

# *Use of the Constrained Vortex Pump in Children Under 20 kg*

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Key words: CPB, pediatric, constrained vortex pump, hemolysis

## **Abstract**

Since the inception of the constrained vortex pump, much controversy has arisen over its use during cardiopulmonary bypass (CPB). Centrifugal pumps used during pediatric perfusion requiring low flow rates have been cited with increased hemolysis and fluctuating flow rates. At the Medical College of Virginia Hospitals, 209 children weighing <20 kg have been placed on CPB utilizing the BioMedicus BP50 pump. This study describes the technique and evaluates pump induced hemolysis by measuring plasma free hemoglobin (PFH) production. Five consecutive pediatric patients, age 0.2-48 months, (2.8-12.8 kg.) undergoing CPB for repair of heart defects at MCVH were studied using the BioMedicus BP 50 pump head. Potential for stagnant areas of flow were avoided during weaning from CPB by decreasing rpms to a minimum of 1800 and controlling flows with screw clamps on both arterial and venous lines to further reduce and terminate CPB. Plasma free hemoglobin samples were drawn prior to bypass, 30 minutes, 8 hrs, and 24 hrs post-CPB. PFH was determined by the Perkins-Elmer Spectrophotometer method. Results showed an expected rise in PFH immediately post-CPB, and all but one patient returned to baseline levels within 8 hrs. None of the 209 pediatric patients managed thus far at MCV utilizing the BP 50 pump head have exhibited clinical evidence of renal damage due to generation of plasma free hemoglobin. The authors conclude that pediatric patients requiring CPB for repair of congenital heart lesions can be safely perfused using a constrained vortex pump.

## **Introduction**

There has been much debate about the application of the constrained vortex pump in pediatric cardiac surgery. Centrifugal pumps are non-occlusive pumps and offer several advantages over the positive displacement pump (roller pump) (1). The theoretical advantages of using a vortex pump include the avoidance of particulate matter embolization from tubing spallation (2,3), no risk of output over pressurization and subsequent rupture from arterial line occlusion (1), reduced risk of negative pressure cavitation, reduced risk of gross air embolization, and better blood handling characteristics (3-6). Centrifugal pumps

have been cited with increased hemolysis and fluctuating flow rates when used during pediatric perfusion requiring low flow states (3). At the Medical College of Virginia Hospitals, the Bio-Medicus BP-50 pump has been utilized in 209 cases for children weighing less than 20 kg. undergoing cardiac repair. Plasma free hemoglobin has been used in many studies as an indicator of pump induced hemolysis. The purpose of this paper was to describe a method for utilizing the BP-50 pump in patients less than 20 kg, and to present the results of five consecutive patients undergoing repair of congenital heart disease (CHD) in whom plasma free hemoglobin was measured in the perioperative period.

## **Methods**

The pediatric circuit was comprised of a Terumo oxygenator, Capiiox Series 308 or 320 or the earlier equivalent Capiiox 0.8 or Capiiox 1.6, Terumo cardiotomy, a Terumo venous reservoir bag (100 cc or 400 cc), the BioMedicus BP 50 pump, and a Terumo bubble trap (Fig. 1). The cardiotomy suction and vent were controlled by conventional roller pumps. The circuit was preflushed with CO<sub>2</sub> and primed with Plasmalyte A, 25 cc of 25% albumin, 20-30 meq. of sodium bicarbonate, 0.5 gm/kg of mannitol, and 500-1000 units of heparin. Additions of washed packed red blood cells were utilized to maintain hemoglobins initially of 6 mg/dl. Prior to termination of bypass, a hemoglobin equal to or greater than 8 mg/dl was achieved by further red blood cell transfusion. Perfusion techniques included blood flows based on 150 cc/kg/min at 37°C and 85-100 cc/kg/min at 22°C. Prior to initiation of bypass, the pump was turned on and rpm increased to at least 1800 before the arterial clamp was released. This technique is different than that used with positive displacement pumps as the output of the constrained vortex pump is related to both afterload and pump speed. Mean arterial blood pressure was controlled between 30 and 65 mmHg. Esophageal, rectal or bladder, and arterial and venous blood temperatures were routinely monitored. Blood gases were evaluated by alpha stat methods with pO<sub>2</sub> maintained between 100 and 200 mmHg (saturation 94-99%). Myocardial protection was achieved by cardioplegia solution (CPS) delivered every 20 minutes with the initial dose based on 20

cc/kg, and subsequent doses of 10 cc/kg. The CPS was made from D5-Ringer's Injection, KCI 30 meq/l, and sodium bicarbonate 20 meq./l, with blood added in approximately a 1:1 ratio. In one of the cases presented, deep hypothermia with circulatory arrest (DHCA) was utilized (patient #5). Weaning from bypass was achieved by utilizing screw clamps on both the arterial and venous lines. Volume given to the patient and blood return from the patient was restricted by means of these clamps. Once the appropriate CVP was achieved, the pump speed was decreased and more volume was returned to the patient. When the pump speed was approximately 1900-2000 rpm, the arterial screw clamp was utilized to restrict flow while pump speed was maintained assuring forward flow. Thus weaning from bypass may be achieved in a stepwise manner, incrementally decreasing flows by as little as 10 cc at a time. Once weaning from CPB was completed, the arterial and venous lines were clamped and recirculation of pump volume was achieved through the AV recirculation loop off the bubble trap and returning to the venous bag. When pressures were stable, the blood volume in the circuit was replaced with crystalloid and washed. The washed cells were then returned to the patient as needed during the next four hours. Plasma hemoglobins were drawn prebypass, 30 minutes after termination of CPB, eight hours post-CPB, and twenty-four hours post-CPB. These samples were placed in green top tubes containing sodium heparin and returned to the clinical laboratory. Plasma hemoglobin concentrations were determined by spectrophotometric technique utilizing a Perkins-Elmer spectrophotometer. Normal measurements for our laboratory are reported as less than 13 mg/dl. Platelet counts were obtained prior to CPB and approximately 24 hours post CPB. No control was made for administration of platelets either intra or postoperatively.

## Results

Five patients, age 6 days to 48 months, weighing 2.8-12.8 kg (mean 7.9 kg.), underwent a variety of operations including Fontan, Rastelli, and valve repair procedures, as well as arch repair with ASD/VSD closure (Table 1). One patient underwent DHCA. CPB times ranged from 148-194 minutes (mean 162 min.). In all cases, pre-CPB plasma Hb was reported as <13 mg/dl. 30 minutes post-CPB, the plasma hemoglobin rose in 4 of 5 patients (range 35-88 mg/dl- mean 59) while the fifth showed no detectable change. Eight hours following CPB, the plasma hemoglobin of four out of five patients had returned to baseline. The first patient studied showed a rise at eight hours which on review was thought by the clinical laboratory to be hemolysed because of inappropriate sample handling. Again at 24 hours, the plasma hemoglobin of four out of five patients remained <13 mg/dl. No sample was available for patient number 1 at 24 hours post CPB. The pre- and post-CPB platelet values are difficult to assess as there was no control over platelet administration post-CPB or in

the early postoperative period. None of the patients studied showed clinical or laboratory evidence of renal dysfunction in their postoperative course.

## Discussion

The use of a constrained vortex pump (eg., the BP-50) has been reported in neonates, infants and children (1,7). The centrifugal pump design has been noted for less trauma to blood cell components. Koja, et al., demonstrated less hemolysis in a canine model when compared with conventional roller pump designs (8). In 18 clinical cases, this study also noted patients undergoing CPB utilizing the BP-80 pump head had a better postoperative course. Takeda, et al., looking at platelet numbers and function, saw no significant difference in numbers, but did note a better prostacyclin/thromboxane profile with the biopump leading to less platelet aggregation (9,10). Because of the basic design differences, the centrifugal pump is considered safer than that of the roller pump in that it is difficult to pump air or emboli into the patient, and inadvertent line clamping will not result in line rupture (11). Taylor has shown that a plasma Hb>150 mg/dl was required to see hemoglobinuria which results in damage to the kidney (12). Though we saw clinical evidence of mild hematuria (no urine lab studies were performed), this cleared in all patients early in the postoperative course. No patient, exhibited laboratory evidence of renal dysfunction as a result of CPB. Renal dysfunction has not been noted in over 200 patients under 20 kg. who have undergone CPB with a BP-50 based system at MCV in the last five years. The use of screw clamps at constant rpm's assures forward flow, but allows one to wean from bypass in increments as low as 10 cc/min. flow rates. We conclude that the constrained vortex pump, when utilized as described, can be safely utilized in patients under 20 kg. without increases in plasma hemoglobin concentrations.

## References

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### Questions and Comments

Robin Sutton

- Q. I was wondering if you correlated any of your plasma free hemoglobins to your packed blood cell usage, if you used more packed blood cells your hemoglobin might have gone up. Did you look at that?
- A. No, we did not.

Gary Sterns, Providence, R.I.

- Q. In the two groups the two hospitals were given protocol for extraneous suction utilizing the same apparatus for both groups? On your patient number one, did that patient expire?
- A. No. The reason for the rise in patient one's hemoglobin levels was just that we did not handle the sample right. We found that if you sent the sample in a tube that creates hemolysis so after that first patient we learned to handle the samples better. The answer to your first question is no. There was no protocol done. It was a randomized study and we need to look, a second study would be to measure the amount of volume we were getting from both the suckers and vent which are traditionally the part of our circuit which creates the most hemolysis. Perhaps in a further study we can look at that.

Jeff Riley, Charleston, S.C.

- Q. I'd respectively submit that the data from the other hospital should not be used as a control group to compare your data to. There are so many variables that affect hemolysis.
- A. I think that I wasn't trying to use it as a control group. To do that we need to have the controls at the Medical College of Virginia.
- Q. Did you have that data for five roller pumps managed under the same conditions to compare your

data to the bio pump?

- A. At the Medical College of Virginia we use solely Biomedicus pumps and in a further study we will attempt to do that.

Russell Holiton, San Antonio, Texas

- Q. Did you use the screw clamps on weaning only or during bypass and if so at what flow did you find it necessary to maintain a forward flow?
- A. We don't use the screw clamps during bypass because our flows, the RPM speed is high enough, that we don't need to. We did find out that as you're weaning over a long period of time the screw clamps need to be used so if your RPMs drop below 1,800 you run the risk of having backbleed through the arterial cannula.
- Q. What is the source of your screw clamps?
- A. It's just a basic NG tube clamp that you can get from any nursing unit.

Steve Thompson, Baltimore, Md.

- Q. I want to make sure I heard you right. Did you say that all five of the patients exhibited hematuria postoperatively?
- A. No, I did not say that. I said that some of them exhibited mild hematuria but it cleared early in the postoperative period.
- Q. How many of them did?
- A. I think three out of five.

Jeff Riley

- Q. Is that normal for your experience, three out of five exhibiting hemoglobinuria and have you seen that in roller pumps in infants, three out of five in the past?
- A. I have seen it in roller pumps. We just took the first five patients that came along. There were consecutive patients and the pump runs were relatively long and whether we can say, I don't think I'm saying that it's, I think that we may have had lots of suction and venting that could have attributed to this.

Table 1

age (m)	CPB (min)	Pre	30 min	8 hrs	24 hrs	platelet pre/post	wt (kg)
13	148	<13	54	134	-	343/231	10.0
14	155	<13	35	<13	<13	133/166	5.4
18	163	<13	88	<13	<13	188/160	8.4
48	152	<13	60	<13	<13	294/250	12.8
0.2	194	<13	<13	<13	<13	216/72	2.8

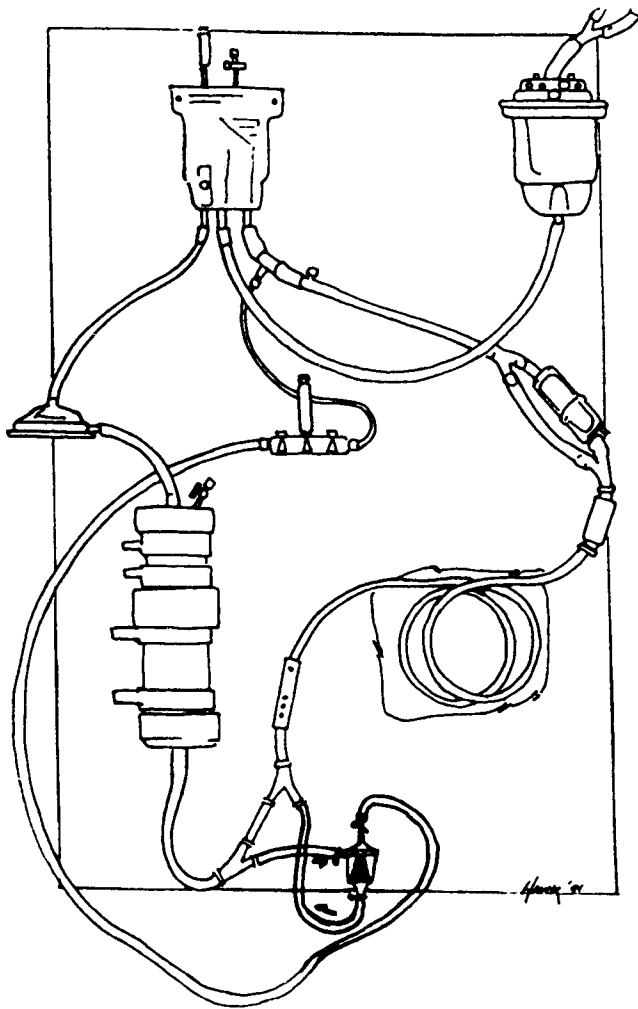


Figure 1.