# A New Cardioplegia Reservoir for the Neonate, Infant and the Pediatric Patient

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## Abstract

The neonate, infant and pediatric patient requires significant modifications in equipment. A new low volume cardioplegia reservoir combined with an established recirculation line system was developed to satisfy both blood and crystalloid cardioplegia users. This system is designed for volumes under 300 ml with precise level increments allowing for specific ratios of blood to crystalloid. This product demonstrates excellent cooling, uniformity of mixing and blood flow capability for the small patient.

## Introduction

Presently, there are not any commercially made cardioplegia systems for neonates, infants or pediatrics. It has been up to the surgical team members to develop a custom system to best suit the needs of the pediatric population. The small patient has presented a challenge for adaptation of existing cardioplegia systems, but not without sacrificing volume and cooling efficiency. Strong evidence towards the neonatal myocardium having a higher tendency to warm up when compared to the adult myocardium has been a concerning issue.[1] Because of the rapid warming time of the neonatal myocardium, a lower level of myocardial temperature is preferred. This further decreases myocardial energy demand and minimizes acidosis. Therefore special emphasis for adequate cooling of cardioplegia, increased frequency of cardioplegia injections and accurate volume infusions should be undertaken in pediatric myocardial preservation.

## Methods and Materials

The development of a new cardioplegia reservoir combined with an established recirculation line system has made it possible for small volumes of crystalloid or blood cardioplegia to be introduced. The purpose of this paper is to demonstrate this new cardioplegia reservoir with an existing Gish[a] recirculation system to pediatric perfusionists. Publications have described the Gish CPS-1000 cardioplegia delivery system and it will not be discussed further in this paper.[2,3]

The CardioMetrics[b] C-NIP reservoir has a maximum volume capability of 300 ml. It is unique in that it is the only system which gives the perfusionist a choice as to at what level the return line should be connected. There are several choices for the perfusionist to choose from, with ports located at levels increments of 25, 50, 100, 150, 200, and 250 ml (Figure 1). The reservoir is a hard-shell polycarbonate plastic resembling the Cardio Metrics NIP open venous reservoir. It contains an anodized aluminum coiled heat exchanger with 100 square inches of surface area. There is a graduated scale across the front of the reservoir with level increments every 25 ml from 50-300 ml, and every 10 ml from 0-50 ml. On one side of the reservoir there are seven (7) luer ports which one can be used as the return line port (Figure 2). The luer port located at the 300 ml level should remain vented at all times and is not to be used as a return site. Cardioplegia or blood is introduced through one of the other available ports while sharing a large bore stopcock (Figure 3). A female luer port is located at the bottom of the reservoir for exiting to the tubing boot. Tubing boot preferences are 1/8" x 1/16", 3/16" x 1/16" or 1/4" x 1/16". In addition to the reservoir, custom holder, and Gish recirculating system, some additional equipment is needed to operate the system. These are: (1) a roller pump head, (2) a water source for cooling and warming the cardioplegia, and (3) a temperature probe of choice is also necessary. We currently utilize either the disposable Mon-a-therm[c] luer lock temperature sensor or the skin temperature sensor. Both of these temperature sensors work very well, but it should be noted that there can be a three to four degree Celsius difference between the two. The luer lock sensor is easily inserted into one of the empty luer ports, while the adhesive skin sensor is placed on the flat surface of the reservoir (Figure 1).

The infusion line is a two-way infuse/recirculation system already described by DiGregorio, et al. The only difference is that the infuse line is directly connected to the pump boot with a luer connection and the return line is connected to any one of the side luers of the reservoir.

The holder is custom made for the reservoir with 1/4" fittings for the water lines from the water source. The holder has two O-rings per inlet and outlet of the heat exchanger.

a Gish Bionedical Inc., Santa Ana, CA 92705
b Cardio Metrics Inc., Sugar Land TX 77478
c Mallinckrodt Medical Inc., St. Louis, MO 63134

## Set-Up and Operation

The C-NIP is easy to setup and operate much like the Gish CPS-1000 system. Set up entails (1) Placing the reservoir in the custom holder, (2) attaching the water source to the heat exchanger while paying special attention to its integrity. (3) A choice of tubing boot needs to be undertaken by the perfusionist. We utilize only two: 1/8" for patients weighing 0-5 kg and 3/16" for patients weighing 5-20 kg. If the 1/8" boot is chosen a male-male adapter is placed at both ends of the boot to attach to the reservoir and the recirculating system. If the 3/16" or 1/4" boots are used a 1/4"-male luer adapter is then used. (4) After calculating the amount of cardioplegia desired (300 ml. or less) the perfusionist must connect the large bore stopcock at the level of his preference. This should be placed at a level to minimize unnecessary splashing. Proper amounts of crystalloid must be manually entered as is blood by simply turning the stopcock to achieve the desired ratio (Figure 3). If blood cardioplegia is desired, variations are available for transport of oxygenated blood from either a post oxygenator luer, recirculating line or arterial filter purge line. (5) Once the recirculating line has been passed from the surgical field the return line is connected to the appropriate luer port at approximately one-half of the circulating volume for better mixing and to prevent splashing and foam formation. The amount of cardioplegia delivered is easily noted by the specific increments on the front of the reservoir. A safe minimum operating level is 5 ml to prevent air emboli. The total prime of this system using the 1/8" boot including the Gish recirculating line is 40 ml. Utilizing the 3/16" boot the prime is 45 ml. These priming volumes do not include the reservoir level desired. With both setups an additional 15 ml of crystalloid is needed to prime the pressure manometer.

## Discussion

Based on our experience at Children's Medical Center of Dallas this is a safe and easy device for delivering crystalloid or blood cardioplegia for volumes less than 300 ml. Temperatures as low as 2.2 degrees Celsius are obtainable with crystalloid cardioplegia. In addition, temperatures of 3.9 degrees Celsius are achievable with blood cardioplegia. These acknowledged temperatures are directly dependent upon the heat exchanger water flow. The option to administer warm cardioplegia is available as well. Low priming volumes with multiple injections can be given with minimal hemodilution. This cardioplegia reservoir combined with a recirculating system provides an effective alternative for pediatric perfusionists requiring less than 300 ml.

## References


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2. Mavroudis, Constantine. Anatomical Repair of Transposition of the Great Arteries with Intact Ventricular Septum in the Neonate. J. Ann Thorac Surg 43:500, May 1987.
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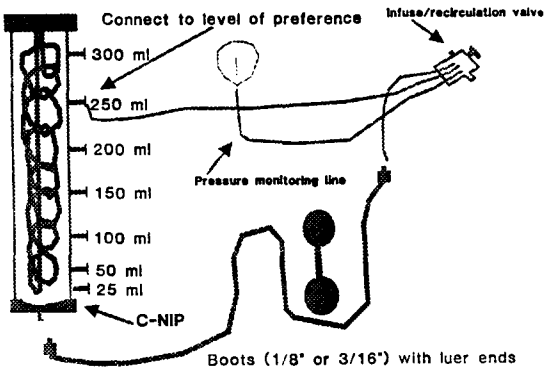
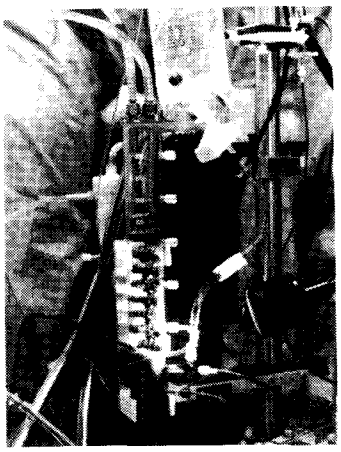



FIGURE 1

Figure 2



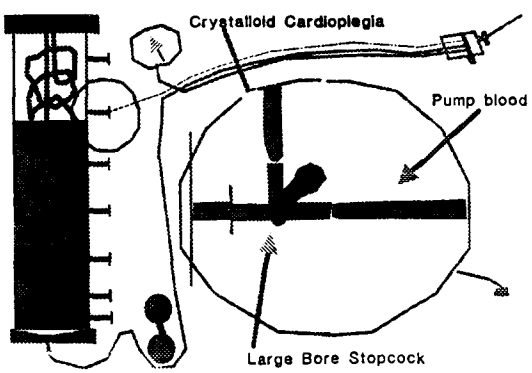



FIGURE 3