

# Circulatory Arrest with Profound Hypothermia

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## INTRODUCTION

Deep hypothermia and cardiocirculatory arrest are used in order to accomplish early surgical correction of congenital cardiac defects in a still, dry heart without obstructing cannulae. The additional surgical risks involved with a palliative procedure and later surgical correction are thus avoided along with the continuing destructive effects to the heart and other organs of the body when complete surgical correction is delayed. The aim of this paper is to outline perfusion management derived from over three hundred clinical cases operated upon using profound hypothermia at the Buffalo Children's Hospital in 1969. To assist in illustrating the perfusion technique used with this type of surgery, I will use an eight month old, 4.5 Kg patient as an example.

## DATA EVALUATION

Let us look at the rationale behind the make-up of the basic prime components as this effects the calculations given in the data evaluation. For the volume of red blood cells (RBC) added to the prime (250 ml in this example), an equal volume of fresh frozen plasma (FFP) (250 ml) is used. The remaining volume of prime required (500 ml) to fill the system is made up of an equal amount of fresh frozen plasma (250 ml) and Ringer's lactate (250 ml). And so, in this example, the required 1 litre of basic prime volume is made up of 250 ml RBC, 500 ml fresh frozen plasma and 250 ml Ringer's lactate.

In the beginning, there is patient data to be gathered. For our example, we will show this in tabulated form.

- (1) patient weight: 4.5 Kg
- (2) immediate preoperative hematocrit: 45%
- (3) patient blood volume:  $\text{weight} \times 80 \text{ ml/Kg (constant)} = 4.5 \times 80 = 360 \text{ ml}$
- (4) infant perfusion flow rate:  $\text{weight} \times 120 \text{ ml/Kg (constant)} = 4.5 \times 120 = 540 \text{ ml/min}$
- (5) patient Heparin dose (Table 1):  $\text{weight} \times 100 \text{ USP} = 4.5 \times 100 = 450 \text{ USP}$
- (6) total prime required for infant oxygenator, tubing, filters: 1000 ml
- (7) predicted hematocrit for initial perfusion (Table 2): 18%
- (8) prime heparin:  $4 \text{ USP/ml blood or plasma prime} - 4 \times (250 \text{ ml RBC} + 500 \text{ ml FFP}) = 3000 \text{ USP}$
- (9) prime CaCl:  $2 \text{ mg/ml RBC} = 2 \times 250 = 500 \text{ mg}$

TABLE 1 Patient heparin dose

0 to 10 Kg—100 USP/Kg
10 to 20 Kg—200 USP/Kg
above 20 Kg—300 USP/Kg

TABLE 2 Hematocrit for initial perfusion

$\text{Hct.} = \frac{(\text{BV}_1 \times \text{Pt. Hct.}) + (\text{BV}_2 \times 35)^*}{\text{BV}_1 + \text{BV}_2 + \text{BV}_3}$
$\text{Predicted Hct.} = \frac{(360 \times 45) + (250 \times 35)}{360 + 250 + 750}$
$= 18\%$
$\text{BV}_1 = \text{Patient blood volume}$
$\text{BV}_2 = \text{Prime blood volume}$
$\text{BV}_3 = \text{Prime dilution volume}$
$35^* = \text{Average bank blood Hct.}$

- (10) prime sodium bicarbonate: 7 mEq/500 ml prime = 14 mEq
- (11) prime mannitol = 0.5 gm/Kg patient weight = 0.5 × 4.5 = 2.25 gm

### EQUIPMENT

A Q-130 Temptrol\* infant oxygenator is set up for the perfusion using a Pall single pass 40 micron filter in both arterial and cardiotomy lines. Heat exchange is carried out exclusively by the integral heat exchanger in the oxygenator with a Sarns 11160 Heater/Cooler providing an independent, closed circuit, water supply for temperature control. A Hypothermic Chamber† accomplishes the external cooling of the infant in optimum time with complete visibility and accessibility. The air within the transparent chamber is force circulated at a temperature of -3°. By using a gaseous cooling media, uniformity and maximum surface area coverage is achieved. The surface on which the patient is lying within the chamber is a circulating hypothermic blanket supplying surface cooling to the contact areas not exposed to the cooling air stream.<sup>2</sup> Monitoring of the patient consists of arterial pressure, central venous pressure, ECG, EEG, esophageal and rectal temperatures. Arterial and venous blood gases, electrolytes, total serum protein, and activated clotting time are measured every fifteen minutes and more frequently when indicated.

### METHODS (Figure 1)

Surface induced cooling to 24°C is employed by using the Hypothermic Chamber. While the patient is being prepared for the cool-down phase, the cardiopulmonary bypass

\* Bentley Labs, Irvine, Calif.  
 † Thermo-Temp Corp., Buffalo, N.Y.

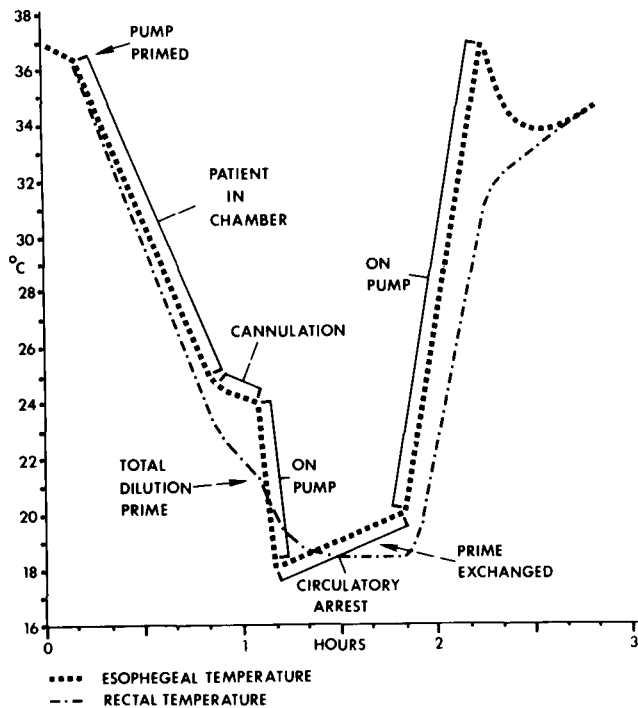


Figure 1

circuit is primed, bubbles purged, pump head occlusion set, and the prime is pre-cooled to 5°C. The prime components are introduced into the arterial reservoir side of the oxygenator, reducing pre-perfusion exposure time through the oxygenation side of the system. We do not employ a shunt, and desire to keep pre-perfusion circulation and saturation to a minimum, beyond complete debubbling of the circuit. The perfusion circuit is thus ready and on standby during the surface cooling phase in case of a drop in cardiac output or fibrillation.

On reaching 24°C, the patient is removed from the chamber and placed upon a thermal blanket on the operating table. Following thoracotomy and cannulation, the patient is placed on bypass for further cooling to 18°C in 5 to 7 minutes. The ascending aorta is then cross-clamped, perfusion terminated, and the patient is exsanguinated through the venous return line until the venous pressure just ceases falling at 0-2 mm/Hg pressure. Cardioplegic solution is injected into the myocardium and the myocardial temperatures are recorded with a Yellow Springs 500\* series probe. The cerebral electrical activity soon falls below two microvolts following cessation of cardiopulmonary bypass.<sup>3</sup>

Prior to the start of rewarm perfusion, during cardiocirculatory arrest, some of the hemodiluted prime is removed from the sample port on the side of the arterial reservoir and replaced by platelet-free packed cells. The volume involved is calculated to increase

\* Yellow Springs Instrument Co., Yellow Springs, Ohio

the hematocrit to 24–26% and is usually 300–500 ml. The cells are added through the cardiotomy (venous) side of the system so that they may be oxygenated and filtered on entering the reservoir.

The prime is pre-warmed during the arrest period to give a differential temperature of 7°C relative to the patient's esophageal temperature probe. The patient's thermal blanket is switched from the cooling to the warming mode prior to the start of the re-warming perfusion, allowing the blanket circuit sufficient time to equilibrate with the patient's temperature. Timing is of the essence in order to avoid having to rewarm the blanket and the patient with the core perfusion.

At the end of the arrest period, the patient is transfused through the arterial line (leaving the venous line clamped) until the desired venous pressure (15 mm/Hg) is reached and maintained at that level during venous re-cannulation. Perfusion flow rates are kept elevated to facilitate rewarming, spontaneous heart action normally occurs by 26°C. The hematocrit is returned to normal by the addition of platelet-free packed cells. Nitroglycerin is added to the pump oxygenator for peripheral vasodilation.

The heparinization is monitored by the activated clotting time method using a Hemochron 400.\* Allowance is made for the effects of temperature and more heparin is given if clotting is evident at 600 seconds while the patient is still under 32°C. This time will fall with rewarming, very rapidly in some cases, below our minimum of 500 seconds.<sup>1</sup> High amplitude, low frequency brain activity returns during the rewarm phase with higher frequencies and lower amplitudes returning by the end of the perfusion. As the esophageal temperature moves through 32°C, most parameters have returned to normal values, and attention is paid to potassium levels and urinary output. Lasix (1 mg/Kg) is given at this time if urinary output is not evident. Perfusion is terminated with an esophageal temperature of at least 36°C and rectal temperature of at least 28°C. Prime that is not transfused into the patient following bypass is returned to the blood bank for centrifugation to be used in the postoperative period.

## COMMENTS

Initial prime, pre-perfusion blood gases, and electrolytes are important, since the opportunity to monitor and correct these during the first short perfusion run is limited. Prime volume is larger than the infant patient volume, as indicated in the example given, and therefore plays a dominant role. Fresh blood components are used. Platelet-free red blood cells and full-factor fresh frozen plasma, thawed immediately upon use, are specified. Platelets are subject to destruction in the perfusion circuit and therefore become debris at the micro circulation level. Since they are rapidly replaced postoperatively by the body, we remove them from the blood added during perfusion and do not add platelets following perfusion. This is simply a matter of weighing the need for additional platelets during perfusion against the increased sludging effects produced by their destruction during the perfusion.

Perfusion flow is calculated at 120 ml/Kg and kept up during cooling and partial bypass rewarming, in order to facilitate heat exchange. This involves increased oxygen transport above hypothermic requirements. Thus, the oxygenator gas flow (98% O<sub>2</sub>, 2%

\* International Technidyne Corp., Edison, N.J.

CO<sub>2</sub>) must be regulated to maintain a safe PO<sub>2</sub> level of 100 to 150 mmHg during re-warming in order to prevent microbubbles from being liberated as well as watching all other parameters such as venous PO<sub>2</sub> saturation, in order that adequate perfusion is maintained.<sup>4,5</sup>

Attention also must be given to the location and reliability of the temperature probes and blood pressure lines. With the temperature probe, poor placement usually is evident by an extended time constant which can result in cooling to the desired level of 18°C only to find that the temperature continues down to 16°C after cooling is terminated. This is normal behavior for the rectal temperature but not for esophageal. The needle temperature probe should be calibrated with the readout to be used in surgery and by making a correction chart against a mercury thermometer to insure correct myocardial temperatures are being recorded. This type of perfusion involves constant change throughout and at no time is there much opportunity to achieve a "steady state" situation.

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