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## TECHNIQUE

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# A Flexible System for Combined Retrograde and Antegrade Delivery of Blood or Crystalloid Cardioplegic Solution

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### Abstract

A flexible but simple cardioplegic delivery system has been designed that offers the advantages of alternating antegrade and retrograde delivery of blood and crystalloid (Plegisol™ solution) cardioplegia to optimize myocardial preservation. Initial antegrade delivery of crystalloid cardioplegic solution achieves rapid cardiac arrest while subsequent retrograde delivery with blood cardioplegia improves myocardial protection due to uniform distribution of the solution. Occasionally, temporary transferral from blood to crystalloid is indicated to clarify the surgical field. This system is designed to allow the repeated rapid switching from crystalloid to blood cardioplegia or vice versa using the antegrade or retrograde routes.

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### Introduction

After the reintroduction of hypothermic potassium cardioplegia by Gay and associates (1), most cardiac surgeons instituted its regular use to protect the heart from ischemic damage. The delivery route accepted almost universally was the antegrade one via the aortic root or directly into the coronary ostia. Although retrograde coronary sinus perfusion with blood was recommended in 1956 and 1957 to facilitate aortic valve operations (2-4) and a decade later for myocardial protection during coronary artery procedures (5), antegrade cardioplegic infusion via the aortic root remains the most frequently used route for cardioplegic delivery. However, in an effort to achieve uniform cardioplegic delivery and to simplify some operations, interest in the coronary sinus as a route for cardioplegic delivery has revived since the late 1970s (6-8). Retrograde perfusion has been recommended as a suitable alternative in patients with aortic insufficiency, multivalvular operations, diffuse coronary disease in multiple vessels, or occlusion of two or more of the

coronary trunks associated with impaired cardioplegic delivery (9-12). One of the drawbacks of retrograde cardioplegia, delayed cardiac arrest, can be overcome by combining an initial antegrade cardioplegic infusion to enable rapid asystole with subsequent retrograde cardioplegia to provide adequate homogeneous cardioplegic distribution (13). Nevertheless, 92% of cardiac surgeons have never used any retrograde method, and only 2.6% have ever used retrograde cardioplegia for coronary artery surgery (14). To optimize myocardial protection, we have designed a flexible yet simple cardioplegic delivery system that offers the advantages of both retrograde and antegrade delivery capabilities. The setup provides two separate coils, one for antegrade and the other for retrograde cardioplegic delivery, that can be attached to each other (Figure 1). This system enables rapid switching from one cardioplegic delivery method to another, so that any combination desired between retrograde and antegrade routes, as well as blood and crystalloid cardioplegia, can be implemented easily when needed (Figure 2).

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### Cardioplegia Solutions

Three different solutions are mixed for use in the antegrade and retrograde systems. Both systems use St. Thomas solution (Plegisol™) to which 45 mEq/l sodium bicarbonate is added. In addition, 20 mEq/l of potassium is added to the antegrade solution, while 40 mEq/l potassium is added to the retrograde solution. The retrograde cardioplegia solution is mixed with four parts blood to take advantage of the superior preservative capabilities of blood cardioplegia (15-17) and to avoid the transient serum hypermagnesemia that we (18) and others (19-21) have experienced when pure Plegisol™ was administered continuously. The extra potassium we add compensates for dilution of the solution with blood. When indicated, blood cardioplegia can be given by the antegrade route. The retrograde system also offers a third alternative, the standard Plegisol™ mixture but with 40 mEq/l sodium bicarbonate. All solutions are cooled to 4°C.

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Figure 1. Flexible cardioplegic delivery system with antegrade and retrograde coils attached to enable rapid switching from one delivery method to another.

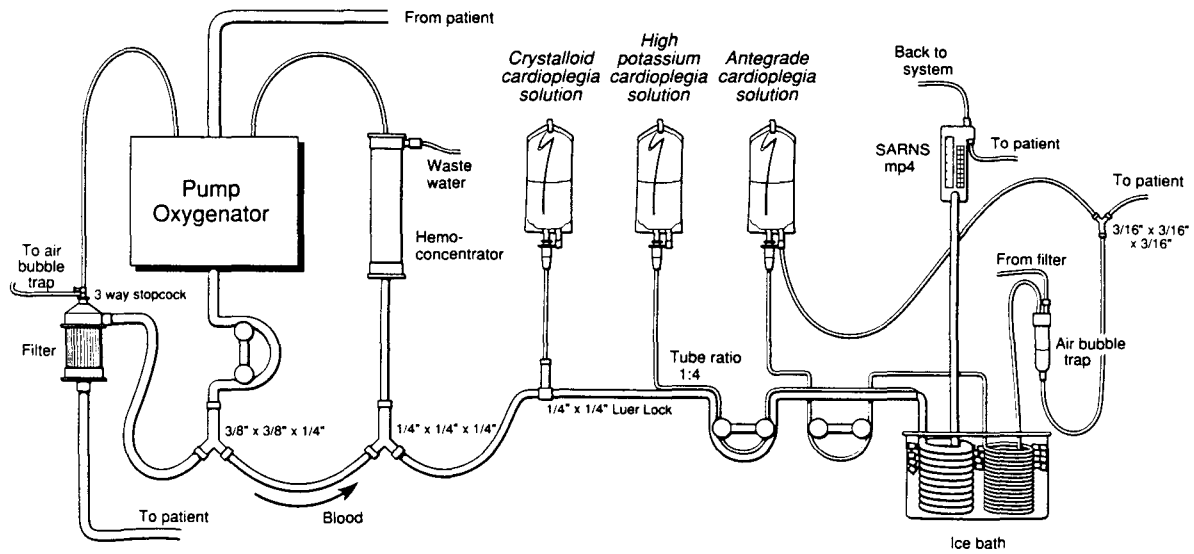


Figure 2. Cardioplegic delivery routes.

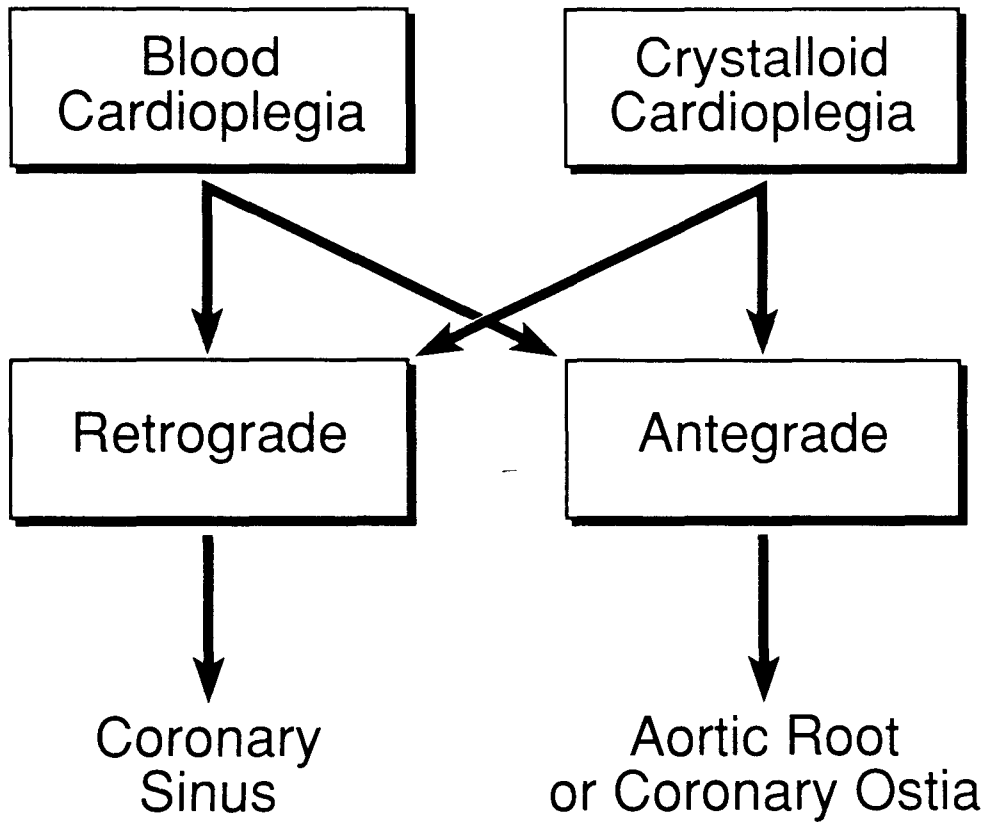


Figure 3. Antegrade delivery system.

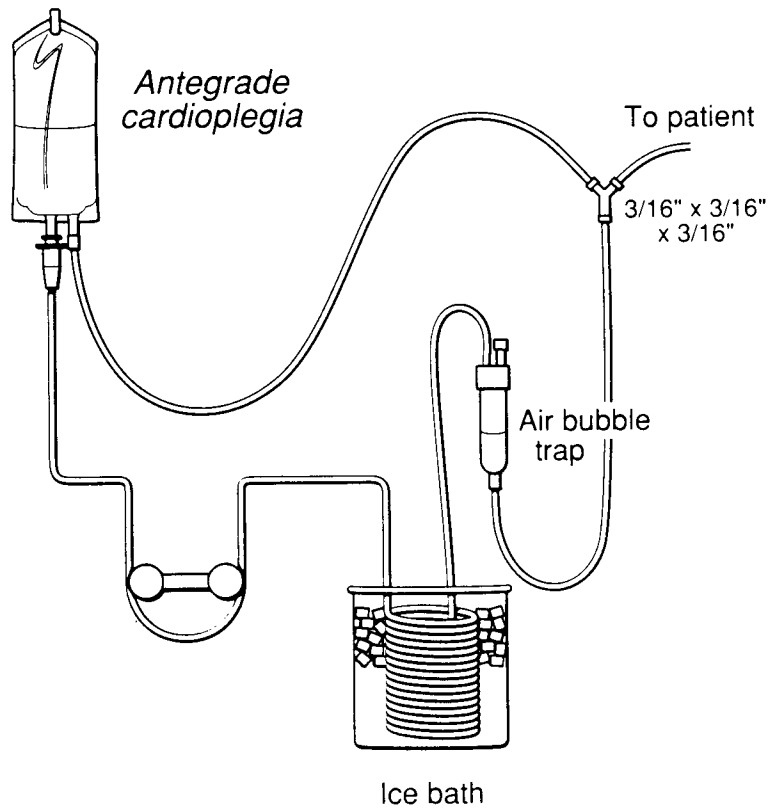


Figure 4. DLP retrograde coronary sinus cannula is inserted into the coronary sinus and connected to the cardioplegia delivery line. The cannula's balloon is distended with saline solution until it straddles the sinus rim and infusion begins through the port.

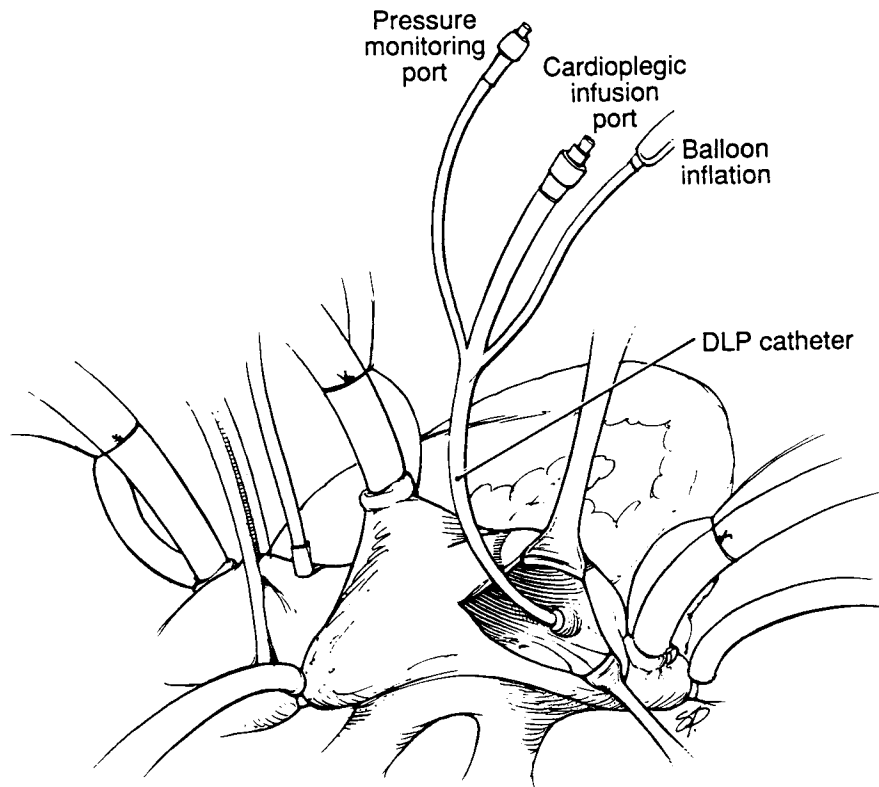


Figure 5. Retrograde coronary sinus perfusion using alternative single atrial cannulation method. The heart is lifted to enable transatrial insertion of retroplegia cannula into coronary sinus.

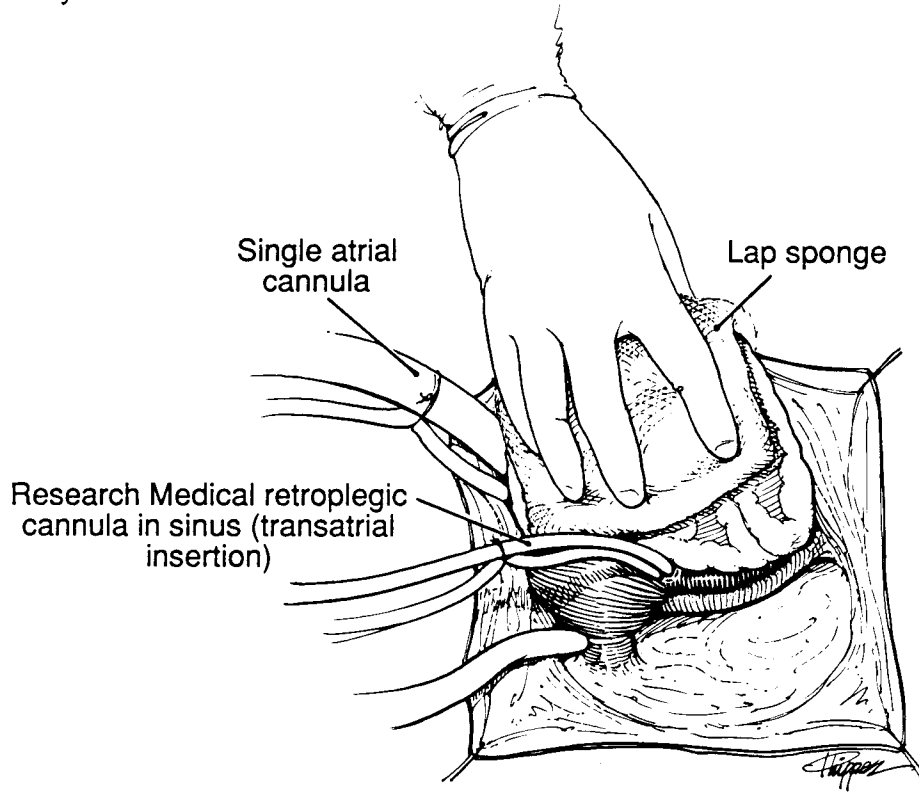


Figure 6. Blood and cardioplegia solution are delivered through retrograde system into the cannulated coronary sinus.

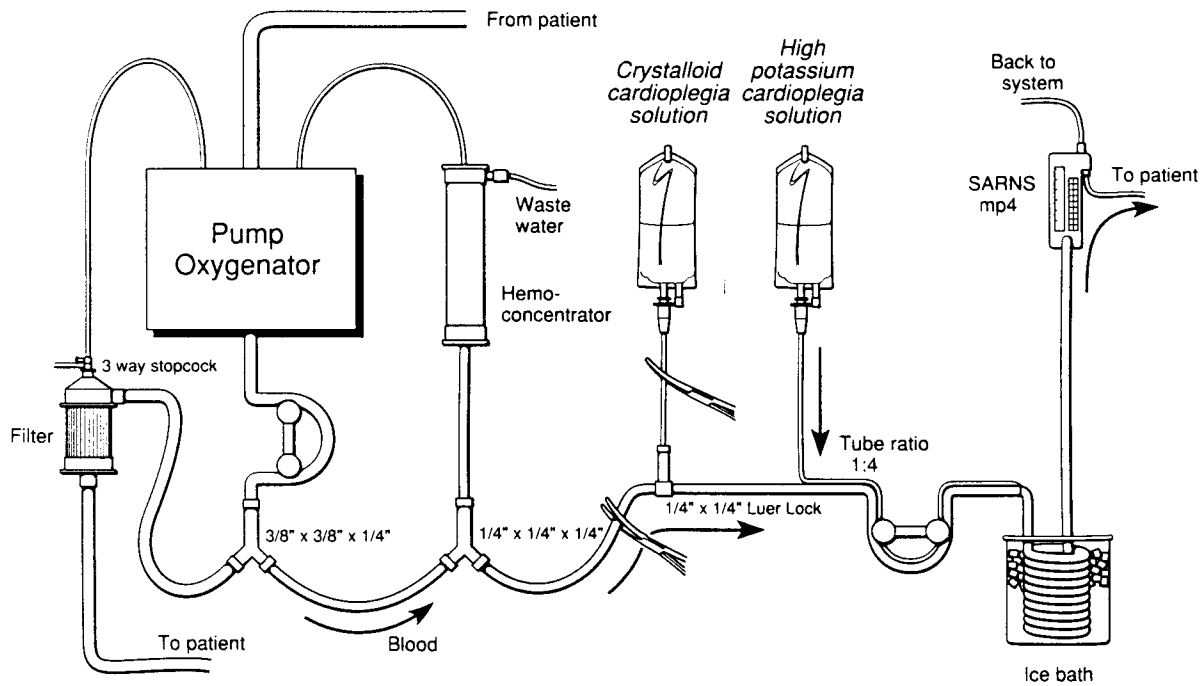


Figure 7. Blood flow is clamped off to enable temporary transferral to delivery of pure crystalloid cardioplegia. A quarter-quarter straight connector with a Luer lock is inserted on the negative side of the pump head and an intravenous line is attached to another bag of Plegisol.

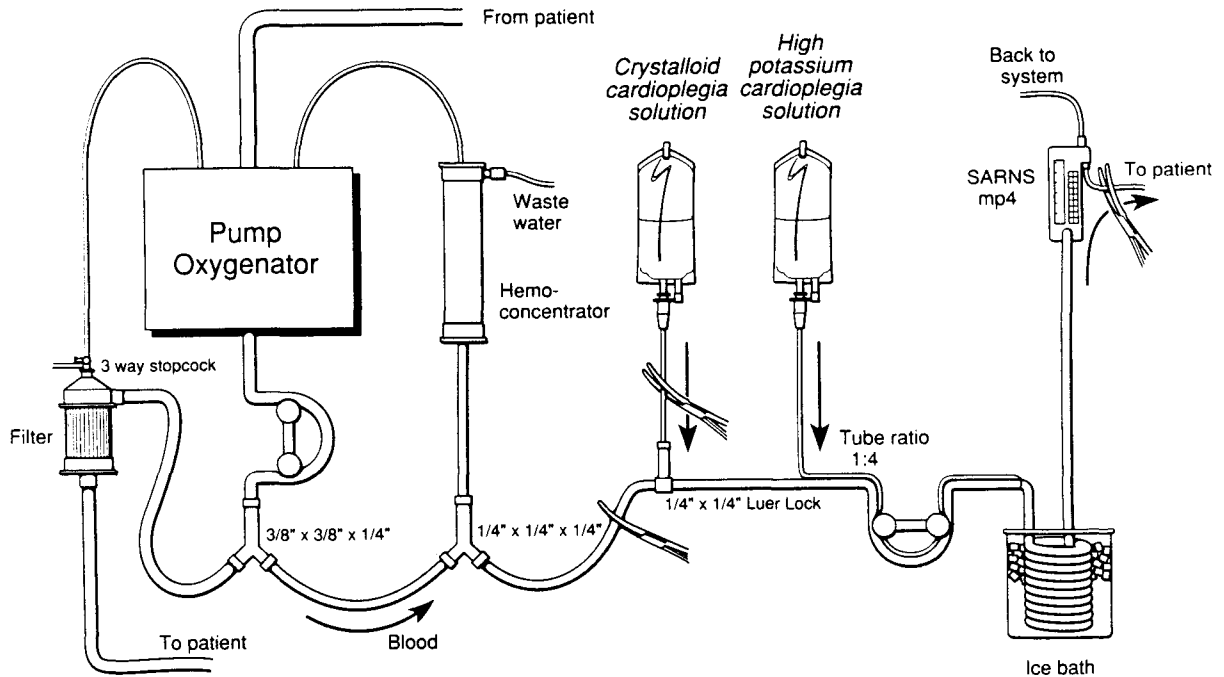
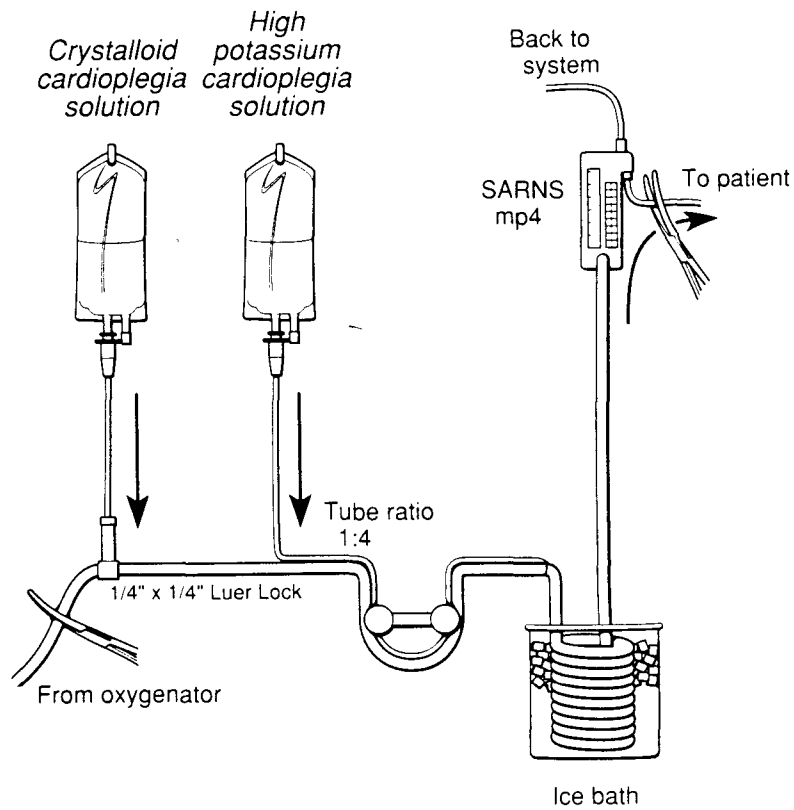


Figure 8. Cardioplegic flow is accelerated through retrograde system by closing off blood flow from oxygenator and passing extra crystalloid into the bubble trap and to the patient.



### **Antegrade Delivery System**

The antegrade coil is a continuous system that recirculates the cardioplegia solution out of its bag, around a pump head, and down into the coil immersed in a bath of ice water (Figure 3). The solution then passes through an air bubble trap and either to the patient or back to the bag. This coil is activated after the cross clamp has been applied to the aorta. Cardioplegia is initially delivered from the antegrade system into the aortic root to stop the heart. Additional aliquots of either cardioplegia solution or cold blood cardioplegia may be administered between grafts or other procedures to maintain myocardial protection.

### **Retrograde Delivery System**

Once the heart has arrested, a retrograde delivery route can be engaged rapidly if indicated. A right atriotomy is performed, the coronary sinus located, a DLP retrograde coronary sinus cannula (a) connected to the cardioplegia delivery line, and the catheter is inserted into the sinus. When the coronary sinus is enlarged, as in massive right atrial enlargements, we place a temporary stitch to narrow the sinus snugly around the catheter and prevent backflow. The catheter's balloon is distended with saline solution until the balloon straddles the sinus rim (Figure 4). Extra myocardial protection can be achieved with an alternative method, coronary sinus perfusion using single atrial cannulation (Figure 5). After cannulation of the coronary sinus either directly or atrially, infusion is begun through the retrograde system. This system consists of a coil, an air bubble detector, a pressure module, and a continuous temperature read-out.

The blood and cardioplegia solution in a 4:1 ratio are delivered through the retrograde system on a one-time pass basis. The blood and solution are pulled through the pump head down into the coil immersed in an ice water bath, through the bubble detector, transducer, and temperature module and finally, through the cannulated coronary sinus (Figure 6). During retrograde perfusion, flow pressure should not exceed 40-50 mmHg (3). We have modified the retrograde system to enable temporary transferral to pure crystalloid cardioplegic delivery when better visualization is required in the surgical field, such as during a distal coronary anastomosis. This modification includes an intravenous line attached to a second bag of Plegisol™ (Figure 7). This setup enables us to clamp off the blood flow from the oxygenator and open the third bag of crystalloid cardioplegia. If the flow of cardioplegia through the retrograde system is too slow, we can open a stopcock off the bubble trap, circulate the blood out of the system back into the oxygenator, and close down (Figure 8). The spare crystalloid solution can then be passed into the bubble trap and delivered within 30 seconds of the time requested.

### **Conclusion**

This dual antegrade and modified retrograde cardioplegic delivery system has been used more than 50 times in patients

a. Model 94015, DLP Inc., Grand Rapids, MI

undergoing aortic valve, coronary, and multivalvular procedures. Its most useful application has been in patients undergoing coronary endarterectomy to multiple vessels. This system has yielded excellent myocardial protection while providing the flexibility to respond quickly to fluctuating operative needs during open heart surgery; yet such flexibility has been achieved without adding undue complexity to the system's assembly or implementation. It can be easily set up and quickly modified by the perfusionist when needed, and it is simple for the surgeon to use and adapt to even the most unpredictable surgical course.

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