A Technique For Infusion of Hypothermic Cardioplegic Solutions

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Abstract _____________ 

The infusion of a hypothermic cardioplegia solution has been accepted as a beneficial adjunct to routine open cardiac procedures.

Methods of cardioplegia infusion vary greatly in terms of efficiency, consistency, and ease of operation.

We have developed an infusion system which has proven safe, reliable, economical, and easily implemented. The system has been utilized in over 170 clinical cases with excellent results and will be described below.

Introduction _____________ 

With the rising trend towards the use of hypothermic cardioplegic solutions for myocardial protection during open heart surgery, we have turned our attention to the implementation of a safe, efficient system for infusion of these solutions.

There is continued debate regarding the composition of solutions used to preserve myocardial energy stores, though solutions with a high potassium concentration (15–30 mEq/L) have been found to be effective both experimentally and clinically. There is general agreement that the infusion temperature of the perfusate is critical. A perfusate temperature of 4°C has been found most effective with the effects of hypothermia and the cardioplegia generally considered additive.

Tyers, et al. and Behrendt, et al. have demonstrated a myocardial temperature between 10–15°C to be optimal for preservation of high energy phosphate stores during ischemic arrest.

According to our protocol, the perfusionists are responsible for the infusion of the cardioplegic solution intraperatively. We believe the most efficient cardioplegia infusion system will be one which meets three criteria:

1. A system that is easily integrated into the existing extracorporeal circuit.
2. A system that is easily controlled by the perfusionist without unnecessary distraction.
3. A system that is capable of delivering required volumes of solution at a constant temperature upon the surgeon’s request.

Methods and Materials _____________ 

Our system incorporates a graduated polycarbonate reservoir (1500 ml capacity), a custom tubing pack, a recirculation coil, and a low flow pump head mounted on a Sarns 5000 console. Cardioplegic solution is introduced into the reservoir through a quick prime line on one of the 1/4" inlets. Solution is drawn out of the reservoir through the 1/8" outlet. A two inch segment of 3/8" I.D. X 1/2" O.D.

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tubing is reduced to $\frac{1}{4}''$ I.D. $\times \frac{3}{8}''$ O.D. tubing by a reducing connector. The $\frac{1}{4}''$ I.D. tubing runs through the pump head to a $\frac{1}{4}''$ "Y" connector with luer lock. The luer lock connector facilitates pressure measurement through the system.

One arm of the "Y" connector is attached to a six foot length of $\frac{1}{4}''$ I.D. $\times \frac{3}{8}''$ O.D. tubing. Five and one-half feet of this segment is double wrapped and is handed to the surgeon using a sterile technique. The other arm of the connector is reduced with a two inch segment of $\frac{3}{16}''$ I.D. $\times \frac{3}{8}''$ O.D. swagged onto a two inch segment of $\frac{1}{4}''$ I.D. tubing. This reduced segment accepts the female end of the recirculation coil. The other end of the coil is connected to identically reduced tubing on the second $\frac{1}{4}''$ inlet of the reservoir.

The infusion line to the sterile field is clamped at the pump and 1000cc of solution is constantly recirculated at approximately 100cc/min. through an ice bath. A 20% alcohol solution is added to the ice bath to facilitate rapid cooling. This results in a perfusate temperature of between 3-5°C.

The infusion line is affixed by the surgeon to a $\frac{1}{4}''$ THI perfusion adaptor, ****, a three-way stopcock, and a 12", 16 g. catheter†. The catheter is inserted into the aorta through a 14 g. needle proximal to the anticipated site of crossclamping (Figure 2). The line is secured by a pure-string suture. The insertion site is chosen with the intention that it will be incorporated into a veno-aortic anastomosis later in the procedure. Further manipulation is unnecessary once the catheter is positioned.

During aortic valve procedures a "Y" connector in the infusion line allows for direct, simultaneous, cannulation of the coronary ostia with Jehle coronary perfusion catheters⁰ of the appropriate size.

An initial infusion of 500-750cc of solution at 4°C combined with topical hypothermia will reduce the intramyocardial temperature to less than 15°C and render the EKG isoelectric. These two parameters are our criteria for adequate cardioplegic arrest. We have found it necessary to infuse approximately 300cc of solution at 20-30 minute intervals to maintain the myocardial temperature at 15°C or less as measured with a 22 g. NTM—100 thermistor probe⁰⁰ placed in the ventricular septum. Per fusate temperature is monitored with an in-line, $\frac{1}{4}''$ sensing connector⁰⁰⁰ placed between the pump head and the "Y" connector.

A pressure of approximately 95 mm/Hg. is generated through the system during recirculation of 1 liter of solution at 100cc/min. with a totally occlusive pump head. A pressure of 25mm/Hg. is generated in the
infusion line at 100cc/min flow with the 16 g. catheter attached. Pressures were measured experimentally at the luer lock “Y” connector. A vascular resistance that exceeds the known system resistance at a given flow rate will cause flow to be partially shunted back through the recirculation coil. For example, at 100cc/min flow, an aortic root pressure of 120 mm/Hg. would cause flow to be shunted. Reverse shunting is apparent immediately and flow is gradually through the recirculation coil. For example, at a second aortic puncture through which actual pressure determined empirically by the surgeon. This eliminates a second aortic puncture through which actual pressure measurement could be taken. Measurement of in-line infusion pressure is not reflective of the true aortic root pressure and has been eliminated. Observance of the perfusate level in the graduated reservoir has proved to be the most effective method of determining adequacy of flow.

Results

The cardioplegia infusion system described has been utilized in over 170 clinical cases. In cases of severe obstructive coronary artery disease we have occasionally been unable to achieve adequate cardioplegia (i.e., septal temperature less than 15°C plus isoelectric EKG). Ultimately, the adequacy of myocardial protection must be measured in terms of postoperative cardiac function. The use of cardioplegia is one of many factors influencing this outcome. During the last two years, our institution has experienced a 1.8% elective mortality rate for coronary artery bypass surgery and a 0% elective mortality rate for valve surgery. The perioperative infarct rate for all open cardiac procedures utilizing this infusion system is 1.8% (5 of 179). There have been no complications related to the mechanics of this system.

This technique has also been employed experimentally in an isolated heart preparation during canine cardiac transplant procedures with good results.(16) The adequacy of cardioplegia is determined by cardiac function post transplantation.

Discussion

Early models of this system were assembled from bulk supplies and sterilized prior to use. This proved to be time consuming, tedious, and resulted in minor variations from pack to pack. The custom tubing pack now employed has eliminated those factors while remaining economical. We have continued to utilize the smaller reservoir because of its design and limited capacity. The greater surface area of a larger reservoir results in less efficient cooling at a slightly greater cost per patient.

Conclusions

The need for adequate myocardial protection during ischemic arrest has lead to the development of cardioplegia solutions and various methods of infusion. We have found the infusion system described to be safe, reliable, economical and easily implemented.

References