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Autologous Priming Technique to Reduce Blood Transfusion in Pediatric Cardiopulmonary Bypass

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Abstract: Excessive hemodilution during cardiopulmonary bypass is associated with decreased oxygen carrying capacity, edema, and organ dysfunction. The use of blood products is often necessary to prime the extracorporeal circuit for pediatric cardiac surgical patients. However, the use of blood products carries serious risks both in the acute and long-term aspects of patient care. Autologous priming of the extracorporeal circuit used in conjunction with ultrafiltration, pharmacologic manipulation, and cell salvage may decrease the need for blood transfusion in the pediatric cardiac surgical population. We have developed a technique that enables us to perform transfusionless complex congenital heart repair targeting patients as small as 5 kg.
Keywords: autologous priming, pediatric cardiopulmonary bypass, blood conservation, hemodilution. *JECT. 2006;38:154–156*

Hemodilution during cardiopulmonary bypass (CPB) is associated with several deleterious effects such as decreased oxygen carrying capacity, vasodilation, generalized edema, and organ dysfunction (1–3). These effects are more profound in the pediatric population because of the immaturity of the capillary membranes and the relatively smaller patient total blood volume compared with the volume required to prime the extracorporeal circuit (ECC) (4). The use of blood in the prime of the ECC is often required as a means of avoiding excessive hemodilution. However, the use of blood products carries several risks, such as immunologic sensitization, anaphylactic reaction, and disease transmission (5, 6). Efforts should be made to decrease or completely avoid transfusions to avoid these negative reactions. The use of autologous priming of the ECC may decrease the amount of hemodilution, thereby significantly decreasing the need for blood transfusion, particularly in the pediatric cardiac surgical patient.

DESCRIPTION

The ECC is specifically modified to allow for both autologous priming and ultrafiltration (Figure 1). The arterial recirculation line enters a manifold containing several high flow stopcocks that allow redirection of blood from the arterial circulation. The venous line contains a shunt proximal to the venous reservoir that connects to the manifold. Circuit components and priming volume are listed in Table 1. The ECC is primed using approximately 450 mL of Plasmalyte A solution (Baxter Healthcare Corporation, Deerfield, IL). After deairing, 1000 units of heparin and 15 mL of sodium bicarbonate (1 mEq/mL) are added to the prime for patients less than 20 kg. The quick prime line is connected to the manifold, enabling volume to be displaced from both the arterial and venous circulation. Fifty milliliters of 25% albumin is added as Plasmalyte A is removed by pumping the volume into the prime bag with a clamp placed distal to the arterial line filter (ALF). The volume in the venous reservoir is approximately 50 mL at initiation of this technique. After heparin administration of 400 units/kg, extended coagulation is verified by activated clotting time using the Hemochron Jr. Signature + (ITC Thoratec Corporation, Edison, NJ). After placement of the arterial cannula, arterial line patency is confirmed by removing the clamp distal to the ALF, enabling pressure monitoring and a test transfusion. The clamp is slowly removed from the quick prime line, allowing the patient's pressure to displace crystalloid retrograde in the arterial line and ALF (Figure 2). Next, the quick prime line is clamped, and a clamp is placed distal to the ALF. After the venous cannulae are in place, the clamp is removed from the quick prime line, and the clamp is slowly removed from the venous line as the hemodynamics are carefully monitored. Simultaneously, the arterial pump head is advanced, displacing crystalloid in the venous reservoir, boot header, and oxygenator (Figure 3). This volume is forced into the quick prime line because of the clamp placed distal to the ALF.

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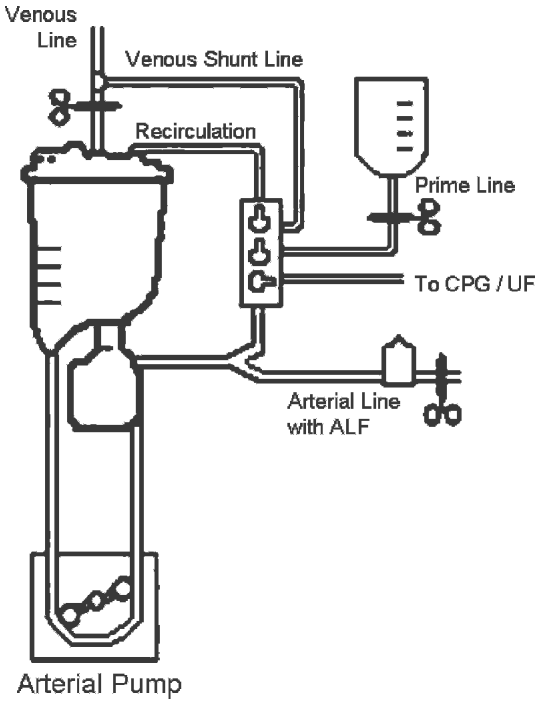

Figure 1. Circuit schematic.

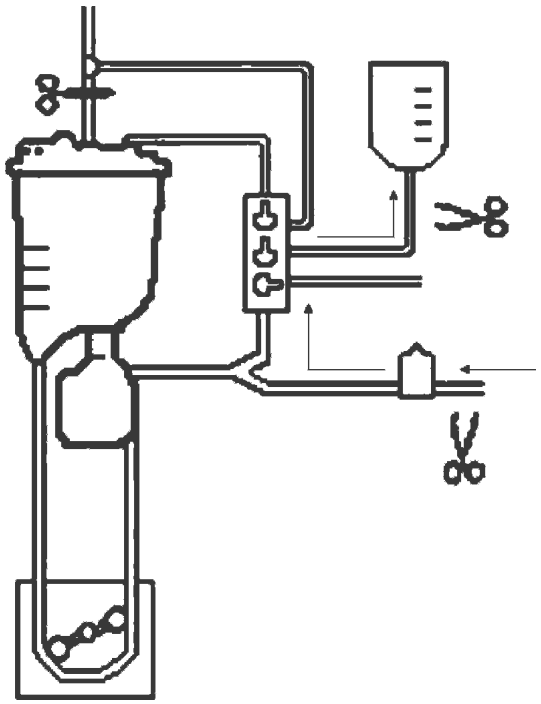

Figure 2. Retrograde autologous prime.

Variations of this technique are used according to the clinical situation. For example, as the venous cannulae are placed, there is occasionally shed blood being returned to the venous reservoir through pump suckers. This blood may be pumped forward to prime the venous reservoir, boot header, and oxygenator. The volume in the venous line is displaced by changing the configuration of the stopcocks in the manifold (Figure 4). This allows the crystalloid from the venous line to be drained by gravity into the prime bag without diluting the blood that has already primed the venous reservoir, boot header, and oxygenator. The configuration of the ECC came from the need to perform veno-venous modified ultrafiltration and is not necessary for using this priming technique. Connecting the quick prime line to the distal end of the ALF purge line allows for retrograde priming of the arterial line and antegrade priming of the venous reservoir, boot header, and oxygenator.

Table 1. Circuit components and priming volumes.

Component	Prime Volume
Capiox Baby-RX Oxygenator with X-coating (Terumo Cardiovascular Systems, Ann Arbor, MI)	43 mL
Capiox AF02 Pediatric Arterial Line Filter with X-coating (Terumo Cardiovascular Systems)	40 mL
Hemochor HPH4000 Hemoconcentrator (Minntech Corporation, Minneapolis, MN)	27 mL
CSC14 Cardioplegia Heat Exchanger (Cobe Cardiovascular, Arvada, CO)	28 mL
0.1875 × 0.25'' Custom Tubing Pack with X-coating (Terumo Cardiovascular Systems)	~200 mL*

*Safe operating venous reservoir level and prebypass filter = total ECC prime volume ~450 mL.

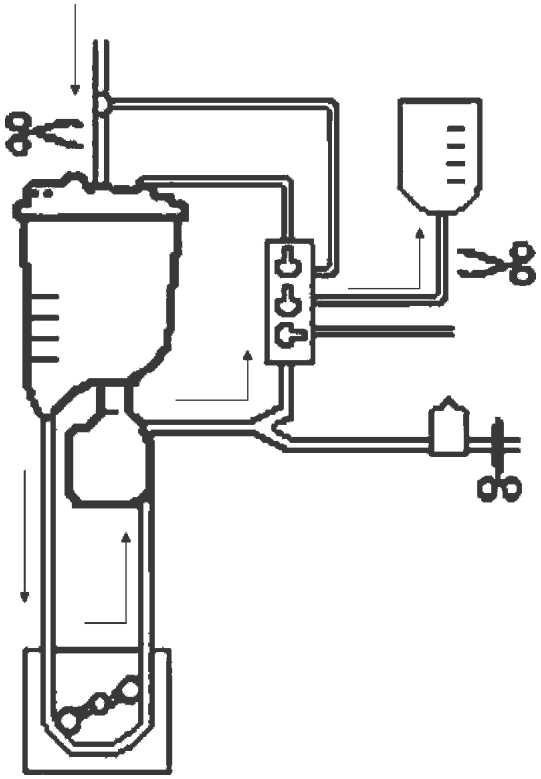

Figure 3. Antegrade autologous prime.

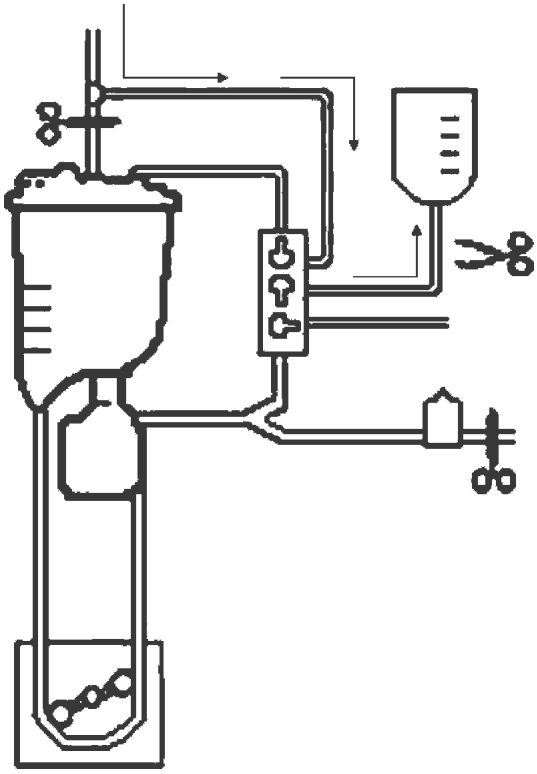

Figure 4. Venous shunt line prime.

Ultrafiltration during CPB and modified ultrafiltration (MUF) after CPB are critical aspects of a bloodless surgical approach. MUF allows for removal of inflammatory mediators, reduction of edema, and reinfusion of the patient's blood volume, resulting in an increased hematocrit (7). In addition, the use of blood salvage with the continuous autotransfusion system (CATS; Fresenius Medical Care, Bad Homburg, Germany) also increases the hematocrit. At our institution, the ECC volume is chased into the CATS after CPB, processed, and returned to the patient.

Pharmacologic manipulation also contributes to the success of this bloodless surgical technique. Aprotinin reduces the inflammatory response to CPB and has a platelet-protective effect. Combined with good surgical hemostasis, there is less postoperative bleeding, decreasing the need for blood transfusions. Lasix may be used to promote urine output and help maintain fluid balance. Mannitol, given before removal of the aortic cross-clamp, acts as an oxygen radical scavenger and also promotes urine output. Albumin is used to increase oncotic pressure and decrease the fluid shift into the third space.

DISCUSSION

For this technique to be safe, careful attention must be paid to the patient's hemodynamics. The goal is to use the patient's own volume to prime the ECC without compromising perfusion pressure. In our practice, we use monitoring devices and pharmacologic agents that enable the most efficacious and safe use of this technique. We have found cerebral oximetry using the INVOS (Somanetics Corporation, Troy, MI) invaluable in showing real-time changes in brain tissue perfusion. Parameters effecting cerebral oximetry useful in this discussion are blood pressure, flow, temperature, and hematocrit. The minimal safe level of hematocrit in pediatric cardiac patients undergoing open heart surgery is patient specific and dependent on many variables; a specific number cannot be assigned as a transfusion trigger. Low pump flow rates caused by inadequate venous reservoir volume, cerebral oximetry desaturation, decreased SvO_2 and low mean arterial pressure may indicate the need to transfuse blood. It is important to note that the volume of packed red blood cells needed to increase the hematocrit when blood transfusion is required during CPB will be decreased with this blood conservation approach. The use of partial units of blood components may dramatically reduce the number of donor exposures.

CONCLUSION

This autologous priming and ultrafiltration technique is not a one-size-fits-all solution. Patient variations in size, hemodynamic stability, anatomy, preoperative laboratory values, and individual tolerance levels dictate the overall effectiveness. Cooperation from all team members is vital to success. With careful monitoring and strict attention to detail, these techniques have proven to be safe and effective to decrease the use of blood products in many pediatric patients undergoing repair of congenital heart defects.

REFERENCES

1. Emhardt JD, Moorthy SS, Brown JW, Cohen MD, Wagner WW Jr. Chest radiograph changes after cardiopulmonary bypass in children. J Cardiovasc Surg (Torino). 1991;32:314–17.
2. Finn A, Naik S, Klein N, Levinsky RJ, Strobel S, Elliot M. Interleukin-8 release and neutrophil degranulation after pediatric cardiopulmonary bypass. J Thorac Cardiovasc Surg. 1993;105:234–41.
3. Hashimoto K, Miyamoto H, Suzuki K, et al. Evidence of organ damage after cardiopulmonary bypass. The role of elastase and vasoactive mediators. J Thorac Cardiovasc Surg. 1992;104:666–73.
4. Utley JR, Wachtel C, Cain RB, Spaw EA, Collins JC, Stephens DB. Effects of hypothermia, hemodilution, and pump oxygenation on organ water content, blood flow and oxygen delivery, and renal function. Ann Thorac Surg. 1981;31:121–33.
5. Ando M, Takahashi Y, Suzuki N. Open heart surgery for small children without homologous blood transfusion by using remote pump head system. Ann Thorac Surg. 2004;78:1717–22.
6. AuBuchon JP. Managing change to improve transfusion safety. Transfusion. 2004;44:1377–83.
7. Hennein HA, Kiziltepe U, Barst S, et al. Venovenous modified ultrafiltration after cardiopulmonary bypass in children: a prospective randomized study. J Thorac Cardiovasc Surg. 1999;117:496–505.