Cardiopulmonary Bypass in Infants Undergoing Heart Surgery

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INTRODUCTION

Whole body perfusion of infants during cardiac surgery continues to be a great challenge to the perfusionist. Techniques that in an adult have broad flexibility become highly critical in the infant. Outlined herein are the procedures that are followed at the Johns Hopkins Hospital during cardiopulmonary bypass in infants. We classify infants in two categories, those 8 Kg and under and those 8 to 15 Kg.

TECHNIQUE

In the near future, as soon as our techniques are perfected, we plan to utilize membrane oxygenators for all patients under 10 Kg. Currently we are using a Bentley Q 130 infant bubble oxygenator. A Sarns double roller pump is used in combination with a Travenol 6LF line set for arterial perfusion. In infants less than 5 Kg a ¼ inch venous return line is used while on those 5 to 15 Kg a ⅜ inch line is used. The oxygenator is mounted as for adult cases on a Travenol motorized mast so that venous pressure can be varied by raising or lowering the oxygenator height during bypass.[1] A one liter cardiotomy reservoir is used to filter and return blood to the oxygenator from the ventricular sump and the coronary suckers. (see Fig. 1). Arterial pressure is monitored by a catheter placed in the radial artery on patients 8 Kg and over and in the femoral artery on those less than 8 Kg. This is connected to a pressure transducer for direct readout on a Electronic for Medicine monitor. Central venous pressure is monitored directly using a water manometer connected to a catheter placed in the suprerior vena cavae via the external jugular vein. Priming for infant perfusion varies with each case but there are certain factors which are basic and constant. At the present time in infants under 8 Kg we utilize a total blood prime to avoid excessive hemodilution. Ideally fresh heparinized blood should be used containing 2000 units of sodium heparin U S P per 500cc.[2] Sometimes, due to lack of time or the availability of heparinized fresh blood, ACD whole blood must be considered. 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 infant 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 to 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 gram of calcium chloride to each 500cc unit of blood will overcome this.[2]

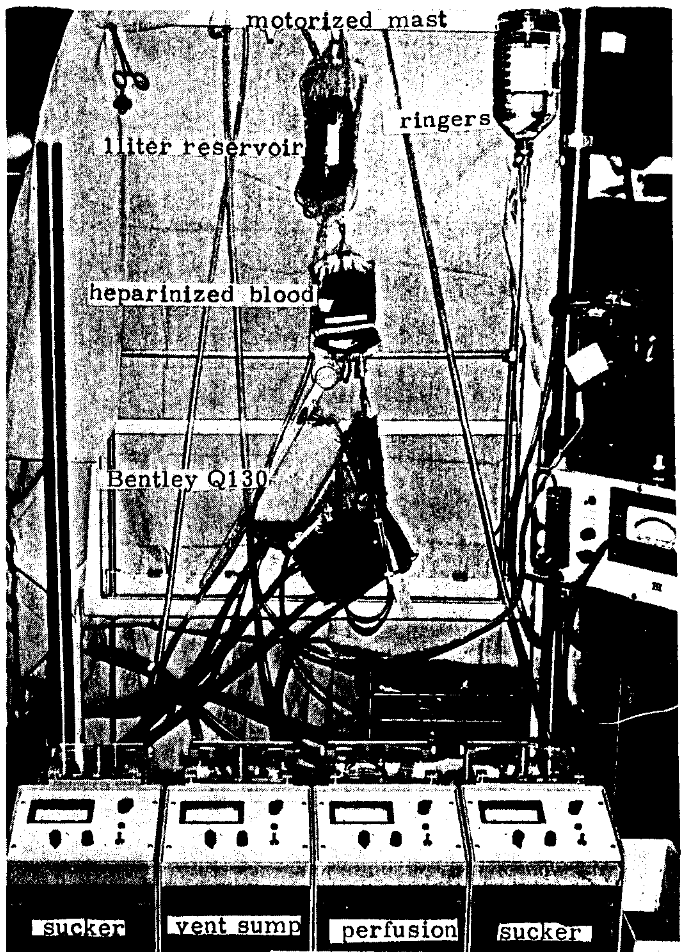

FIGURE 1

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 of the passage of the extracorporeal circuit. 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 of Ringers Lactate is equal to the daily fluid intake calculated from the body weight.[3] (see Fig. 2) The blood or solution with equivalent oncotic pressure is then added to this volume. The solutions such as Plasmanate are used mainly in cases with high preoperative hematocrit as in the severely cyanotic child. In all cases hemodilution should not lower the hematocrit below 30%. Dextrose 50% USP is added to all primes in an amount sufficient to make the prime a 5% 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 units per 500cc of prime volume. After bypass excess fluid is removed by the use of diuretic agents such as mannitol or furosamide.

Prior to the placement of the perfusion canulae, the patient is heparinized with an initial dose of 400 units (4mg) per Kg of body weight. During bypass supplements equal to ½ the original dose are given at two hour intervals. Cannulation of the ascending aorta is selected as the route for the return of arterialized blood to the patient. Venous blood is returned to the pump via a cannula placed in the superior vena cava and the inferior vena cava respectively. In some cases the cannulae present such as obstruction to the cavae that they must first be placed in the antrium and partial bypass instituted. After the patient has stabilized on partial bypass the cannulas are then moved into the cavaes. In these patients this procedure must be reversed to terminate bypass.

RECOMMENDED DAILY FLUID REQUIREMENTS FOR PRIMING

Infant size in Kg	H_2O ml/Kg	Na meq/Kg	K meq/Kg
Premature	50	1.5	1.5
Newborn	40	0.5	0.5
4	120	1.8	0.5
6	112	1.7	0.5
8	108	1.6	0.5
10	100	1.5	0.5
12	92	1.4	0.5
14	86	1.3	0.5
16	80	1.2	0.5

FIGURE 2

PERFUSION FLOW RATE CHART

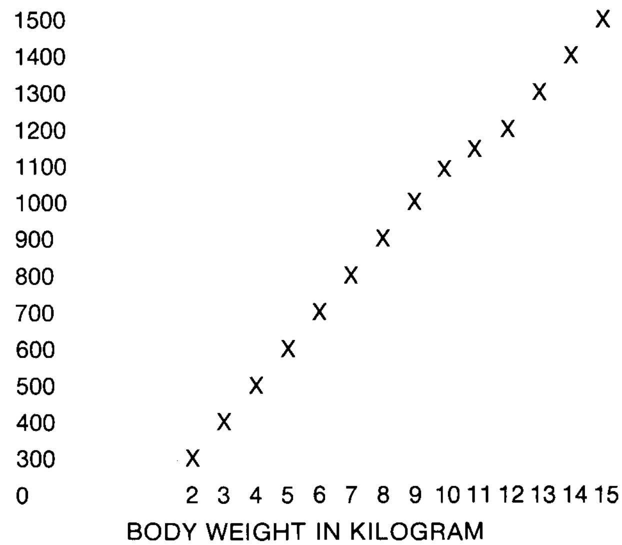

FIGURE 3

FLOW RATE IN CC/MIN

Perfusion flow is determined by using flow rates equivalent to 100 to 130cc/Kg of body weight. (see Fig. 3) To start bypass, infusion is slowly begun while at the same time slowly increasing the venous return. This procedure is carefully regulated until full flow is reached and venous pressure is stabilized to approximately 2-3 cm/of water. After a ten minute stabilization period blood gases are assessed to determine the adequacy of the perfusion.[4] If the arterial pressure is below 40mmHg at this time, flow is increased to give an optimal arterial pressure of 50 to 70mmHg. If the increased perfusion flow does not raise the perfusion pressure adequately, then pressure is raised by the addition of phenylephrine (.01-.95mg) or mephenteranine (3-4mg) into the oxygenator reservoir. We find that an arterial pressure between 50-70mmHg gives the best results both in adequate tissue oxygenation and renal function as reflected by normal blood gas determinations and adequate urine output. Oxygen flow (100%O_2) is adjusted to give arterial O_2 partial pressures of 150mmHg and CO_2 partial pressure between 25 and 30. The advantage of higher O_2 pressures is questionable and has the negative effect of causing CO_2 washout which leads to severe respiratory alkalemia and upward shift of pH as much as 7.5 to 7.7 pH units. Respiratory alkalemia will also lead to increased cerebral vascular resistance and increased lactate levels when CO^2 washout exceeds the metabolic CO_2 production.[2] Normothermia is maintained on procedures less than 1½ hours. Cases over this length of time are maintained with slight hypothermia 32°C during perfusion. Careful attention must be paid to oxygenator blood level in infant perfusions. Because of the small volume contained in the infant oxygenators chance of air embolism is exeedingly great.

Immediately at the end of bypass, blood gases, potassium level, Hct. levels are evaluated and necessary corrections are made. An attempt is made to transfuse as much blood as possible from the pump oxygenator reservoir to maintain venous pressure during the first 15 minutes post bypass. This helps to decrease the amount of fresh bank blood required to maintain adequate blood volume. All cannulae and lines are then disconnected and all further blood losses are replaced with fresh bank blood. Heparin is converted using a 2:1 ratio of protamine, taking into consideration the active half life of all heparin given. We have had excellent results using the above techniques in infants at this institution over the past two years.

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