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Retrograde Autologous Priming Technique to Reduce Hemodilution during Cardiopulmonary Bypass in the Pediatric Cardiac Patient

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Abstract: Blood conservation techniques during pediatric congenital heart surgery continue to be a vital strategy in reducing hemodilution during cardiopulmonary bypass. Development of mini circuits, retrograde autologous priming, modified ultrafiltration, and use of a cell saver are methods adopted by pediatric heart programs to limit transfusions. Excessive hemodilution may warrant the need for transfusion in the pediatric patient, which carries significant risks in the overall care of the patient. Retrograde autologous priming is a safe and effective way to limit the amount of hemodilution, and thereby reduce the need for transfusion. **Keywords:** pediatric cardiopulmonary bypass, retrograde autologous priming, hemodilution, blood transfusion. *J Extra Corpor Technol. 2019; 51:100–3*

Hemodilution due to crystalloid priming of the extracorporeal circuit continues to be a significant issue in pediatric cardiopulmonary bypass (CPB). Although steps are in place to reduce CPB prime volume, there is still a substantial amount of hemodilution that can affect postoperative outcomes. Hemodilution is associated with many detrimental effects, such as decreased oxygen-carrying capacity from a decrease in red cell volume, generalized edema, reduction in plasma colloid osmotic pressure, organ dysfunction, dilutional coagulopathy, and vasodilation (1–3). These effects are especially more prevalent in the pediatric population due to the large discrepancy between total patient blood volume and the volume required to prime the extracorporeal circuit (1). The effects of hemodilution can be offset by priming the extracorporeal circuit with blood products. However, the use of blood products is not without risk. Blood transfusions are associated with several complications, including acute lung injury, anaphylactic reaction, immunologic sensitization, organ dysfunction, and disease transmission (1,4). In pediatric cardiac surgery, bank blood in the priming solution has been a source of bradykinin and interleukins, resulting in inflammatory reactions that can lead to postoperative complications such as longer intubation times and intensive care length of stay (5). Substantial progress has been made in reducing the need for blood products during pediatric cardiac surgery by implementing techniques such as modified ultrafiltration (MUF) and universal cell saver (6–8). One perfusion strategy used to avoid blood transfusions and decrease the amount of hemodilution in the pediatric cardiac patient is retrograde autologous priming (RAP).

MATERIALS AND METHODS

The CPB circuit components used for this technique include the Terumo HCO5 hemoconcentrator and Terumo Capiox CP50 cardioplegia system (Terumo Cardiovascular Group, Ann Arbor, MI) (Figure 1). The circuit prime volume consists of Baxter Plasmalyte A, 25% albumin,

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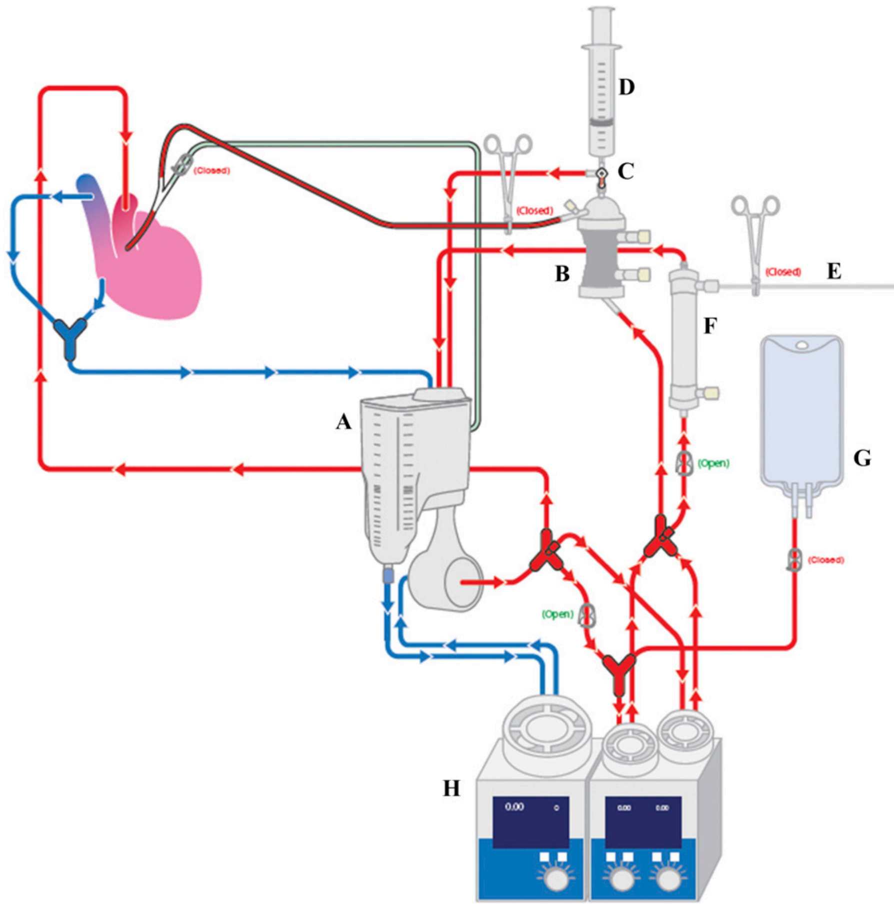

Figure 1. Children's Hospital and Medical Center, Omaha, bypass circuit for RAP. (A) Terumo Capiox FX05/Terumo Capiox FX15, (B) Terumo Capiox CP50, (C) three-way stopcock, (D) 60-mL luer lock syringe, (E) effluent line, (F) Terumo Capiox HCO5, (G) del Nido cardioplegia, (H) Stockert SV roller pump.

8.4% $NaHCO_3$, tranexamic acid, and heparin. The total prime volume for the Terumo FX05 circuit is 200 mL, and the total prime volume for the Terumo FX15 circuit is 500 mL. Calculated prime volumes, dilution hematocrit, patient physiology, and the operative procedure are all considered before implementing a bloodless strategy. If the patient meets the criteria, RAP will be used to reduce the amount of circuit volume, thereby decreasing the effect of hemodiltution.

After bolus heparin and placement of the aortic cannula with stable hemodynamics, RAP is commenced. The dual-head cardioplegia roller pumps are overridden to work independently of the arterial roller pump. The cardioplegia circuit is isolated accordingly to allow only blood to flow through the hemofilter, which circulates the blood back to the venous reservoir and provides separation from the del Nido cardioplegia solution (Figure 2).

At this time, the dual-head cardioplegia roller pumps are initiated at 5–10 mL/kg/min using the patient's blood drawn from the aortic cannula to displace the crystalloid volume in the hemofiltration circuit. Once forward flow is established through the hemofilter, the effluent line clamp is released, allowing for the removal of free water (Figure 2). The rate of free water removal can be augmented by increasing the vacuum applied to the system or by increasing the transmembrane pressure. The roller heads are then slowly increased to a flow rate of 10 mL/kg/min in infants and increased as tolerated but not exceeding 300 mL/min in larger patients. The arterial roller pump is then initiated in continuity with the cardioplegia roller pumps at a rate of 10–100 mL/min, slowly transferring the prime volume from the venous line, venous reservoir, and oxygenator to the hemofiltration device. This method allows for 100% clearance of all crystalloid prime solution.

The final step in this technique is the removal of the prime volume of the cardioplegia system. This can be achieved by clamping out the hemofilter and unclamping the del Nido solution, allowing for a 1:4 blood to crystalloid solution to displace the existing priming solution into a 60-mL syringe attached to a stopcock at the top of the blood cardioplegia device (Figure 3). If the patient is not undergoing aortic cross-clamping, the del Nido solution can remain clamped, using only the patient's blood volume to displace the existing priming solution. Alternatively, this final step can be carried out after the initiation of CPB if the patient becomes hemodynamically unstable.

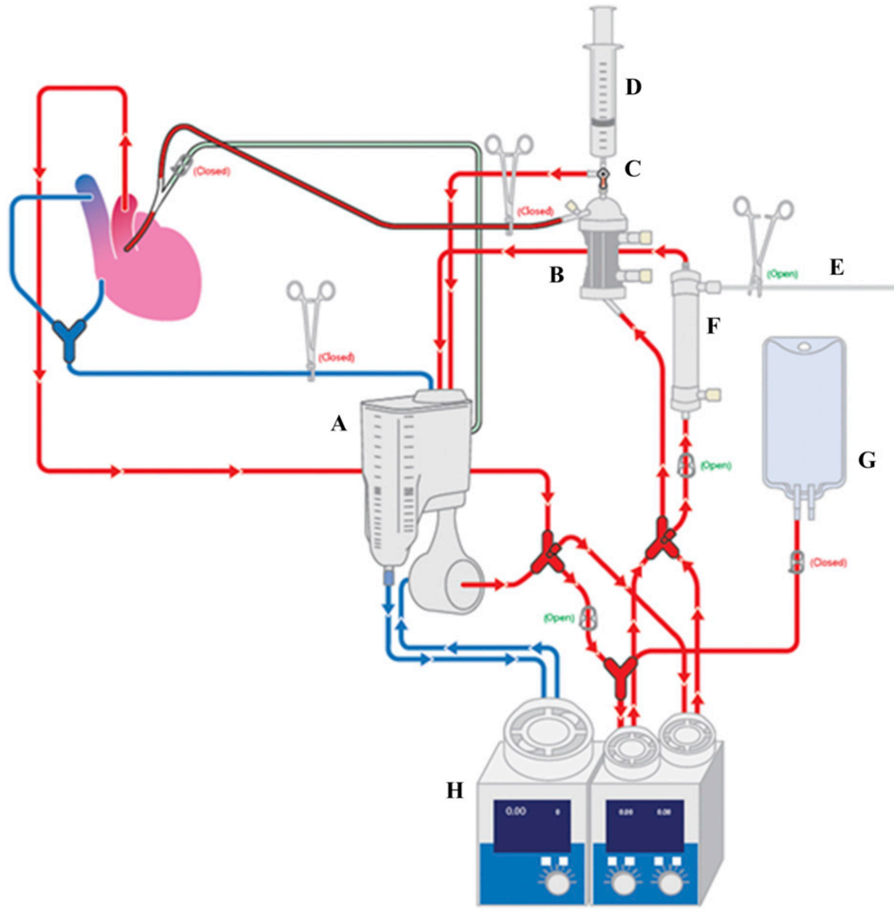

Figure 2. Retrograde autologous priming position for hemofilter, venous reservoir, and oxygenator. (A) Terumo Capiox FX05/Terumo Capiox FX15, (B) Terumo Capiox CP50, (C) three-way stopcock, (D) 60-mL luer lock syringe, (E) effluent line, (F) Terumo Capiox HCO5, (G) del Nido cardioplegia, (H) Stockert SV roller pump.

DISCUSSION

During RAP, it is imperative to monitor patient hemodynamics such as blood pressure, heart rate, saturations, and electrocardiogram changes and communicate any changes with the surgical team. The patient's arterial blood pressure is closely monitored to ensure adequate perfusion pressure as well as cerebral and renal saturations via the INVOS cerebral/somatic oximeter (Medtronic, Minneapolis, MN). If the patient becomes hemodynamically unstable, the blood flow rate through the hemofiltration device can be decreased or the arterial blood flow rate can be increased. There is a finesse involved with balancing the rate of RAP via the dual-head cardioplegia device and the arterial system similar to MUF, but this becomes better with experience. In the event where lowering flow rates does not help in increasing perfusion pressures, pharmacologic agents such as phenylephrine may be needed to allow for the completion of RAP. It is a joint effort by all surgical team members that makes this RAP technique successful.

There are many benefits to adopting this RAP perfusion strategy to limit the amount of hemodilution that occurs. This RAP technique allows for the reduction of extracorporeal circuit volume with minimal loss of prime drugs. Volume distribution can be easily controlled by the perfusionist with the manipulation of pump flow rates to accommodate any hemodynamic changes experienced by the patient. The sterility of the circuit is kept intact by not having to make any breaks in the circuit to displace the volume required in other RAP strategies. Any excess perioperative fluid administered before CPB can be removed by continuing its flow through the hemofilter after the circuit prime volume has been removed. Finally, this method allows for easy initiation of CPB if the RAP technique is not tolerated or other surgical problems arise.

In 2017, we performed this RAP method on 92 of our patients undergoing CPB. The weight of these patients ranged from 5.1 to 119.4 kg. This RAP technique is a standardized procedure that allows it to be used on a wide range of patient sizes. In all, 76 (82.6%) of these patients did not receive any intraoperative packed red blood cells (PRBCs). Of the 16 patients who did receive intraoperative PRBCs, 50% had redo operations, with 37.5% falling in the 5- to 10-kg range (Figure 4).

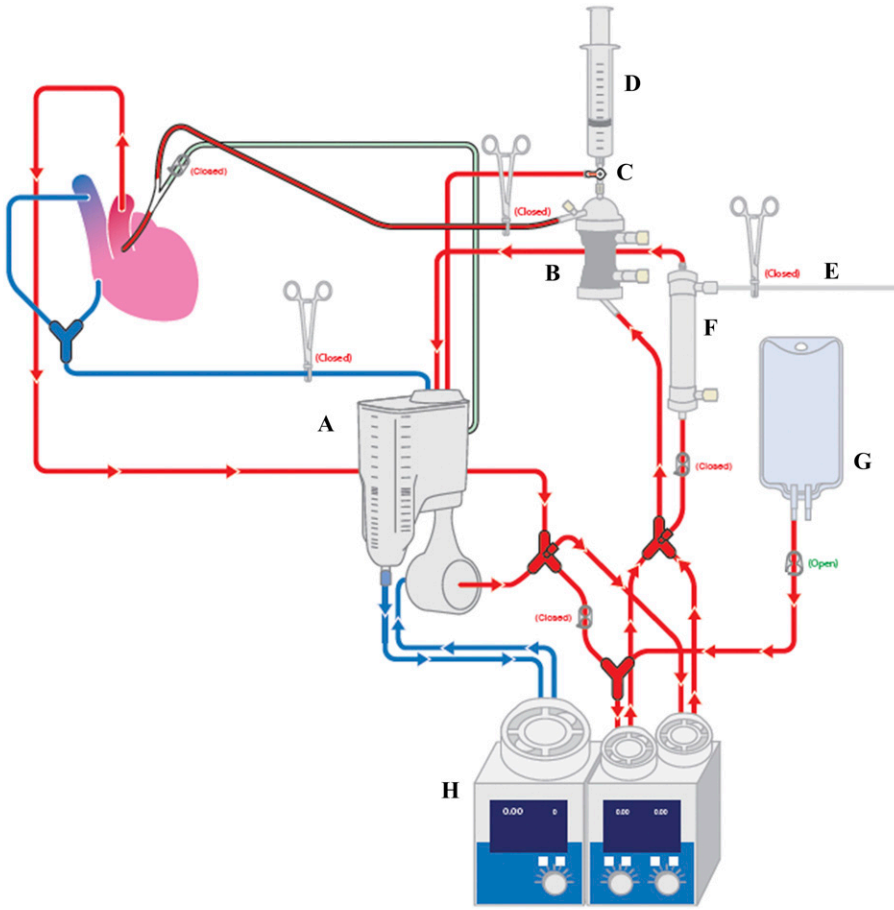

Figure 3. Retrograde autologous priming position for blood cardioplegia. (A) Terumo Capiox FX05/ Terumo Capiox FX15, (B) Terumo Capiox CP50, (C) three-way stopcock, (D) 60-mL luer lock syringe, (E) effluent line, (F) Terumo Capiox HCO5, (G) del Nido cardioplegia, (H) Stockert SV roller pump.

CONCLUSION

Retrograde autologous priming is a safe and effective strategy in reducing hemodilution in pediatric cardiac patients. However, there are many patient variables to consider, such as patient size, congenital defect, preoperative laboratory values, and medical history, to determine the suitability for RAP (1). With careful patient selection, team collaboration, and close management of patient hemodynamics, this RAP strategy has been proven successful in reducing the amount of blood products needed for most of our pediatric cardiac patients.

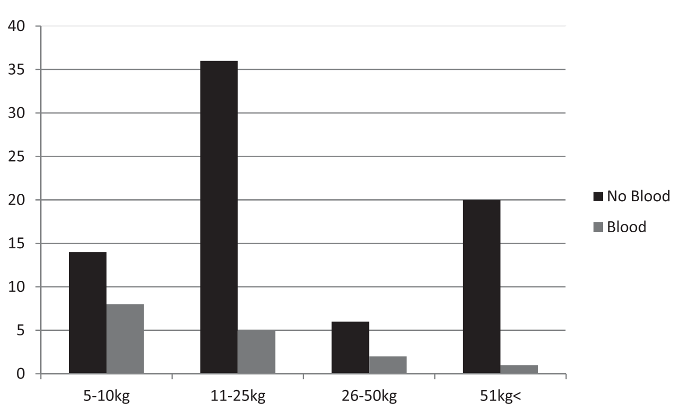

Figure 4. Children's Hospital and Medical Center, Omaha, RAP patients, 2017.

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