Avoiding cardiopulmonary bypass in extracardiac cavopulmonary connection: Does it really matter?

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Objectives: We examined the effect of avoiding cardiopulmonary bypass on the early outcome variables after fenestrated extracardiac total cavopulmonary connection.

Methods: Between May 2001 and January 2009, 102 patients with univentricular heart physiology underwent fenestrated extracardiac total cavopulmonary connection. Patients were divided into one of 2 groups: the cardiopulmonary bypass (n = 48) group and the no cardiopulmonary bypass (n = 54) group. In both groups there were patients with primary and staged fenestrated extracardiac total cavopulmonary connection. Duration of mechanical ventilation, pleural effusion, hemodynamic status, incidence of arrhythmia, and mortality were compared between the 2 groups.

Results: Both groups were matched, except for more cases of tricuspid atresia in the no cardiopulmonary bypass group ($P = .014$) compared with other diagnostic morphologies and higher preoperative hemoglobin levels in the no cardiopulmonary bypass group ($P = .01$). Avoiding cardiopulmonary bypass did not reveal any significant effect on postoperative outcomes. A cardiopulmonary bypass time of more than 120 minutes caused not only a meaningful increase in the mean of mechanical ventilation duration (35 ± 9.6 vs 13 ± 2.1 hours, $P = .026$) but also increased the incidence of mechanical ventilation for more than 12 hours ($P = .04$). Bypass time of more than 120 minutes did not have influence on any other postoperative variables.

Conclusion: Avoiding cardiopulmonary bypass in fenestrated extracardiac total cavopulmonary connection had no direct effect on the early outcome variables. (J Thorac Cardiovasc Surg 2010;139:1183-8)

The early and midterm outcomes of surgical management in patients with a single ventricle have been influenced by many factors, especially by the modifications made to improve the flow dynamics in the Fontan operation since its first successful performance in 1971.[1] The dramatic improvements in morbidity and mortality have been credited to both better selection and technical modifications that include lateral tunnels, staging, fenestration, extracardiac conduits, and avoidance of cardiopulmonary bypass (CPB). However, various studies have yielded different results depending on the number of risk factors used as the selection criteria, the modifications implemented, and the definition of outcome variables.[2–5] There are multiple studies that showed the feasibility of performing fenestrated extracardiac total cavopulmonary connection (FECTCPC) without the use of CPB.[6–11] However, the effect of avoiding CPB on early outcome has not been thoroughly examined. Furthermore, the majority of prior studies in which FECTCPC was performed without the use of CPB were staged, and the combined effects of primary versus staging with or without CPB have not been studied either. This report tries to address these issues in a group of matched patients after primary and staged FECTCPC.

MATERIALS AND METHODS

To assess the effect of CPB on the early outcome of patients palliated with extracardiac total cavopulmonary connection, 102 single-ventricle patients who were operated on by a single surgeon with this type of intervention from May 2001 to January 2009 were enrolled in the study.

Both demographic and clinical data during the pre-, intra-, and post-Fontan periods were gathered from a preformatted form and patients' medical records. The longer-term follow-up information was collected from follow-up records completed by cardiologists and the cardiac surgeon.

Demographic characteristics (age and weight), morphologic features (tricuspid atresia [TA] and non-TA), oxygen saturation in room air, pulmonary vascular resistance (PVR), and pulmonary artery (PA) pressure were compared between the CPB and no-CPB groups. Collected intraoperative information included superior vena cava (SVC), inferior vena cava (IVC), and PA pressures in addition to post-Fontan transpulmonary pressure gradient (TPG) changes. TPG equals the mean PA pressure minus the mean

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Abbreviations and Acronyms

CPB = cardiopulmonary bypass
FECTCPC = fenestrated extracardiac total cavopulmonary connection
ICU = intensive care unit
IVC = inferior vena cava
PA = pulmonary artery
PVR = pulmonary vascular resistance
SVC = superior vena cava
TA = tricuspid atresia
TPG = transpulmonary pressure gradient

atrial pressure. Intraoperative TPG change was defined as the difference between the TPG values before and after extracardiac total cavopulmonary connection.

The outcome variables during the immediate postoperative period were duration of mechanical ventilation, duration of chest tube drainage in hours, persistent pleural effusion, arrhythmia, hemodynamic instability in the intensive care unit (ICU), and early mortality. We did not use the length of ICU stay as an outcome variable because it would be affected by many factors, such as the limited number of ward beds, which can delay patient transfer from the ICU to the ward. Mechanical ventilation duration is the time from the patient's arrival to the ICU until extubation. Persistent pleural effusion was defined as either when chest tubes were required to be in place for more than 7 days or the patient required repeated drainage after removal of the chest tubes. Arrhythmia was considered as any deviation from normal sinus rhythm, even transient deviation. Hemodynamic instability was defined as when the ejection fraction was less than 50%, as determined by means of transthoracic echocardiographic analysis; inability to maintain hemodynamic stability despite conventional doses of inotropes (milrinone, 0.75 $\mu g \cdot kg^{-1} \cdot min^{-1}$; epinephrine, 0.05–0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$); oliguria; or delayed rewarming for more than 3 to 5 hours. Mortality was considered early if death occurred within 30 days after the operation and late if death occurred more than 30 days after the operation. In-hospital mortality was defined as death occurring during the same hospitalization as the surgical procedure, regardless of when after the operation the death occurred. The number of deaths and operations would be the numerator and the denominator, respectively.[12]

Patient Population

A total of 102 patients palliated with FECTCPC were enrolled nonrandomly into the study. Reasons that CPB was used electively included an intracardiac procedure (eg, enlargement of either an atrial or ventricular septal defect) in 22 patients and absence of accessory pulmonary blood flow in 7 patients. Intraoperatively, we decided to use CPB in 17 patients because of the blood pressure decrease or arrhythmia and in 2 patients for the correction of cardiac lacerations resulting in massive bleeding.

We electively performed primary FECTCPC because of the older age of our patients, unless one of the following criteria for staging existed: post-PA banding, extensive PA reconstruction, intraoperative mean PA pressure of greater than 15 mm Hg, ventricular dysfunction, and azygous continuation of the IVC. This study was approved by the ethics committee of our institute. Informed consent was obtained for data extracting from patients' medical files.

Statistical Analysis

Our study was a clinical trial without randomization. Both univariate and multivariate analyses were used for data analysis. In univariate analysis continuous variables were tested for normality by using the Kolmogorov–Smirnov goodness-of-fit test. Normal data were compared among groups by means of independent samples t tests. With nonnormal data, we used the Mann–Whitney test to compare 2 groups or the Kruskal–Wallis test to compare more than 2 groups. We showed the continuous results with means and standard deviations. The Pearson χ^2 test and the Fisher's exact test were used to test the relationship between qualitative variables. Furthermore, the Mantel–Haenszel test was applied to adjust the effect of confounding variables. For data analysis, SPSS software (version 15; SPSS, Inc, Chicago, Ill) was used.

Surgical Technique

In the no-CPB technique 2 central venous line monitoring catheters were placed. One catheter was placed in either the right or left internal jugular vein, and the other was placed in either the right or left groin. After full heparinization, a temporary bypass, an SVC–atrial shunt, is constructed with 2 right-angled venous cannulas (SVC cannula of 14F–24F and atrial cannula of 24F–32F) to crossclamp the single SVCs. In patients having bilateral SVCs, the veins could be simply crossclamped one by one without placing a temporary bypass. We chose the shortest possible cannula so as to minimize resistance while keeping it out of the field. Drainage of the SVC into the PA through temporary bypass tubing was helpful when no previous aortopulmonary shunt was present or when the previous right modified Blalock–Taussig shunt had to be replaced with the SVC–PA anastomosis. The SVC was connected to the PA after side-biting, finalizing the bidirectional cavopulmonary anastomosis. The azygous vein was ligated in the staged procedure and left intact in the primary Fontan operation. The enlarged noncardiac end of the main PA was then anastomosed to the selected polytetrafluoroethylene tube conduit (14–22 mm). We optimized the conduit dimensions in relation to the intraoperatively measured actual IVC diameter, with the upper limit of the conduit/IVC ratio being approximately 1.2. For most children, the conduit was 18 to 20 mm in diameter. Direct IVC cannulation at the most inferior site decompressed the IVC blood to the atrium through the temporary shunt (straight cannula, 18F–28F). The venoatrial junction was divided obliquely, leaving a short rim of atrial tissue around the IVC. Here mobilization of pericardial reflection was very helpful to achieve an adequate stump at both sides. The inferior end of the conduit was anastomosed end-to-end to the noncardiac end of the IVC. We selectively performed superior conduit anastomosis first to decrease IVC hypertension in the no-CPB group.

In older patients with a weight of greater than 40 kg, temporarily bypassing the IVC to the atrium with the available cannula could result in IVC hypertension, postoperative jaundice, and increased serum amylase levels. The superior polytetrafluoroethylene conduit–PA anastomosis was performed first to minimize this risk. When the IVC drainage becomes inadequate and the IVC pressure exceeds 20 mm Hg, it is advised to side-bite the lateral IVC–atrial junction for end-to-side conduit–IVC anastomosis before proceeding to crossclamp and transect this junction. When the only source of blood flow to the lungs was a right aortopulmonary shunt, an IVC–PA pathway was reconstructed first. In the case that the shunt was placed near the hilum, it was possible to preserve the shunt temporally and implant the SVC onto the PA.

CPB was performed with ascending aortic and bicaval cannulation during moderate hypothermia (rectal temperature, 28°C–30°C). Cardiac arrest with crystalloid cardioplegia was avoided unless a concomitant intracardiac operation was necessary. Cardioplegia was repeated at 20-minute intervals.

Fenestration was created in all cases with direct 4- to 6-mm side-to-side anastomosis of the extracardiac conduit to the atrium by using the punch technique and suturing atrial wall tissue around the fenestration distant from the fenestration's edge to ease possible device closure. After decannulation, protamine was administered only when hemostasis was not satisfactory. Bilateral pleural chest tubes were placed in all patients. We removed them once drainage was less than 2 $mL \cdot kg^{-1} \cdot d^{-1}$ for each tube. It is