Intraoperative assessment after pediatric cardiac surgical repair: Initial experience with C-arm angiography

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Surgical excellence in pediatric cardiac surgery depends, to a large extent, on the ability and willingness of the surgeon to verify the effectiveness of the repair after cardiopulmonary bypass. Traditionally, this has been accomplished by means of direct cardiac chamber measurements of pressure or saturation supplemented by echocardiographic analysis. Nonetheless, these barometric and imaging tools have limitations in specific situations, such as evaluation of systemic–pulmonary shunts (APSs), coronary vessels, pulmonary arteries (PAs), right ventricle–PA conduits, and major aortopulmonary collateral arteries (MAPCAs) after unifocalization.

Since June 2008, we have allocated a portable C-arm (Philips BV Pulsera) to the cardiac operating room (OR) at Children's Hospital Boston. This report details our experience from June 2008 to June 2009 and describes 2 cases in which the outcome was favorably altered after its application.

CLINICAL SUMMARY

Patient 1

A 5-year-old child with tetralogy of Fallot (TOF)/pulmonary atresia/MAPCAs was managed with a staged approach and had previously undergone right-sided unifocalization into an APS. He presented for left-sided unifocalization through a left thoracotomy, which was performed uneventfully. During chest closure, saturations started to decrease precipitously. The thoracotomy was reopened, and the left-sided shunt was deemed patent based on Doppler signals, but saturations remained low. Immediate angiographic analysis was performed with a 4F hemostatic sheath inserted into the descending aorta through left thoracotomy access. An angiogram performed with a pigtail catheter in the left subclavian artery confirmed the patency of the left-sided APS, and a separate angiogram in the innominate artery demonstrated acute occlusion of the right APS (Figure 1). Through the same descending aortic sheath, a shaped end-hole catheter

FIGURE 1. Intraoperative aortic angiogram confirming occlusion of the right modified Blalock–Taussig shunt (*).

FIGURE 2. Patent modified Blalock–Taussig shunt after guidewire insertion.

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Received for publication June 14, 2009; revisions received Sept 1, 2009; accepted for publication Oct 16, 2009.

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J Thorac Cardiovasc Surg 2010;140:e1-3

0022-5223/\$36.00

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doi:10.1016/j.jtcvs.2009.10.030

TABLE 1. Intraoperative angiography

Surgical procedure	n	Age	Weight	Surgical plan change	Outcome
PA assessment, including systemic–pulmonary and/or RV–PA connection					
TOF/PS/PA/MAPCAs complete repair	8	5 d–9 mo (range)	3–8.4 (range)	Yes in 2 patients (untwisting RPA anastomosis and insertion of APS)	One death caused by chronic bronchopulmonary disease (patient 2)
Unifocalization of MAPCAs	2	2 mo and 5 y	4 and 17	Yes in 1 patient (recanalization of thrombosed right APS; patient 1)	Alive and well
Rebanding PAs after hybrid stage I for HLHS	2	10 and 13 d	2 and 3	None	Alive and well
Stage I Norwood repair for HLHS	2	3 d and 4 mo	3 and 4	Yes in 1 patient: thrombectomy of LPA and insertion of innominate artery–LPA shunt and stent	One death (intracerebral bleed on ECMO)
Truncus arteriosus repair	2	3 and 4 d	2 and 2.5	Yes in 1 patient: plicating the RV–PA conduit to reduce sternal compression on conduit and Fogarty balloon of PA emboli	Alive and well
Coronary artery assessment					
Repair of coronary artery fistula	1	14 d	3	None	Alive and well
Intraoperative coronary stent deployment s/p Ross procedure	1	2.5 mo	4	No	Alive and well
Mitral valve replacement	1	1 mo	4.1	None (no compression of circumflex artery)	Death
RV–PA conduit change s/p Rastelli procedure	1	21	59	None	Alive and well
Pulmonary vein assessment					
TAPVR repair	1	5 d	3	None	Alive and well

RV, Right ventricle; PA, pulmonary artery; TOF, tetralogy of Fallot; PS, pulmonary stenosis; PA, pulmonary atresia; MAPCAs, major aortopulmonary collateral arteries; RPA, right pulmonary artery; APS, systemic–pulmonary shunt; HLHS, hypoplastic left heart syndrome; LPA, left pulmonary artery; ECMO, extracorporeal membrane oxygenation; s/p, status post.

was positioned at the origin of the occluded shunt, and a hydrophilic guidewire was passed through the occlusion and into the unifocalized right PA. Patency of the shunt was then established with serial balloon angioplasty up to a 6-mm balloon (Figure 2). Systemic saturations improved, and the patient left the OR in good condition. A complete repair was performed 3 months later uneventfully.

Patient 2

A 3 month-old baby with TOF/pulmonary atresia/MAPCAs was transferred for worsening cyanosis. He had multiple major noncardiac anomalies, including central nervous system and skeletal anomalies and DiGeorge syndrome. He had been intubated since birth. Bilateral MAPCAs and true PAs were unifocalized into a right ventricle–PA conduit. The child was not separated from cardiopulmonary bypass because of profound cyanosis. Angiography was performed through a 4F sheath inserted in the conduit. This revealed a critical stenosis of the right-sided MAPCA and the conduit. A central shunt was placed into the MAPCA, with improvement in arterial saturations. He left

the OR in good condition. The child's further intensive care unit course was characterized by diffuse tracheobronchial malacia with airway stenoses. He eventually died after informed withdrawal of care.

We have performed intraoperative angiographic analysis in 18 cases (Table 1). Apart from the 2 described cases in which intraoperative surgical management was influenced by the results of the on-table angiogram (and was life-saving in patient 1 above), the remaining cases were all diagnostic in nature.

DISCUSSION

Hybrid concepts are becoming increasingly adopted in the practice of cardiac surgery.^{1,2} Intraoperative angiography is now a mainstay of endovascular repair.³ Although there are isolated case series of intraoperative angiography in pediatric cardiac surgery,⁴ the present study represents a large-volume single-center experience after implementation of a dedicated C-arm in the OR.

In most circumstances, catheterization after congenital cardiac surgery requires transport of a sick patient and

manipulation of catheters across fresh suture lines.⁵ In addition to the risks of transporting a sick patient, this might prolong the time to confirm or refute any outstanding surgical concerns during surgical intervention. Intraoperative angiography might be able to reduce the need for early postoperative catheterizations by alerting the surgeon to potential or actual surgical concerns in a timely fashion. The C-arm has a role in both elective and emergency cases. The counterrotation of the operating table relative to the C-arm is an additional benefit that helps in achieving optimal radiographic imaging. We currently use the catheterization laboratory team and also involve interventional cardiologists in every case requiring the C-arm.

When compared with standard imaging in the catheterization laboratory, the intraoperative C-arm suffers from lower quality of image acquisition while crowding the OR by requiring more personnel. Given the extra demand for more human resources, our initial study indicates that adoption of C-arm intraoperative angiography can change the outcome and benefit selected patients. Improved technology, as well as better device ergonomics, will optimize intraoperative angiography. However, validation of use of this technology remains difficult at present and requires more formal prospective studies.

Our initial experience with intraoperative angiography has been rewarding, with a direct effect on patient outcome. Given the continuous appreciation of known and unknown operative hazards, selective intraoperative angiography has a favorable risk/benefit profile. This imaging tool is a new addition to the practice of congenital heart surgery, with a dual role in providing objective relevant operative data while therapeutically intervening when necessary.

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Mitral and tricuspid valve repair 21 years after cardiac transplantation

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Mitral and tricuspid repair techniques have been well documented for rheumatic, myxomatous, and ischemic etiologies but have not been extensively described in the transplanted heart. With the limited pool of donor grafts available, valve repair may be a useful technique for extending the functionality and durability of the transplanted heart, especially if there is no coronary disease noted.

CLINICAL SUMMARY

A 42-year-old woman presented 21 years after orthotopic biatrial heart transplantation. She initially underwent trans-

plantation for postpartum cardiomyopathy. She had a 6-month history of a progressive decrease in activity, weight gain, edema, orthopnea, abdominal fullness, near syncope, and palpitations. Transthoracic echocardiographic analysis showed severe tricuspid regurgitation, moderate mitral regurgitation, and biatrial enlargement in the posttransplantation heart. She had a normal ejection fraction and moderately enlarged right ventricular chamber size. Cardiac catheterization was performed and demonstrated no significant vasculopathy. Intravascular ultrasonographic analysis was not performed.

The patient underwent a redo sternotomy and was started on bypass through aortic and bicaval venous cannulation. The tricuspid valve was exposed through a right atriotomy. The chordae were intact, and the leaflets were without fenestration. The mechanism of tricuspid regurgitation was annular enlargement. The mitral valve was exposed through a transseptal approach. The leaflets were normal, and the mechanism of regurgitation was annular dilation. The mitral valve was repaired with a 28-mm Geoform rigid complete annuloplasty ring, which was downsized from her anterior leaflet size of 32 mm. The patient then underwent tricuspid

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Disclosures: None.

Received for publication Nov 25, 2009; revisions received Jan 12, 2010; accepted for publication Feb 1, 2010; available ahead of print April 12, 2010.

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J Thorac Cardiovasc Surg 2010;140:e3-4
0022-5223/\$0.00

Published by Elsevier Inc. on behalf of The American Association for Thoracic Surgery
doi:10.1016/j.jtcvs.2010.02.007