CASE REPORTS

Transfusion-Free Cardiac Surgery with Cardiopulmonary Bypass in a 2.2-kg Neonate

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ABSTRACT Particularly in neonates, complex cardiac surgery employing cardiopulmonary bypass normally requires the transfusion of autologous blood components. This is predominately caused by the relatively high priming volume of the circuit with subsequent extreme hemodilution. We report on a synoptic approach to avoiding transfusions in a 2.2 kg neonate with scheduled for correction of an intracardiac total anomalous pulmonary venous connection to the coronary sinus and a persistent foramen ovale. In this patient with a preoperative hemoglobin value of 16.5 g/dL, minimization of the cardiopulmonary bypass circuit, adjustment of the perfusion technique and strict reduction of blood sampling resulted in complete avoidance of transfusions during the entire course of the operation while maintaining safe hemoglobin levels, which never fell below a concentration of 8 g/mL. *(J Card Surg 2005;20:180-182)*

The complications of the transfusion of blood products in cardiac surgery are increasingly appreciated.[1] In consequence, sophisticated blood conservation strategies have been developed to avoid the need for transfusions. However, particularly cardiac surgery with cardiopulmonary bypass (CPB) in neonates usually requires utilization of blood components to avoid the extreme hemodilution caused by the relative high priming volume of the CPB circuit. Minimization of the CPB system, while still incorporating fundamental safety features such as an arterial filter, and adjustment of the perfusion strategy may help to avoid the need for transfusions even in selected small neonates. We report on a 2.2 kg non-Jehovah's-Witness neonate who underwent cardiac surgery employing CPB without administration of blood products during the entire perioperative course. In this patient safe minimization of the CPB circuit and adoption of a special perfusion strategy resulted in the maintenance of safe hemoglobin levels of more than 8 g/dL (hematocrit 24%) even in the critical period of extracorporeal circulation.

CASE REPORT

A 9-day-old small neonate diagnosed with an intracardiac total anomalous pulmonary venous connection to the coronary sinus (TAPVC), a persistent foramen ovale (PFO), a small apical ventricular septal defect and left superior vena cava (LSVC) was scheduled for correction of the TAPVC and PFO closure. The body weight was 2.2 kg and the body surface area calculated at 0.17 m^2. After induction of anesthesia and placement of an arterial line and central venous catheter, surgery was performed. The preoperative hemoglobin value after induction of anesthesia and placement of the lines was 16.5 g/dL. Since the CPB priming volume was 190 mL a hemoglobin level of more than 8 g/dL (hematocrit 24%) during CPB was expected. As this was regarded as safe, we decided to initiate CPB with a nonhemic prime. After median sternotomy, aprotinin (Trasylol®, Bayer, Frankfurt, Germany) was administered with a bolus of 4×10^5 KIU for the patient, 4×10^5 KIU in the priming volume of the CPB and a continuous infusion of 1×10^5 KIU during the period of extracorporeal circulation. Heparin level based heparin management was performed according to the Hepcon HMS Plus™ system (Medtronic Inc, Minneapolis, MN) with a target level of 6 IU/mL. All components of the CPB system were nonheparin-coated. The priming volume consisted of an electrolyte solution (Thomaejonin, DeltaSelect GmbH, Pfullingen, Germany) and 5000 IU heparin. Very short tubing connections were made possible by positioning the arterial roller pump head close to the oxygenator inlet and the cardiotomy and the vent roller pump heads close to the cardiotomy reservoir inlet using a designated neonatal CPB console (S3 Mast-Mounted Pump, Stoeckert, Munich, Germany)

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Figure 1. *The specially designed neonatal Stoeckert S3 Mastpump allowing the low prime circuit. In the foreground: the arterial roller pump near the heat exchanger/oxygenator inlet. In the left background: the suction pumps in proximity to the cardiotomy reservoir inlet.*

with two remote double head roller pumps on masts (Figure 1). All blood-containing components were brought into close proximity to the operation table. The tubing diameters were downsized to 3/16″ in the entire ECC system with the exception of the roller pump segments which consisted of 1/4″ silicone rubber tubing. The bubble detector was placed between the oxygenator and the arterial filter for maximum shortening of the arterial line. A hollow fiber membrane oxygenator (Safe Micro, Polystan, Vaerlose, Denmark) with a priming volume of 52 mL and a 40-micron D736 arterial line filter (Dideco, Mirandola, Italy) with a priming volume of 40 mL were used. The LSVC was drained by accessory cannula. The total priming volume of the system was 190 mL. With the onset of CPB systemic cooling to 32°C (bladder) was initiated, the aorta cross-clamped and 15 mL crystalloid cardioplegic Kirsch solution (Mg-Aspartat Procain, Köhler-Chemie, Alsbach, Germany) and 20 mL colloidal cardioplegic solution (Fresenius AG, Bad Homburg, Germany) infused. Moreover, a bolus of 2 mg furosemide was administered to establish forced diuresis. For correction, a right atrial approach was chosen. An incision of the tissue between the coronary sinus and the ASD was made, thus extensively unroofing the coronary sinus. Closure of the resultant atrial septal defect was accomplished with autologous pericardium. Ligation of the ascending vertical vein to the LSVC was performed.

The cross-clamping time of 30 minute was followed by a reperfusion period of 10 minute for systemic rewarming. In this period, venous drainage was augmented by vacuum-assisted venous drainage facilitated by a maximum negative pressure of 15 mmHg with a vacuum regulator (Polystan vacuum controller) to achieve a venous return of more than 3 L/min/m^2. During CPB, blood gas analyses (0.3 mL volume) were performed at intervals of 15 minutes. Measurements of the heparin level were reduced to one after infusion of cardioplegia and one for determination of protamine requirement after conclusion of CPB. No hemofiltration was performed; the hemofilter was left unprimed. Forced diuresis (10 mL/kg/h) was achieved with two

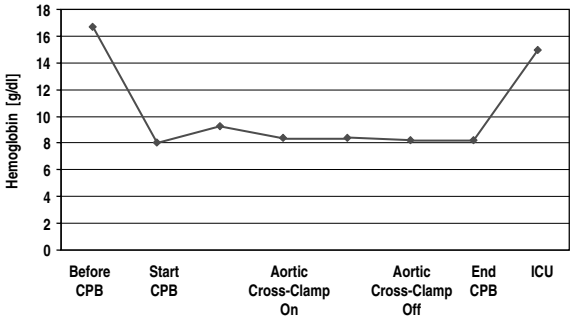

Figure 2. *Course of hemoglobin levels.*

boluses of 2.0 mg furosemide on initiation of CPB and on rewarming. The hemoglobin level before CPB was 16.7 g/dL and after initiation of CPB 8.0 g/dL (hematocrit 24%) representing the lowest hemoglobin value during the bypass period (after induction of cardioplegia) (Figure 2).

Separation from CPB proceeded with moderate inotropic support (adrenaline 0.04 μg/kg/min. During separation from bypass the volume of the venous line and of the venous reservoir was used for preloading of the heart. This procedure was augmented by short-term vasoconstriction with repeated boluses of noradrenalin (0.2 mL of a 1:100 solution) after the beginning of lung perfusion. Administration of such boluses was necessary during a period of 15 minutes to achieve a mean arterial blood pressure of between 35 and 40 mmHg. After termination of CPB the volume left in the oxygenator and heat exchanger was directly transfused through the arterial line. The remaining blood left in the arterial filter and arterial line was immediately given to the patient as venous retransfusion. Contrary to institutional standards in neonates, no modified ultrafiltration (MUF) was carried out in order to avoid additional hemodilution due to the relative high priming volume of the MUF circuit (approximately 80 mL including 20 mL for the infusion warmer system used as standard at our institution) for this procedure. After "complete" emptying of the CPB, the system was flushed with 500 mL saline and this volume processed by a cell saver (Autolog, Medtronic, Minneapolis, MN). This resulted in a final volume of 130 mL with a hemoglobin level of 4.4 g/dL. This volume was slowly reinfused into the patient after initiation of forced diuresis with 2 mg of furosemide, which resulted in a final intraoperative urine output of 200 mL.

The chest of the patient was closed and the patient was transferred to the ICU. The hemoglobin level after arrival on the ICU was 15.1 g/dL. The following morning the hemoglobin was 15.2 g/dL. The total 12 hour postoperative blood loss was 15 mL. During the entire postoperative course, blood sampling was reduced to one blood gas analysis (0.3 mL). The patient was weaned from the ventilator after 4 days and transferred from the ICU with a hemoglobin level of 13.0 g/dL after 6 days.

DISCUSSION

The present case demonstrates that even in very small neonates cardiac surgery with CPB can be safely performed without the use of blood products. In particular, the significant reduction of the priming volume to 190 mL (compared to 410, 420, and 540 mL in previous reports) contributed to successful management.[2–4] This was achieved by (1) reducing the length of the CPB lines by use of the special designated CPB console, (2) reducing the diameter of the CPB lines, (3) using a small oxygenator and arterial filter, and (4) abandonment of any hemofiltration procedures, as filling of the filter and lines (60 mL) would have contributed to further hemodilution.

Using this strategy, extreme hemodilution was prevented and the hemoglobin levels even in the most critical phase of CPB were maintained in a safe range. Flushing of the CPB circuit after it had been emptied and processing of this volume with the cell saver Autolog™, which concentrates the harvested red blood cells to a small final volume of approximately 130 mL, provided additional volume with a nonneglectable total amount of hemoglobin and contributed to the elevation of the hemoglobin concentration after CPB. Moreover, implementation of strategies to preserve the hemostatic system during CPB, such as the use of aprotinin and heparin-level based anticoagulation management, prevented greater postoperative hemorrhage.[5,6]

Although we are aware that the high preoperative hemoglobin levels of our patient were the foundation of our success, we believe that with strict use of blood-saving strategies safe transfusion-free cardiac surgery with CPB even in small neonates must no longer be the exception.

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