Technique and Pitfalls of Retrograde Continuous Warm Blood Cardioplegia

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The recent development of normothermic myocardial preservation and systemic perfusion during bypass has questioned the fundamental need for hypothermia during cardiac operations. The antegrade technique of almost continuous perfusion by the aortic root and vein grafts has been supplemented by continuous normothermic blood cardioplegia through the coronary sinus. Recently, great interest has been shown in this technique. It is important to describe the method in detail along with its potential shortcomings and dangers. This communication describes the technical details, pitfalls, and shortcomings of retrograde continuous warm blood cardioplegia.

The retrograde continuous warm blood cardioplegia (RCWBC) technique is similar for all types of cardiac procedures, as recently reported [1]. Standard cardiopulmonary bypass techniques are used with cannulation of the ascending aorta and single- and double-stage venous canulas. In mitral valve replacement both venae cavae are cannulated but not snared. Before commencement of normothermic bypass, the coronary sinus cannula is usually inserted transatrially, as previously reported [2]. Placement of the cannula before cardiopulmonary bypass is easier as the coronary sinus ostium is distended. Placement has been successful in 96% of our cases [3]. Its position is confirmed by finger palpation with the hand behind the heart in the atrioventricular groove. If the patient's condition is unstable, partial bypass is instituted and then the coronary sinus is cannulated. The purse-string in the atrium is made close to the coronary sinus, because there is a tendency for displacement of the cannula, but should be on right atrial tissue and not on the coronary sinus opening to the right atrium. The surgeon then should inspect the heart for possible anomalies, such as a left superior vena cava draining into the coronary sinus. Although rare, this anomaly may preclude the use of this technique, and if missed, may cause serious problems with lack of cardioplegic delivery to the heart.

The heart is arrested using high-potassium blood cardioplegia, employing four portions of blood to one portion of high-potassium Frenes solution (D5W, 500 mL; KCl, 50 mEq; MgSO4, 9 mEq; Tromethamine, 6 mEq; CDP solution, 10 mEq; osmolality = 425 mOsm/L; pH = 7.95; total volume = 557 mL). As soon as diastolic arrest occurs the perfusion system is switched to the retrograde cannula. Some surgeons prefer to deliver 1 L of cardioplegia antegrade before switching to the retrograde route, but this is not necessary. Low-potassium Frenes solution (same composition as high-potassium Frenes solution but KCl = 30 mEq/L) is delivered in the same proportion at a maximum mean pressure of 40 mm Hg, measured at the side port of the coronary sinus cannula. Cardioplegic delivery should not exceed 250 mL/min. The infusion pressure and flows are constantly monitored by the perfusionist during the procedure. Should electrical activity occur, additional high-potassium cardioplegia (usually 200 to 300 mL of high-potassium Frenes solution) is infused retrogradely until arrest occurs. Alternatively a higher maintenance potassium concentration may be employed (40 mEq/L). Electrical activity has recurred after arrest in approximately 10% of our cases. Before aortic unclamping, cardioplegia is discontinued and the cannula is removed if no rearrest is planned. Alternatively the cannula may be opened to air. This occurs in case of mitral valve repairs when the surgeon may elect to perform further repair or replacement. Our clinical experience so far indicates that rearrest is safe with crystalloid cardioplegia [4] and with RCWBC.

Antegrade Arrest

Although we have on occasion infused continuous warm blood cardioplegia retrogradely to arrest the beating heart, we have not consistently employed this technique because of the lengthy time to diastolic arrest. Even in case of severe aortic insufficiency, initial antegrade cardioplegia is administered until arrest occurs, or the aorta is opened and the coronary ostia are cannulated directly for antegrade arrest.

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Position of the Coronary Sinus Cannula

The technique of insertion has evolved as described by Drinkwater and colleagues [2], with the exception that we advance the cannula as far as it goes into the coronary sinus. This is the case even in hypertrophied ventricles (left or right). Failure to do so, especially in complex procedures, may cause unrecognized displacement of the cannula into the right atrium, leaving the heart ischemic and normothermic. This was the cause of death in at least 1 patient in our initial experience, whose catheter displaced during the procedure. Although unproven, we believe that the mechanism of myocardial protection through the coronary sinus in humans is different than in animals. Although conventional methods of cardioplegia administration relied on cold cardioplegia and topical cooling, this method relies on continuous perfusion and chemical arrest, not hypothermia [5].

How then can one be assured of the position of the catheter? Meticulous care in its insertion and with the atrial pursestring suture and placement of the catheter as far as possible into the coronary sinus are two important concepts. This is particularly important in mitral valve operations, in which retraction of the interatrial septum may dislodge the cannula. Although palpation may seem 100% reliable, at times it is difficult to know by palpation alone where the catheter is, especially in a fatty heart. This can cause undue delay in or lack of cardioplegic delivery. In patients who undergo aortic valve replacement, blood can be seen coming from both coronary ostia, or from the coronary arteries when bypass grafting is performed. The desaturated blood can be seen emanating from the left ventricle and aortic root in mitral valve replacement or repair. We do not recommend discontinuation of warm blood cardioplegia in hypertrophied hearts, although we have done so for brief periods of time in hearts undergoing coronary bypass grafting [5].

Such qualitative assessment, however, is not foolproof. Pressure monitoring of the side port of the cannula at present remains the most reliable method of surveillance for catheter position. An abrupt change in pressure, ie, from between 30 and 40 mm Hg to between 1 and 4 mm Hg or negative pressures, indicates catheter displacement. The catheter at this time should be checked and positioned appropriately to ensure cardioplegic delivery. By filling up the right atrium (with partial venous occlusion) and observing pressure changes in the coronary sinus catheter, the surgeon can determine whether the catheter has been displaced into the right atrium. (The pressure in the catheter port will increase with filling of the right atrium.) This is not true with some catheters in which coronary sinus occlusion may be inadequate, and therefore any decrease in coronary sinus pressure should result in immediate inspection of catheter position and the degree of balloon inflation.

Catheter position can also be monitored during RCWBC by measuring myocardial temperatures (37°C when cardioplegia is delivered and room temperature when not). We are currently investigating the use of a needle oxygen tension probe that will allow monitoring of instantaneous myocardial oxygenation.

The heart becomes pale when the catheter is out of the coronary sinus. Distention and filling of the great cardiac veins with pink blood implies good catheter position, whereas empty and dark veins usually imply displacement. We rely heavily on this technique, although there is no guarantee of adequacy of cardioplegic delivery.

How to Deal With Flooding of Blood in the Operative Field

As we have become more confident and comfortable with warm heart operations, it has become apparent that short periods of ischemia (10 to 15 minutes) are well tolerated by the arrested heart [3]. This is presumably because of the finding that oxygen consumption of warm- and cold-arrested hearts are not clinically significantly different [6, 7]. Current research is underway to determine the safety of intermittent warm cardioplegia. In coronary operations blood in the operative field is dealt with by local irrigation with warm saline solution, insertion of a probe into the coronary artery, snaring of the coronary artery, or discontinuation of cardioplegia for short periods of time. These techniques are not ideal. Recently, we [8] have employed a stream of oxygen at 10 to 12 L/min to enhance visualization of the coronary anastomoses.

How Much Cardioplegia Should the Surgeon Administer?

There is no firm basis as yet to indicate what flow rates should be administered to the warm, chemically arrested heart. In our clinical practice it ranges from 40 to 150 mL/min in hearts with coronary artery disease and up to 250 mL/min in hypertrophied hearts. It is hoped that soon we will be able to predict what volumes are required on an individual basis through clinical trials and animal research. Because the solution is basically blood with low potassium concentrations, we tend to administer more than what we think is needed, especially in hypertrophied hearts, to have a large safety margin.

Use in Combined Valvar and Coronary Operations

This technique is particularly suitable to combined valvar and coronary operations. One of the attractions of RCWBC is that the order of the procedure does not matter. For example, in critical left main stenosis combined with aortic valve disease, we have performed a valve replacement before coronary bypass. The reverse may also be done. Venous effluent through the coronary ostia does not seem to impair the technical aspects of aortic valve operation, as the volume of blood exiting by the coronary ostia is small. Indeed, the adequacy of left and right ventricular perfusion by the coronary sinus is constantly assured by the return of the desaturated blood.
Is Potassium a Problem at the End of the Procedure?

Clinical data indicate that potassium is not a problem [3, 5]. Should the potassium level become elevated during the operation, the problem may be treated by maintaining urine output with furosemide or employing glucose, insulin, and bicarbonate. Rarely has this been a serious problem. In fact, with warm perfusion the ability of the body to cope with the potassium loads may be enhanced when compared with cold heart operations. If a long cross-clamp time or other causes for hyperkalemia are anticipated, 10 to 20 mg of furosemide given into the pump at the beginning of RCWBC may be appropriate.

Injury to the Coronary Sinus

Our experience now nears 300 patients over 4 months using this technique. No injuries to the coronary sinus have occurred. This seems to be the experience of others who have used this method as well. We have employed the Research Medical Retroplegia Cannula as described by Drinkwater and colleagues [2].

Right Ventricular Preservation and Postoperative Problems

The key question that has not been completely answered is the extent of right ventricular preservation during RCWBC. The full answer to this question will require further clinical experience and controlled clinical trials. To date we have performed all valvar and combined procedures using this method, irrespective of the degree of ventricular hypertrophy and pulmonary artery pressures. There has not been a single case of right ventricular failure [3]. Further basic research is under way at our laboratories using models of left and right ventricular hypertrophy [9, 10] to answer this important question. After cross-clamp removal, approximately 96% of hearts revert to spontaneous sinus rhythm. Junctional rhythm may occasionally occur; however, it is rare for pacing to be necessary postoperatively. Occasionally, patients may require pacing to come off cardiopulmonary bypass; however, once potassium levels decrease to a more normal range, they return to sinus rhythm.

Summary

In summary, RCWBC is a new concept in myocardial protection [3], offering many advantages over the antegrade method [5]. These include the elimination of cannulas in the coronary ostia during valvar operations, elimination of left ventricular distention due to aortic insufficiency during retraction of the heart, and elimination of concerns related to the distribution of cardioplegia due to severe coronary artery stenosis. As with any technique, caution is required during its use, and certain principles of cardioplegic delivery must be followed (monitoring of infusion pressure and surveillance of catheter position during infusion) to ensure appropriate delivery. Used appropriately, the method appears to be safe and effective. Additional studies, however, are necessary to document any improvement over traditionally employed techniques of myocardial protection.

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References

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