibrated measurements from preoperative cardiac catheterization. In addition, PAs were sized with a Hegar dilator that could be introduced into the PA. Only balloon-expandable stents were used, and all were mounted by hand on a preselected high-pressure balloon (inflatable to 8 to 16 atmospheres). A guide wire was advanced by the surgeon under direct visualization into the PA branch, and the stent/balloon was positioned in the branch PA by the surgeon over this guide wire. The balloon was inflated to the maximum recommended pressure by the interventional cardiologist. The balloon was reinflated distally and proximally after advancing it beyond the ends of the stent to ensure complete inflation. Intraoperative fluoroscopy was not used. Following inflation, the position of stent was confirmed visually.
On follow-up, stent redilation was performed in 3 patients within 6 months; 2 patients appeared to have had initial incomplete inflation of the stent (Figure 3), and in the remaining 1 patient, stent was redilated following diagnostic catheterization for intimal peel formation. All patients had a significant improvement in right ventricular systolic pressure following the procedure. The right ventricle systolic pressure to systemic pressure ratio reduced significantly from a mean of 75 mm Hg (range 55 to 90 mm Hg) to a mean of 45 mm Hg (range 28 to 68 mm Hg). Some of the reduction in right ventricular systolic pressure, however, may be attributed to the concomitant right ventricular outflow tract surgeries.

Discussion

Primary or secondary branch PA stenosis is a common problem in patients with congenital heart disease. Percutaneous stenting may be used for treatment of these stenoses.3 When percutaneous access to the site of stenosis is difficult or absent, however, a “hybrid procedure” can be used. Hybrid procedures in the management of congenital heart disease involve the intraoperative use of catheter-based technology, typically incorporating an open approach to delivery of a device. The first description of a combined surgical and interventional approach in congenital heart disease was reported by Bhati et al5 in 1972 for treatment of patent ductus arteriosus. In a hybrid PA stenting procedure, the stent is placed under direct visualization.6 The data on results of hybrid intraoperative stenting are limited to date,6–10

Intraoperative PA stent procedures may be an option when (1) percutaneous access to the pulmonary circulation is difficult or impossible either because of vascular access issues, complex anatomy, or a mechanical pulmonary valve; 2) concomitant surgery for additional surgical issues; or 3) a rescue procedure following complications of percutaneous procedure. A traditional surgical patch angioplasty for branch PA stenosis may be challenging as the result of difficult surgical access, previous surgical attempts to repair by patch angioplasty, and lack of autologous pericardium. Moreover, circulatory arrest may be needed because of a longer duration of surgery. Intraoperative PA stenting may be a better option than PA patch angioplasty in these cases and can be accomplished in a few minutes.11 Furthermore, complications of percutaneous stent placement, such as hemodynamic instability, balloon rupture, and vascular tear, can be avoided or easily addressed in the operative suite.1 In the case of bilateral severe branch PA stenosis, even transient occlusion of the PA is not tolerated. In these patients, either an elective extracorporeal membrane oxygenation or a hybrid procedure may be needed for stent placement.3,12 Endovascular stents also provide an excellent structural support to the repaired PA, preventing it from collapsing or being compressed by surrounding structures. In all situations possible, balloon-expandable stents with a maximum possible diameter of 18 to 20 mm should be used unless technically impossible because of patient size. However, when such stents are implanted under direct surgical visualization, it is
unusual that a large-diameter stent would not be accommodated, even if mounted on a smaller balloon. If needed, these balloon-expandable stents can be redilated percutaneously at a later date. We have not considered using a self-expanding wall stent because of its greater propensity for endothelial ingrowth and lack of suitability for subsequent redilation.

Potential complications of intraoperative PA stenting are (1) PA dissection or rupture, (2) stent migration, (4) incomplete expansion of stent, (3) stent thrombosis, (4) obstruction of secondary PA branches, (5) stent restenosis, (6) deleterious effect on PA growth, and (7) transient pulmonary edema.¹¹⁻¹⁶ In our cohort, none of the patients needed intervention for PA injury or stent thrombosis. All patients received aspirin therapy postoperatively. Stent migration can be prevented by suturing the proximal end of stent to the PA artery. There has been no incidence of stent migration since these techniques were instituted. Judicious review of preoperative angiograms, proper calibrated measurement, and careful selection of stent length and size should help to prevent potential entrapment of side branches. Ideally, intraoperative stenting should be performed in a hybrid suite with capability for biplane fluoroscopy and angiography.³

Intraoperative PA stenting, however, when performed by
experienced operators, even in the absence of fluoroscopy, may be a safe and effective technique. The potential adverse long-term effect of a stent on future PA growth is an important concern. However, judicious patient selection, careful follow-up, and redilation of balloon-expandable stents when needed will alleviate some of these issues.


Figure 2. (A) Proximal right pulmonary artery stenosis (arrow) with severe right ventricular outflow tract conduit valve (arrowhead) regurgitation. (B) Follow-up cardiac catheterization showing the appropriately placed stent and the replaced pulmonary valve (arrowhead).

Figure 3. (A) Incomplete inflation (arrow) of the right pulmonary artery stent placed during hybrid procedure. (B) Percutaneous dilation (arrow) of stent on follow-up.


