Case Report

Bloodless Prime in Pediatric Cardiopulmonary Bypass Circuits

James C. Conley, BS and Carol A. Zografos, RN, CCP
Maine Medical Center, Portland, Maine

Keywords: hemodilution, pediatrics, cardiopulmonary bypass, prime, bloodless

Abstract

Hemodilution during cardiopulmonary bypass is a well established practice. In pediatric cardiac surgery the volume of the prime may cause excessive hemodilution. In most institutions hemodilution in pediatric patients is controlled by adding blood to the prime. This case involves a female patient weighing 15.4 kilograms who received no blood other than that recovered during her surgery. The blood was processed in a cell washing device. A 968 milliliter clear prime was utilized. The data collected during and post bypass was examined and demonstrated the adequacy of perfusion in this patient. Parameters utilized to demonstrate the adequacy of perfusion include pH, urine output and venous oxygen saturation.

Introduction

Blood utilization in the prime of pediatric cardiopulmonary bypass circuits is a commonly accepted practice. The rationale for this is that hemodilution occurring in bloodless circuits would decrease the oxygen carrying capacity, the osmolarity and the viscosity of the perfusate beyond the tolerable limits of pediatric patients. At this institution different criteria are now being used to distinguish between pediatric patients who are able to withstand hemodilution and those who require a blood prime. The criteria used to identify patients for whom a non-blood prime is appropriate are: first, the estimated hematocrit on bypass must be 17 percent or greater; second, the patient's blood chemistry and coagulation status must be within normal limits, except for conditions which can be directly attributed to the defect; third, autotransfusion must be utilized throughout the procedure so that the maximum possible post bypass hematocrit may be achieved.

This case involves a 15.4 kilogram female on whom atrial septal defect, secundum type, repair was performed. Extreme care was taken to salvage all blood during bypass and the remaining pump volume after termination of bypass. This patient received only autologous blood during her stay in the hospital. Very little has been written about this technique; therefore, it warrants reporting.

Materials and Methods

The cardiopulmonary bypass circuit consisted of a Cobe VPCML membrane oxygenator[a], an Olson custom pediatric pack[b], Pall prebypass filter, Pall AV3 arterial line filter[c] and a GEM-6 Plus in-line blood gas analyzer[d]. Autotransfusion was employed throughout the procedure using the Haemonetics Cell Saver 3 Plus[e] with a 125 ml bowl. The prime consisted of 900 ml of lactated Ringer's solution (LR), 2.8 mg/kg mannitol, 25 mEq sodium bicarbonate and 2000 USP units of beef lung heparin.

Crystalloid cardioplegia was delivered by means of a roller pump. A dose of 15 ml of crystalloid cardioplegia per kg patient weight was calculated. The pre-bypass activated clotting time (ACT) was determined to be 140 seconds using the hand-held method. A loading dose of 3000 units/kg of heparin was administered and an ACT performed five minutes later was 350 seconds. An additional 3000 units of heparin was given to the patient pre-bypass which resulted in a pre-bypass ACT of 675 seconds.

The patient was placed on bypass and cooled. After five

Address correspondence to:
Carol A. Zografos, RN, CCP
Maine Medical Center
22 Bramhall St.
Portland, ME 04102

a Cobe laboratories, Lakewood, CO 80215
b Olson Medical Sales Inc., Ashland, MA 01721
c Pall Biomedical Products Corp., Glen Cove, NY 11542
d Mallinckrodt Sensor Systems, Ann Arbor, MI 48106
e Haemonetics Inc., Braintree, MA 02184

Table 1

Time on bypass		pH	pCO_2	HCO_3	pO_2	SAT %	Hct	BE
5 min	art	7.50	34	26.4	544	100	19	+3.4
	ven.	7.40	42		42	77.1		
20 min	art.	7.41	40	25.0	293	99.9	19	+1.0
	ven.	7.36	46		46	79.6		
36 min	art.	7.42	38	24.4	237	99.8	19	0
	ven.	7.36	46		29	51.5		
45 min	art.	7.34	45	24.0	250	99.8	18	+0.5
	ven. (no time for a venous sample)							

Table 2

Time	Hct	Platelet count	Arterial pH	Arterial Sat
pre-bypass	33.5	423,000	7.43	99%
post-bypass	28.7	227,000	7.41	99%
24 hr postop	30.1	270,000	7.39	99%

minutes the nasopharyngeal temperature was 29.4°C, the cardiac index (CI) was 1.6 l/m²/min and the mean arterial pressure (MAP) was 25 mmHg. The gas sweep rate and FiO_2 remained at 2.5 LPM and 70 percent, respectively. An ACT was performed with a result of 735 seconds. The aorta was clamped at this time and 230 ml of cardioplegia was delivered into the aortic root. Arterial and venous blood samples were taken after five minutes on bypass and analyzed on the GEM 6 Plus. The results, using the alpha stat method, are shown in Table 1. A centrifuged Hct was performed at this time for comparison. The result was 17 percent.

In order to elevate the MAP, the blood flow was increased to 2.2 l/m²/min resulting in a MAP of 35 mm/Hg.

Following the blood gas result, the gas sweep rate was decreased to 1.75 LPM and the FiO_2 was decreased to 55 percent to bring the arterial blood gas to within normal limits. 75 ml of LR was added to the circuit via the venous reservoir in order to maintain an adequate operating level.

After 20 minutes on bypass, the patient's temperature was 29.2°C. A second set of blood gases was performed at this time. The results are shown in Table 1. The centrifuged Hct at this time was 18 percent.

After 25 minutes on bypass, warming of the patient was initiated. At this time, the arterial blood flow rate was at 2.2 l/m²/min, the MAP was 33 mmHg, the sweep rate and the FiO_2 were increased to 2.0 LPM and 65 percent respectively.

After 36 minutes on bypass the patient's nasopharyngeal temperature was 30°C. No changes were made in the arterial blood flow, gas sweep rate or FiO_2. A third blood gas analysis was performed. The results are in Table 1.

At this time the arterial blood flow rate was increased to 2.6 l/m²/min in order to raise the venous oxygen saturation. The MAP remained at 35 mmHg. The gas sweep rate remained at 2.0 LPM and the FiO_2 was increased to 70 percent. 125 ml of LR was added to the circuit via the venous reservoir in order to maintain a safe operating level.

After 38 minutes on bypass, the patient's nasopharyngeal temperature was 38°C. The aortic clamp was removed and the arterial blood flow was increased to 3.4 l/m²/min to meet the patient's higher oxygen requirements due to the temperature change. The MAP, gas sweep rate and FiO_2 remained unchanged.

At 46 minutes after initiation of bypass, the patient was weaned from bypass with a MAP of 60 mmHg and pulmonary artery diastolic pressure of 10 mmHg.

An ACT was performed just prior to termination of bypass with a result of 515 seconds. The protamine dose of 100 mg was given to the patient. The dose was determined using a Bull Dose Response Curve[1]. The remaining perfusate from the circuit was processed using the cell saver resulting in a total of 250 ml of autologous red blood cells, which was transfused immediately following bypass. Table 2 compares the Hct, platelet count, arterial oxygen saturation and arterial pH preoperatively, immediately post-pump and 24 hours postop-

eratively. The patient made approximately 10 ml/kg/hr of urine on bypass and was given furosemide postoperatively because her original blood volume had been expanded by approximately 500 ml on bypass.

Discussion

Hemodilution during cardiopulmonary bypass is a well-established practice[2-6]. Utilization of a clear prime in pediatric cardiopulmonary bypass circuits, as was first attempted during the 1970s, has not gained wide acceptance[7].

This case is an example of a patient who received the benefits of a bloodless prime without being hemodiluted beyond her limits of tolerance. The benefits are exemplified through careful examination of the case data.

The major benefit of using a bloodless prime with autologous transfusion is that the patient is not exposed to blood products which may cause transfusion reactions, precipitate formation of atypical antibodies or be a source of viral infection[8-10].

The fact that the patient put out 10ml/kg/hr of urine on bypass indicates that there was adequate renal perfusion[8,11].

The Hct, pH and venous oxygen saturation were within acceptable limits post-bypass which indicates that the patient's oxygen carrying capacity remained adequate. This is another indicator of adequate tissue perfusion[9,12-14]. The arterial oxygen saturation was 99.8 percent. This only proves that the oxygen carrying capacity of the hemoglobin was maximized; not that the oxygen content available for exchange at the tissue level was adequate. Therefore, the pH and the HCO_3 must be scrutinized. The final blood gas on bypass showed a pH of 7.34 with a pCO_2 of 45 and a HCO_3 of 23. These results demonstrate the adequacy of perfusion because the production of lactate resulting from anaerobic metabolism would have depressed the pH even further.

During the late 1980s interest was rekindled in this approach to pediatric perfusion[9,10,15,16]. We have used this technique successfully on 10 pediatric patients weighing as little as 11 kg, including one Jehovah's Witness patient. Their defects varied from an atrial septal defect to a Tetralogy of Fallot.

Bloodless primes have a place in pediatric open heart surgery. We demonstrated that this technique can be safely performed as evidenced by an adequate post-bypass hematocrit and by the lack of a significant acidosis.

References

1. Bull B, Korpman RA, Huse WM, Briggs B: Heparin therapy during extracorporeal circulation. J Thorac Cardiovasc Surg, 1975; 69:674-689.
2. Neptune WB, Bougas JA, Panico FG: Open heart surgery without the need for donor-blood priming in the pump oxygenator. N Engl J Med, 1960; 263:111-115.
3. Bailey CP, Hirose T, Gollub S, Hazan E, Folk F: Open heart surgery without blood transfusion. Vasc Dis, 1968; 5:179-187.
4. Urzua J, Irarrazaval M, Moran S, et al: Bloodless cardiac surgery utilizing a new low prime oxygenator. Artif Organs, 1979; 3(4):361-364.
5. Cohn LH, Fosberg AM, Anderson WP, Collins JJ: The effects of phlebotomy, hemodilution and autologous transfusion on systemic oxygenation and whole blood utilization in open heart surgery. Chest, 1973; 68:283-287.
6. Wiley J, Wachtel C, Cain R, Spaw S, Collins J, 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(2):121-133.
7. Buckley MJ, Austen WG, Goldblatt A, et al: Severe hemodilution and autotransfusion for surgery of congenital heart disease. Surg Forum, 1971; 22:160-162.
8. Litwak RS, Jurado RA, Lukban SB, et al: Perfusion without donor blood. J Thorac Cardiovasc Surg, 1972; 164:714-728.
9. Kawaquichi A, Bergsland J, Subramanian S: Total bloodless open-heart surgery in the pediatric age group. Circulation (Suppl), 1984; 70:1-37.
10. Stein JI, Gombotz H, Rigler B, Metzler H, Suppan C, Beitzke A: Open heart surgery in children of Jehovah's Witnesses. Pediatr Cardiol, 1991; 12:170-174.
11. Larch DR: Anesthetic management during cardiopulmonary bypass. In: Hensley FA, Martin D, eds: The Practice of Cardiac Anesthesia. Boston: Little Brown Co, 1990; 229.
12. Berger EC: The physiology of adequate perfusion, St. Louis: CV Mosby, 1979; 130.
13. NiiniKoski J, Laaksones V, Meretoja O, Jalonea J, Inberg MV: Oxygen transport to tissue under normovolemic, moderate and extreme hemodilution during coronary bypass operation. Ann Thorac Surg, 1981; 31(2):134-143.
14. Moores WY: Oxygen delivery during cardiopulmonary bypass. In: Utley J, Ashleigh EA, eds. Pathophysiology & Techniques of Cardiopulmonary Bypass. Baltimore: Williams & Wilkins; 1982; 1-11.
15. Youqi H, Zhaokang S, Wenxiang D: Cardiopulmonary bypass of bloodless prime used in open heart surgery of children and infants (48 case analysis). [Abstract] J Extra-Corp Tech, 1990; 22(1):7.
16. Henling CE, Carmichael MJ, Keats AS, Cooley DA: Cardiac operation for congenital heart disease in children of Jehovah's Witnesses. J Thorac Cardiovasc Surg, 1985; 86:914-920.