Priming Solutions and Fluid Balance for Pediatric Patients Undergoing Open Heart Surgery

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The selection of priming solutions and additional fluids for the pediatric patient is a challenging task. A delicate balance of various fluids including blood must be utilized to maintain metabolic stability. Volumes that have broad flexibility in adult cases are highly critical in the pediatric patient. Outlined herein are the techniques utilized at The Johns Hopkins Hospital during cardiopulmonary bypass in the pediatric patients. We classify the pediatric cases in two categories, those under 15 Kg. as infants, and 15 to 35 Kg. as children.

Technique

The first step in the priming procedure is to calculate the patient's blood volume. We accept that the neonate blood volume is approximately 88cc/Kg. of body weight. As the child grows to an adult the volume is reduced to a level of approximately 65cc/Kg.[1,2] We have elected to divide our patients into five groups as shown in Figure 1. The blood volume can then be quickly determined

BLOOD VOLUME ESTIMATION

Weight Group	Volume
Newborn to 10 Kg.	85cc/Kg.
10 Kg. to 20 Kg.	80cc/Kg.
20 Kg. to 30 Kg.	75cc/Kg.
30 Kg. to 40 Kg.	70cc/Kg.
40 Kg. & Over	65cc/Kg.

FIGURE 1

by simple calculation. After a blood volume determination is made, red cell content is calculated by multiplying the blood volume by the hematocrit. A total circuit volume is obtained by adding the patient's blood volume to the amount of volume required to prime the pump oxygenator circuit. The next step is to calculate the amount of red cells it will take to establish a total circuit hematocrit of approximately 30%. This is done by multiplying the total circuit volume by 0.30. The patient's red cell volume is then deducted and the balance, if needed, is made up by using packed red cells. On all cases under 15 Kg. we utilized fresh heparinized blood containing 2000 units of sodium heparin U. S. P. per 500cc.[3] Sometimes due to the lack of time or the availability of heparinized fresh blood, ACD blood must be used. Acid Citrate Dextrose (citric acid, sodium citrate, dextrose) preservative presents certain problems. The first is that there is a metabolic acid load placed on the body by the ACD solution. In the adult this is rapidly metabolized and excreted in the urine, but in the small pediatric patient it is not so readily removed. Analysis of ACD blood samples have shown pH ranges of 6.5 to 6.9 and a base excess range from −13 to greater than −25. To offset this acid load, sodium bicarbonate (8 to 12 milliequivalents) should be added for each 500cc unit of ACD blood. Another point to consider is the binding of the calcium by the citrate causing ACD blood to be hypocalcemic. If not corrected, hypocalcemia

will cause severe depression of the myocardium. The addition of 20 milliequivalents or 1 gm of calcium chloride for each 500cc unit will overcome this.[3,4] The length of time blood is stored in ACD solution is very important for two reasons. First as the erythrocytes age they become fragile and rupture easily. Second the ACD solution is hypertonic causing the red cells to shrink making the wall of the cell very rigid so that it does not change shape easily when it moves within the capillaries of the patient. These factors cause high plasma hemoglobin levels and aggregation of the cells resulting in plugging of the microcirculation.[5] In infants over 8 Kg. hemodilution using Ringers Lactate is employed. The amount varies from that equal to the daily fluid intake requirements in the smaller patients to a maximum of a total Ringers prime in the large patients.[6,7] (see Figure 2) Ringers

RECOMMENDED DAILY FLUID REQUIREMENTS FOR PRIMING USING RINGERS LACTATE

Patient Size by Weight	Volume Required in ML
Premature	50 ml/Kg.
Newborn	40 ml/Kg.
4 Kg.	120 ml/Kg.
6 Kg.	112 ml/Kg.
8 Kg.	108 ml/Kg.
10 Kg.	100 ml/Kg.
12 Kg.	92 ml/Kg.
14 Kg.	86 ml/Kg.
16 Kg.	80 ml/Kg.
18 to 20 Kg.	50 ml/Kg.
20 to 50 Kg.	1500 ml + 30 ml/Kg. above 20 Kg.

FIGURE 2

Lactate is used because it also supplies a quantity of balanced electrolytes. Dextrose 50% USP is added to all primes, except in the diabetic patients, in an amount sufficient to obtain a 5% prime solution. This is done to supply substrate for the myocardial metabolism and also to aid in the diuresis of the patient. Heparin is added at the rate of 2000 USP units per 500cc of prime volume. For deep hypothermia patients low molecular weight dextran (Dextran 40) in an amount equal to 10% of the blood volume is infused prior to bypass to help retard the aggregation of the erythrocytes and to further reduce the hematocrit. Dilution is important because as the temperature is reduced the viscosity increases and a reduction in hematocrit is necessary to maintain constant viscosity.[8] (see Figure 3) After the addition of the above items the remaining volume is made up of fresh plasma or Plasmanate.* This will balance the prime to an oncotic pressure that will retard the excess shift of the intravascular fluid into the interstitial space.

During bypass fluid must usually be added to make up for unavoidable losses during surgery. These losses include urine output, blood not returned to the pump, evaporation, and some loss into the tissue. The fluid additions during bypass must be selected to maintain adequate circulatory volume, hematocrit and minimize excess fluid loss in the tissue. If all of the calculated daily water intake volume was not added to the prime the balance may be added during the perfusion as Ringers Lactate. This addition should not lower the hematocrit below 25%. If the water intake has previously been added then the volume should be replaced with an oncotically equivalent solution such as Plasmanate until the hematocrit reaches 25%. Whole blood or packed cells should then be used to raise the hematocrit to 28-29%. Maintaining a hematocrit range from 25-29% during bypass helps keep the viscosity down during moderate hypothermia and helps retard red cell aggregation and the blockage of the microcirculation by these aggregates.[5]

*Manufactured by Cutter Laboratories, Inc., Berkeley, California.

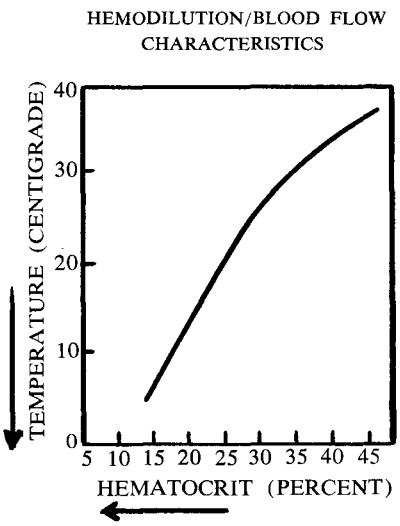

FIGURE 3

Chart shows relationship of hematocrit to blood temperature to maintain constant blood viscosity during hypothermia.

Graph reproduced from Anesthesia Rounds volume IV, No. 2 July 1973[8]

During bypass the flow should be adjusted between the calculated high and low ranges to maintain a mean arterial pressure of 50-70mm/Hg.[4] If the flow reaches the highest calculated rate and the pressure is below 50mm/Hg. then various drugs may be given to increase the pressure. This is preferred over using a very high flow rate which results in the need for extra fluid additions. We elect to use mephentermine (3-4mg) or methoxamine (.5-1mg) to increase the pressure. If stronger action is needed phenylephrine (.01-1mg) is used. Another advantage of maintaining higher perfusion pressure we have found is that good renal output is usually achieved without the use of diuretics. Rarely is there a patient whose urinary output falls below .5ml/hr/Kg and in these cases 2-25gms. of Mannitol are added to improve renal function. If further diuresis is desired, Furosamide (2-25mg) can be used. Lower urine output we have found is more prevalent with lower arterial pressures.[9] In cases with acute hypertension the pressure can be lowered if not contraindicated, using halothane (.1-1%).

We have used the foregoing procedures during the last two and one-half years at this institution for a total of 240 open heart procedures. There have been no complications that were attributable to the priming technique or the fluid additions used during bypass in this series of patients.

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