

Intraoperative Hybrid Cardiac Surgery for Neonates and Young Children with Congenital Heart Disease: 5 Years of Experience

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Objective: This study intends to summarize 5 years of intraoperative hybrid procedure (IHP) experience with neonates and young children having congenital heart disease (CHD).

Methods: From March 2003 to March 2009, a total of 152 consecutive patients younger than 2 years old who had undergone IHP were enrolled. In the balloon plasty group (n = 72), transventricular pulmonary valvuloplasty, or transaortic balloon dilatation were performed for pulmonary atresia, pulmonary stenosis, or coactation of the aorta. In the device group (n = 43), transventricular device closure was performed for ventricular septal defect (VSD), or transatrial device closure for atrial septal defect (ASD). In the collateral arteries occlusion group (n = 37), the major aortopulmonary collateral arteries (MPCAs) were occluded with coils for tetralogy of Fallot or other cyanotic CHDs. All procedures were image guided and performed in a specially designed hybrid operation room. All surviving patients were followed up, and the major adverse cardiovascular events that occurred were recorded.

Results: In the balloon plasty group, all patients received successful transventricular valvuloplasty or transaortic balloon angioplasty. However, severe right ventricle outflow obstruction was observed in 2 cases. One patient was transferred to regular open-heart surgery immediately, and another underwent regular open-heart procedure after discharge. Furthermore, 1 neonate with pulmonary atresia with intact ventricular septum died from liver failure 6 months after IHP. In the device closure group, the device closure failed to be performed in 3 cases (2 with ASD and 1 with VSD). One young child with VSD died from pneumonia, even after successful device closure. No device malposition was observed in the device closure group during follow-up. All patients who received MPCA occlusion and associated open-heart correction were eventually discharged.

Conclusion: IHP could avoid or shorten the application of cardiopulmonary bypass and reduce surgical trauma for selected young children with CHD. Although IHP is feasible and safe, the image outfits, image-guided technology, and IHP-related devices should be developed and improved. (*Ann Thorac Cardiovasc Surg* 2010; 16: 406–409)

Key words: hybrid cardiac surgery, congenital heart disease

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Table 1. Perioperative characteristics of the patients

Groups	Case No.	Age (months)	Weight (Kg)	Diagnosis/No.	Associated Procedures/No.
Balloon Plasty	72	8.1 ± 7.2	7.1 ± 2.27	PS/50; PAIVS/18; CoA + VSD/4	PDA Ligation/13; Modified BT Shunt/6 Bidirectional Glenn Shunt/4; VSD Repair/4
Device Closure	43	12.2 ± 5.9	9.8 ± 2.12	VSD/4; ASD/39	TOF Repair /29; Modified BT Shunt/3
Collateral Arteries Occlusion	37	13.9 ± 5.7	9.2 ± 1.9	TOF/29; PAA + VSD/5; DORV/3	Rasetelli Procedure/2; DORV Repair/1; Bidirectional Glenn Shunt/2

PS, pulmonary artery stenosis; PAIVS, pulmonary artery atresia with intact ventricular septum; CoA, Coarctation of aorta; VSD, Ventricular septal defect; PDA, patent ductus arteriosus; BT, Blalock-Taussig; ASD, atrial septal defect; TOF, tetralogy of Fallot; DORV, double outlet right ventricle

Introduction

Congenital heart disease (CHD) has ranked first in neonatal congenital defects and has become the predominant cause of death for infants and young children in China.¹ Although tremendous progress has been made in the surgical treatment of CHD, surgical trauma and cardiopulmonary bypass (CPB) still greatly affect young patients' prognoses.

A hybrid approach for CHD is a combined therapy of conventional surgery and catheter-based intervention. In 2002, Hjortdal and associates reported preliminary experiences of intraoperative stenting for complex CHD.² But until now, most hybrid procedures were performed in sequence between a catheter lab and an operation room. From 2004, we proposed a one-stop intraoperative hybrid procedure (IHP), which combined surgical and interventional approaches simultaneously.³

Methods

The data in the present study and the patients enrolled in it extend from March 2003 to March 2009 and cover 152 consecutive neonates and children younger than 2 years old who had undergone IHP for CHD. Three groups were identified: balloon plasty, device closure, and collateral arteries occlusion (as shown in Table 1).

Procedures: All procedures were performed in a specially designed one-stop IHP theater.

In the balloon plasty group, a purse-string suture was placed in the right ventricular outflow tract (RVOT) 2 cm away from the pulmonary trunk. A 16G IV catheter was then inserted transventricularly and passed through the pulmonary valve (PV). A guide wire was then inserted

into a sheathe to guide the balloon across the PV. The sequential dilations were performed until a full PV opening was obtained with the help of echocardiography.⁴ For pulmonary stenosis (PS), a postoperative transannular pressure gradient of lower than 40 mmHg was acceptable. For the neonatal management of pulmonary atresia with intact ventricular septum (PAIVS), a 3.5 mm modified Blalock-Taussig shunt was routinely placed and patent ductus arteriosus (PDA) ligated to avoid postoperative prostaglandin infusion. For the young children with PAIVS and poorly developed right ventricle (Z value of the tricuspid valve diameter lower than -3,⁴) a bidirectional Glenn shunt would be performed if the oxygen saturation of blood was lower than 75% (while the fraction of inspired oxygen was 30%) after successful valvuloplasty. In patients with coarctation of the aorta (CoA) and ventricular septal defect VSDü, a purse-string suture was placed on the ascending aorta and a balloon was introduced into the aorta to locate at the site of coarctation with the guidance of angiography. Regular open-heart VSD repair was then performed after successful balloon angioplasty.

In the device-closure group, for patients with atrial septal defect (ASD), the right atrium was exposed via a right subaxillary 4th intercostal or right parasternal minimal incision. A sheathe was inserted through the atrium and then passed through the defect with the transesophageal echocardiography (TEE) guidance.⁵ The left atrial disk was deployed and pulled gently against the atrial septum. For VSD, the heart was exposed with midline sternotomy; then a sheathe was punctured through the RVOT and crossed the defects under the TEE guidance. Lastly the device was released after confirmation of the appropriate position and nonresidual shunt.

Table 2. 6-month clinical outcomes after intraoperative procedure

Groups	Successful Rate	Mortality	Systolic Pressure Gradient*	Device Malposition	Residual Shunt
Balloon Plasty					
Transventricular	97%	1.47%	26 ± 9 mmHg	–	–
Transaortic	100%	0%	13 ± 5.2 mmHg	–	–
Device Closure					
ASD	94.8%	0%	–	No	No
VSD	75%	25%	–	No	No
Collateral Arteries Occlusion	100%	0%	–	No	No

VSD, Ventricular septal defect; ASD, atrial septal defect.

*The data of the systolic pressure gradient were obtained by an echocardiographic examination of the transpulmonary valve or the aortic pressure gradient.

In the collateral arteries occlusion group, after general anesthesia, angiocardiology was performed to identify major aortopulmonary collateral arteries (MAPCAs). The MAPCAs were then occluded with coils.⁶⁾ Regular open-heart surgery was then performed via a middle-line incision.

Follow-up: In the follow-up periods, every patient underwent an echocardiography, a chest X-ray (CXR), and an electrocardiogram (ECG) on postoperative day 7 and at 3 months and 6 months after discharge.

Results

All balloon dilatations were performed successfully. The simultaneous procedures included 13 cases of PDA ligation, 6 cases of modified Blalock-Taussig shunt placement, and 4 cases of bidirectional Glenn operation. One child with severe PS was transferred to a regular RVOT plasty using CPB because of a significant transannular systolic pressure gradient.

Two cases of ASD and 1 case of VSD were transferred to regular defect repair because of the failure of occlusions.

In the collaterals group, angiographies identified 46 collaterals, of which 36 were occluded successfully. All of the patients underwent a corrective operation, including tetralogy of Fallot (TOF) (29 cases), double outlet of right ventricle (3 cases), and pulmonary atresia with VSD (5 cases).

One patient died during a hospital stay because of severe pneumonia related to a large unrestricted VSD. Although the occlusion was performed successfully, the young child didn't recover. All patients in the collateral group recovered uneventfully after IHP, and the average ICU stay was 5.4 ± 5.1 days.

During follow-up, no residual shunt or device malpositions were observed in the device closure group. One case

of severe PS in the balloon plasty group underwent a second operation for transannular patch plasty because of subannular muscular stenosis. One case of PAIVS died of noncardiogenic hepatic failure at 6 months after discharge. The 6-month clinical outcomes are summarized in Table 2.

Discussion

With the development of devices and techniques of real-time imaging, setting up a truly hybrid operation room to perform both surgery and catheterization at the same table became a reality. Such a one-stop operation could not only reduce the applications of anesthesia and the unnecessary patient transfer, most important is that it also offered a new platform to promote cardiologists and surgeons working together to improve outcomes for the patients.

Echocardiograms offered the most convenient imaging support for surgeons during IHPs. To avoid injury to the esophagus by a TEE detector, an epicardial detector was manipulated by the operator for patients with low body weight.⁷⁾ In our series, fluoroscopic guidance was mainly used for collateral occlusion and balloon angioplasty for CoA. Because of the disturbance of trabecular muscles and papillary muscles, it was very difficult to close VSD only through the route of RVOT without fluoroscopic guidance. Therefore Diab and associates advocated a truly hybrid strategy with the aid of combined ultrasound and fluoroscopic-guided techniques.⁸⁾

During IHP, the interventional apparatuses can be deployed via atrium and ventricle without any vascular access and body weight limitations. In a developing country such as China, the percutaneous laser or radiofrequency-assisted perforation for the neonates with PAIVS was far from popular. Furthermore, only a few centers can routinely perform percutaneous PV valvuloplasty for low-

weight patients with severe PS. Thus these young patients were usually recommended for open-heart repair. Because of these considerations, we developed a trans-ventricular catheter-based therapy and achieved satisfactory results. This hybrid procedure should be a good alternative approach for centers where materials for percutaneous perforation weren't available and the experience of percutaneous catheter therapy was limited.

MAPCAs are the predominant factor influencing the prognosis of cyanotic complex CHD with decreased pulmonary blood flow. A staged interventional and surgical strategy was used in our center before the application of IHP. But the staged treatments would increase medical costs; most important, the preoperative occlusion could increase the risk of hypoxia, and postoperative occlusion could delay the treatment for perfusion-induced lung injury. We therefore developed a one-stop hybrid strategy for cyanotic CHD with suspicious MAPCAs. In our cohort, we found that 53.5% of the patients had MAPCAs. In this series, 1 patient's oxygen saturation and heart rate decreased significantly after occlusion of the MAPCAs, open-heart surgery was performed immediately, and the patient was discharged uneventfully.

Compared with conventional ASD treatment, IHP decreased the cost of CPB (including medical consumption and blood products), but this benefit was offset by the cost of interventional materials. Ultimately the total cost of IHP was still 15%–20% higher than regular treatment.⁵⁾ This motivated us to develop a new conscious-device occlusion procedure with parasternal minimal incision for ASD. With the abandonment of general anesthesia, the cost has now been significantly reduced.

In conclusion, five years of practicing one-stop IHP demonstrates its feasibility and efficacy for the neonates and younger children with selected CHD. However, we need further study for the image-guided technology and

specially designed IHP-oriented devices for the popularity of IHP to increase.

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