
Cardiopulmonary Bypass in the Neonate: Case Report

P. R. Cappola, E. Keough, R. J. Connolly, M. A. Khan, L. M. Wilcox, & J. J. Amato

Departments of Pediatric Cardiology and

Pediatric Cardiovascular Surgery

Children's Hospital of New Jersey

UHMC, Newark, New Jersey

and

Departments of Ophthalmology and Surgery

Tufts New England Medical Center

Boston Massachusetts

Abstract

Extra-corporeal perfusion was utilized during the surgical repair of congenital cardiovascular abnormalities in a twenty-four-hour-old neonate. Modifications of standard perfusion techniques are described. The need to monitor and carefully control the oxygen tension is discussed. High oxygen tension has been linked to retrolental fibroplasia (RLF) in neonates, and high oxygen tension can occur during extra-corporeal circulation. It is a logical precaution to keep the partial pressure of oxygen as close to normal as possible when perfusing neonates. The theoretical relationship between extra-corporeal oxygen exposure and RLF in neonates during open-heart surgery is discussed.

Introduction

Since 1954, cardiopulmonary bypass has been successfully employed in children and adults. Improvements in techniques and equipment now permit utilization of cardiopulmonary bypass in the neonate. Some unique perfusion considerations are presented with

neonates. This paper will discuss the perfusion techniques utilized in a 3.2 kilogram, one-day-old infant with a pulmonary artery to inferior pulmonary vein fistula and aneurysm of pulmonary vein communicating with the left atrium.

Materials and Methods

The superior and inferior vena cava were respectively cannulated with 12 French and 14 French drainage cannula.* Arterial blood was returned through a 10 French aortic perfusion cannula.** The extra-corporeal pump was an occlusive modular pump,*** with a $\frac{3}{8}$ inch internal diameter $\times$ $\frac{1}{8}$ inch wall thickness silicone rubber pumphead tubing. A $\frac{1}{4}$ inch internal diameter arterial line filter****, was placed 15 inches distal to the pumphead. A pressure monitoring line was incorporated from the top of the filter purge port to an aneroid manometer. The pumphead occlusion was set to hold a pressure of 120 torr.

Communications should be addressed to: Paul R. Cappola, B.S., Department of Pediatric Cardiovascular Perfusion, Children's Hospital of New Jersey/UHMC, 15 So. 9th St., Newark, New Jersey 07107.

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* U.S.C.I.—Division of C.R. Bard Inc., Billerica, Mass. 08121, Model #007724 (12 Fr), #007725 (14 Fr).

** Argyle-Sherwood Medical Inc., North Brunswick, N.J. 08902, Model #8888-591008.

*** Cobe Laboratories, Inc., Lakewood, Colorado.

**** Pall Biomedical Products Corp., Glen Cove, N.Y. 11542, Model #EC1440.

Temperature was controlled and oxygenation was provided by a Shiley S-70 infant oxygenator⁺. Gas flows were administered via two low-flow flowmeters⁺⁺ in conjunction with two stage pressure regulators⁺⁺⁺ requiring inlet pressures of 20 pounds per square inch. Two separate tanks of gas were utilized consisting of 100% oxygen and 95% oxygen—5% carbon dioxide (calibrated and certified) mixtures. The gas sources were then “Y” ed together, filtered and connected to the oxygen port of the oxygenator. Operating temperature was in the 20 degree Centigrade range, and a mixture of 95% oxygen—5% carbon dioxide was used to augment cerebral blood flow and adequate perfusion during hypothermia.¹(pp. 367–368) During the rewarming phase the flow of carbon dioxide was decreased, and the flow of oxygen was increased to accommodate an increased metabolic need. Gas flow mixtures never exceeded 700cc per minute on bypass.

Results

The highest pO₂ on bypass was 264 torr with a gas flow of 500cc per minute of 95% oxygen—5% carbon dioxide during hypothermia (blood temperature 22.9 degrees Centigrade). During the transition from hypothermia to normothermia, the highest pO₂ on bypass was 228 torr with a gas flow of 500cc of 100% oxygen per minute and 200cc per minute of 95% oxygen—5% carbon dioxide (blood temperature 28.4 degrees Centigrade).

Although the neonate described in this report was subjected to higher than normal partial pressures of oxygen during perfusion, the patient exhibited no symptoms of RLF in examinations 13 and 90 days postoperatively. This may be due in part to the special efforts taken in this case to reduce the intensity of the hyperoxygenation and the duration of exposure. However, no conclusions can be drawn concerning safe limits during by-pass.

Discussion

A number of the technical aspects of standard cardiopulmonary bypass techniques must be carefully

considered and modified when perfusing neonates. These include the use of two venous drainage cannulae, low calibrated pumphead occlusion, hypothermia, and carefully regulated gas flows.

Two venous cannulae are preferred over a single larger, right atrial cannula to minimize obstruction of venous drainage by surgical manipulation of the heart within the restricted operating field. Drainage from both vascular beds should be monitored while the patient is on bypass. It is imperative to maintain normal venous pressure in the neonate. Alterations of fluid balance can cause rapidly developing abnormalities. The rate of fluid balance (input and output) in the neonate is seven times that of an adult. The newborn has twice the metabolic rate of an adult in relation to body mass. These conditions coupled with an incomplete renal function present a clinical picture of acidosis and possible overhydration in the normal newborn.¹(pp. 996–997) It is reasonable to assume that obstructing venous return will compound these existing conditions and may cause vascular trauma and post-operative edema. It is prudent to avoid stressing the body systems of the neonate in their immature development by monitoring venous drainage.

A pumphead occlusion pressure of 120 torr delivers predictable flows under clinical conditions while allowing some slippage of blood through the roller head in the event of high line resistance. Silicone rubber pump head tubing, having more elasticity than polyvinyl chloride, is more likely to diminish any mechanical strain on the patient with regard to pressure and flow within the arterial circuit. The pumphead occlusion pressure is easily measured by placing a pressure monitoring line and manometer off the arterial line filter. Pressurizing the manometer to several hundred millimeters of mercury may be accomplished by placing a tube occluding forcep distal to the arterial line filter. With the clamp in place, the arterial roller head is advanced forward to a predetermined location in the backplate housing of the roller pump. Adjustment of the pumphead's occlusion mechanism can now be modified until the desired pressure is obtained. This technique of a low pumphead occlusion pressure coupled with silicone rubber tubing in the pumphead will afford a degree of patient safety in the face of possible changes in the peripheral vascular resistance or by accidental kinking or clamping of tubing while on bypass.

A gas flow of no less than one liter per minute is recommended by the oxygenator manufacturer to

⁺ Shiley Corp., Irvine, Ca 92714.

⁺⁺ A Div. of Philips Co., Hackensack, N.J., 07606 Model, # 10A1348-17133AH.

⁺⁺⁺ Ohio Medical Products, Madison, WI 53701, Model #8400 Regulator Series.

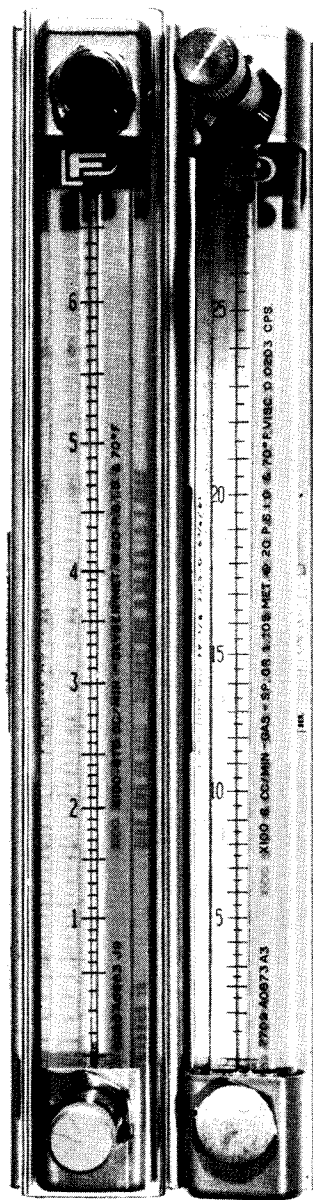


FIGURE 1. These are industrial gas gauges that have been adapted for regulating gas flows during extracorporeal circulation. The meters are manufactured by the Fisher and Porter Company and distributed by I.M.I., a division of the Philips Company, Hackensack, New Jersey 07606. The direct reading scale on the left side reads up to 600cc per minute. The scale on the right reads up to 2500cc per minute. These direct reading scales (Model # 10A1348-17133AH) coupled with a means to continuously monitor ventilating gases on bypass will afford the open-heart team a fine adjustment of oxygen tensions.

prevent fluid from draining into the oxygen dispersing plate and obstructing it.² However, it was tenable to safely lower the gas flows to 500cc per minute by utilizing the gas gauges and regulators used in this case. If RLF is a risk to the neonate undergoing cardiopul-

monary bypass due to excessive oxygen administration, excessive oxygen delivery should be avoided. RLF, or retinopathy of prematurity, is a retinovascular disorder which was linked in the 1950's with administration of high oxygen to premature infants.^{3,4} Although usually thought of as a disease primarily affecting incubator premature infants, full-term newborns are also susceptible since the temporal retinal periphery is not fully vascularized until after birth. In response to high levels of oxygen, vessels in the immature temporal areas will vasoconstrict with eventual danger to the capillary endothelium and closure of areas of the vascular bed.^{4,5} Exposure to normal oxygen levels thereafter results in retinal vessel dilatation and proliferation with neovascularization in the retina and into the vitreous body. Vitreous and retinal hemorrhages can occur causing retinal elevation and detachment. Occular damage caused by RLF ranges from areas of irregular pigmentation to totally detached, scarred retina with blindness.

Bubble oxygenators have a tendency to over-oxygenate neonates requiring blood flow rates in the 200cc to 350cc per minute range. There are several approaches to surgical teams coping with the elevated pO₂ of extra-corporeal bypass systems and possible RLF consideration. We have demonstrated a conservative approach by utilizing specially designed gas flowmeters

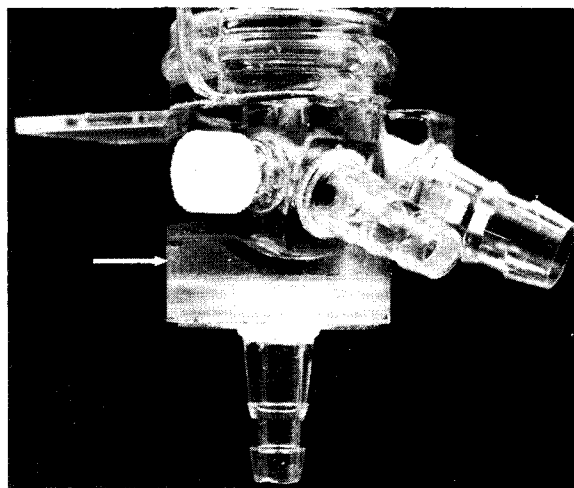


FIGURE 2. The arrow points to the oxygen dispersing plate (magnified) of the S-70 pediatric oxygenator. Gases are passed via the bottom 1/4" tubing port upwards through the dispersing plate into the gas transfer column. Gas flows in the 100cc-300cc per minute range will prevent perfusate fluids from draining down through the oxygen dispersing plate and obstructing it. Lowering of gas flows below the manufacturer's recommendations with close attention to a free-flowing oxygen dispersing plate is possible.

(See Fig. 1.) for low, accurate gas manipulations below the manufacturer's recommendations. Employment of 5% CO₂ administration during hypothermia is beneficial in lowering the pO₂ on bypass and increasing cerebral blood flow for adequate perfusion. Gas flows can be administered in the 100cc–300cc per minute range with close attention to a free-flowing oxygen dispersing plate in the S-70 oxygenator (See Fig. 2). A more radical approach could involve manipulating room air or compressed air to maintain lower pO₂ values on bypass. There are commercially available oxygen blenders (for example, Bird, Model 5101) that may be employed during extra-corporeal circulation for decreasing oxygen tension in the blood. However, there is a possibility of inducing nitrogen microemboli and infusing them into the patient.⁶ Gaseous microemboli may cause local areas of hypoxia, ischemia, infarction and necrosis.⁷

Summary

Neonates can be perfused successfully with preliminary precautions against any mechanical strains upon the underdeveloped systems of the body. Newborns are more apt to be afflicted with mechanical injuries induced by extra-corporeal apparatus than pediatric or adult patients. Our combined experience with

RLF and cardiopulmonary bypass indicate that a possible relationship could exist between the aforesaid. Normal neonates who were not exposed to elevated partial pressures of oxygen have developed RLF. There may exist a variability in sensitivity of infants to high oxygen. Over-oxygenation of body cells provides no obvious benefit, and normobaric oxygen toxicity may be a source of potential danger.⁸ It may be prudent to limit the exposure of all neonates to high oxygen pressures during extra-corporeal circulation.

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