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## A Simple and Effective Method for Administration of Blood Cardioplegia

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### Abstract

A simple blood cardioplegia delivery system is described that is capable of delivering cardioplegia solution at any designated temperature between 8° C. and 37° C. Specific ratios of blood to crystalloid solution are possible. Infusion pressure monitoring is simple. It is relatively inexpensive and can be easily utilized with available equipment.

### Introduction

Multi-dose, cold, hyperkalemic, cardioplegia has become a common technique for myocardial preservation during cardiac surgery, providing immediate arrest, maintenance of asystole and hypothermia, and intermittent washout of acid metabolites.<sup>1,2</sup> The net effect is a low level of myocardial energy demand and avoidance of myocardial acidosis.

Because it has been shown that the ischemic myocardium continues to have some energy demands even in the hypothermic, arrested state,<sup>3</sup> oxygenated cardioplegia solutions have been investigated in the laboratory and clinically. The idea of providing oxygen for aerobic glycolysis during arrest, in conjunction with less hemodilu-

tion, makes blood an attractive vehicle for cardioplegia delivery. Several studies<sup>4-7</sup> have been undertaken to evaluate the performance of blood cardioplegia in preventing intraoperative myocardial injury. The equipment and techniques described in this report have been found to be both simple and effective for the delivery of blood cardioplegia.

### Methods and Materials

The Gish<sup>a</sup> CPS-1000 cardioplegia delivery system consists of three parts: the reservoir, table pack/infusion line, and the holder (Fig. 1). The reservoir is a hard-shell poly-carbonate plastic resembling a cardiotomy reservoir which contains a black anodized aluminum coiled heat exchanger with 105 square inches of surface area. There is a graduated scale across the front of the reservoir ranging from 0–1700 ml. Located on the top are two standard I. V. administration sites and one 1/4" quick-prime port. Additionally, a female luer port is on the lower back portion and two 1/4" ports for the connection of pump tubing issue from the right side. At the top right of the reservoir are three 1/8" × 1/32" PVC tubings to which the infusion lines are connected.

The infusion line consists of three 1/8" × 1/32" PVC tubings of equal length (10 feet). At one end is a two-way infuse/recirculation valve (Fig. 2) with a male luer lock connection. At the other end are the three reservoir connections: the aortic root pressure monitoring line, the infusion line, and the

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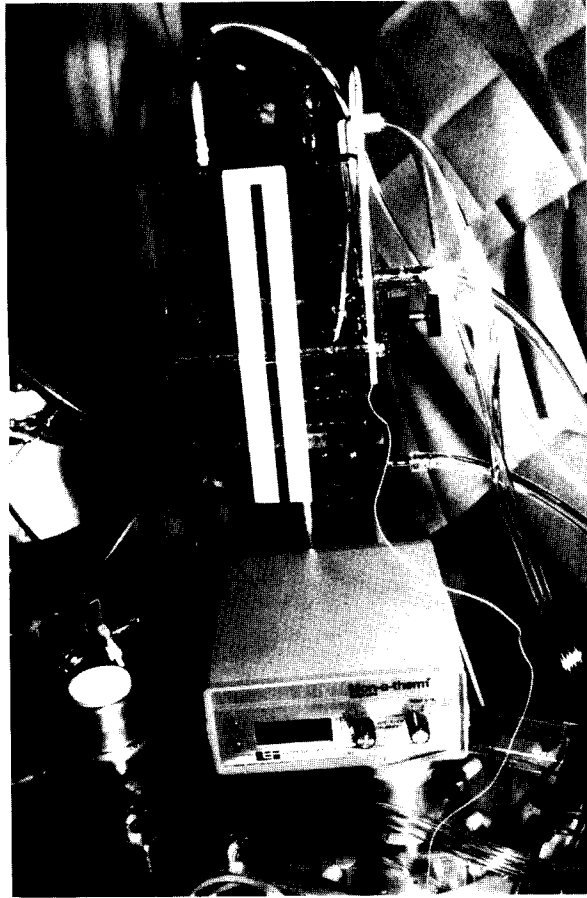


FIGURE 1. The CPS-1000 Reservoir.

return line for recirculation. (Due to a recent design change in the table pack, newer units may have the pressure line connecting directly to the manometer). The infuse and return lines have luer connections, and the pressure line contains a three-way stopcock which aids in priming and de-airing.

The holder is custom made for the unit and has the proper  $\frac{1}{4}$ " Hanson quick-disconnect fittings for the water lines from the water source. This holder can be placed on any size pole up to  $1\frac{1}{2}$ " in diameter.

Additional equipment required to operate this system is minimal. A pressure manometer, some type of water source for cooling or heating, two specific lengths of  $\frac{1}{4}$ " tubing to run through a roller pump (exact lengths are dependent upon each individual set-up), a low-flow roller pump, and some type of temperature probe are necessary.

Temperature monitoring can be achieved in several different ways, and is strictly a matter of

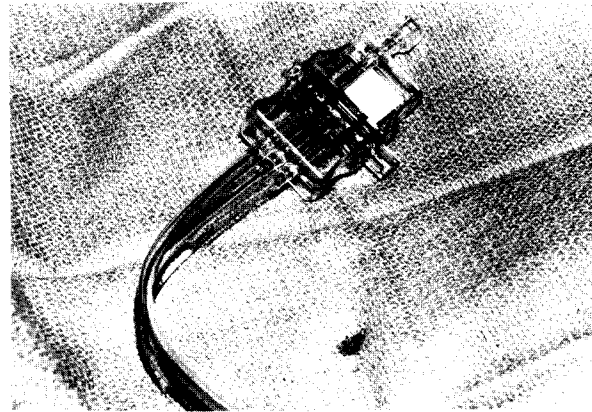


FIGURE 2. The infuse/recirculation valve.

choice and convenience; all are relatively simple. In our experience, the easiest choice was to purchase the TYS-02 luer lock temperature probe available from Gish<sup>a</sup>. This probe fits the rear luer port of the reservoir and will adapt to any Yellow Springs 400<sup>b</sup> temperature box (the standard box found on many heart-lung consoles today). Alternatively, the Sarns<sup>c</sup>  $\frac{1}{4}$ "  $\times$   $\frac{1}{4}$ " disposable temperature probe can be placed into the  $\frac{1}{4}$ " line coming from the reservoir and monitored via the temperature box on the heart-lung machine as well. Or a sterile disposable esophageal probe similar to those used by Anesthesia can be inserted into the reservoir through one of the top prime ports of the oxygenator. Although this works, it is probably the least popular, because a separate temperature box is usually required. It is also difficult to insert, and gives a somewhat inaccurate temperature due to its proximity to the heat exchanger. Although the design of the unit allows the reservoir to function as a bubble trap, one could easily be incorporated into the system if desired.

### Set-Up and Operation

The CPS-1000 is easy to set-up and operate when using either a bubble or membrane oxygenator. Set-up consists of: (1) placing the reservoir in the holder, (2) attaching the water lines and priming the heat-exchanger to ensure its integrity, (3) connecting the infusion tubing to the  $\frac{1}{4}$ " ports on the side of the reservoir and inserting it in a

<sup>a</sup> Gish Biomedical, Inc., Santa Ana, CA 92705

<sup>b</sup> Yellow Springs Instrument Company, Inc., Yellow Springs, OH 45387

<sup>c</sup> Sarns, Inc., Ann Arbor, MI 48013

roller pump, and (4) connecting the line to transport blood from the oxygenator to the reservoir.

Step four has some variations which make it easily adaptable to almost anyone's needs or equipment. The easiest way to transport the blood to the reservoir is to connect a male-male high pressure purge line from the arterial line filter to one of the I. V. administration sites on top of the reservoir. This method requires no additional roller pumps and can be used with either a bubble or membrane oxygenator. The only disadvantage is that, due to the small inner diameter of the tubing, it may take longer than five minutes to fill the reservoir.

An alternative with a bubble oxygenator is to attach the appropriate length of 1/4" tubing to the coronary perfusion port, run it through a pump head and then into the reservoir via the quick-prime port on the top. Although this method requires the use of an additional pump head, it considerably reduces the time it takes to fill the reservoir and also gives the operator control over the rate of filling. This is important, as filling too rapidly can cause splashing, and in turn could lead to the creation of foam. In our experience, the extra pump head is a superior method for filling the reservoir when using a bubble oxygenator.

An alternative to the previously mentioned way of obtaining blood when using a membrane oxygenator with a recirculation line is to place a 1/4" equal "Y" connector in the recirculation line, attach an appropriate length of 1/4" tubing to one arm of the "Y" (the recirculation line goes on the other arm), and then attach the other end of the tubing to the quick-prime port on the reservoir. The pressure generated during perfusion will fill the reservoir rapidly. Filling rate can be controlled by partially occluding the line while filling. We routinely use this method with the Sci-Med<sup>d</sup> membrane oxygenator, and it can probably be used with all membranes using a recirculation line.

These four set-up steps can be done in the pump room in conjunction with setting up the oxygenating system. The final steps take place in the operating room with the aid of a scrub nurse:

1. The table pack/infusion line is passed off the field by the scrub nurse to the operator, the

end with the two-way valve remaining on the sterile field.

2. The proper connections are made using sterile technique, attaching the infusion lines to the reservoir and monometer.
3. The reservoir is then filled with about 100–200 cc. of clear cardioplegia.
4. With the valve on recirculate, the roller pump can be turned on and the fluid will begin to recirculate in the tubings, priming and removing all air from the infusion lines.
5. The pressure line is primed by applying resistance to the outflow, turning the valve to infuse, and opening the stopcock on the pressure line to air, closing it to the monometer. This will de-air that line. When the pressure line is de-aired satisfactorily, the stop-cock can be closed to air and opened to the manometer.

An alternative way to monitor pressure is to employ the use of a Pressureveil (by Concept<sup>e</sup>), a device that is simple to prime and use. It is essentially the gel-filled barrel of a 30 cc. syringe with a balloon in it. The larger end is plugged by a rubber stopper which accepts the stem of an aneroid manometer. The veil is primed with heparinized saline and the pressure monitoring line is attached to the luer-lock end of the Pressureveil. The advantage of the Pressureveil is that it provides a sterile interface between a fluid system (cardioplegia line) and an air pressure measuring device (aneroid monometer) which can withstand higher pressure than the type of fluid trap which incorporates a hydrophobic membrane and becomes inoperative if wetted. The fluid pressure transmitted to the Pressureveil is exerted against the outside of the air-filled balloon within the device and the inside of the balloon is in direct contact with the aneroid monometer. Therefore, fluid pressure outside the balloon is converted to air pressure within the aneroid monometer. This system has proven to be more reliable in the face of high pressures (greater than 150 mm) which may be generated during priming of the system or during cardioplegic administration.

The only remaining step is to manually enter the proper amounts of cardioplegia and blood into the

Sci-Med-Life Systems, Inc., Minneapolis, MN 55441

<sup>e</sup> Concept, Inc., Clearwater, FL 33516

reservoir necessary to achieve your desired ratio. This system can be used with any blood to crystalloid ratio from 1:1 to 4:1. The only adjustment necessary is to alter the concentration of drugs in the bag of crystalloid to achieve the proper results for your desired ratio. At this point the blood cardioplegia is mixing and cooling in preparation for the surgeon's call for administration at the time the aorta is cross-clamped. The valve on the table pack is switched to infuse (on the field), and the flow rate of delivery is adjusted to achieve the proper pressures and flows desired by the surgeon. The amount delivered is easily noted on the front of the reservoir. One note of caution: To avoid introduction of air, never let the level in the reservoir fall below 100 ml.

## Discussion

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In our experience, the CPS-1000 is a simple, effective, and safe device for delivering blood cardioplegia. Due to the versatility of this device, we have noticed several advantages over the other systems currently available. Temperature monitoring is available at three different sites. Our experience is that because the unit uses a stainless steel integral heat exchanger, it allows for more rapid and precise temperature control than do PVC coils. The constant recirculation of the blood through the unit when not administering cardioplegia allows for consistent temperature as well as keeping the volume in the administration line cold. The option to give warm blood cardioplegia<sup>8</sup> prior to unclamping of the aorta is available with the CPS-1000, something not easily achieved with most of the other units we have tested.

The CPS-1000 is adaptable to any blood to crystalloid ratio from 1:1 to 4:1 without the need for special size tubings or tubing inserts. The bags of crystalloid can easily be prepared in your hospital pharmacy.

Other advantages include the unit's adaptability to virtually any heart-lung set-up, its easy control

of flow and pressure, and its ease in determining the amount of blood cardioplegia delivered.

Finally, the CPS-1000 system is less expensive. It currently costs about \$65.00 per unit, including table pack; temperature probes are \$5.00, and the tubing costs \$3-\$10.00 depending on the length and type of tubing desired. Total cost per case is about \$75.00. This system does cost more than a cooling coil, but the inconsistency of temperature in a coil, as well as the inability to rewarm the cardioplegia, eliminates the coil from our consideration.

One further note: When the CPS-1000 reservoir is being filled with blood, temporarily stealing from the arterial flow, there may be a small decrease in mean arterial pressure. The drop in pressure is small and transient, and has had no adverse affect on the patient. Also, like a cardiotomy reservoir, this unit should be vented to avoid pressurization of the reservoir.

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