Technique

Technical Aspects of Simultaneous Antegrade/Retrograde Normothermic Blood Cardioplegia

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Presented as a poster at the International Symposium, Myocardial Preservation, October 7-8, 1994, Chicago, Illinois

Keywords: cardiopulmonary bypass; cardioplegia, retrograde; cardioplegia, antegrade; cardioplegia, continuous; cardioplegia, normothermic

ABSTRACT

Techniques of myocardial protection are a source of controversy in the field of cardiac surgery. Numerous studies have been carried out over the years to prove or disprove one method over another. The following techniques: cold vs. warm, antegrade vs. retrograde, and intermittent vs. continuous are some of the most controversial. Cold intermittent antegrade blood cardioplegia has been an accepted routine for many years. However, the use of warm blood cardioplegia has recently sparked much interest, and many studies have recognized its advantages over cold methods.

If cardioplegia is given intermittently, regardless of any other variables, there will be some degree of ischemia with a resultant delay in myocardial recovery. A logical solution to avoid this ischemia is to deliver oxygenated substrate enhanced warm blood cardioplegia continuously and simultaneously via antegrade and retrograde routes for improved regional distribution. This combined technique is described.

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INTRODUCTION

Cardioprotective techniques in cardiac surgery have evolved from simple infusion of cold crystalloid cardioplegia to oxygenated crystalloid to the more recent oxygenated blood cardioplegia. However, the use of warm blood cardioplegia has recently sparked much interest (1-10), and many studies have recognized its advantages over cold methods (1, 3-8, 11-13). These advances are in an effort to provide improved myocardial protection to an ischemic myocardium (4, 8).

It has been common practice to use intermittent cold blood cardioplegia with cessation of flow for up to 20 minutes. These periods of ischemia can and should be avoided, especially in hearts that have been subjected to ischemic insult. If cardioplegia is given intermittently, regardless of any other variables, there will be some degree of ischemia with a resultant delay in myocardial recovery (14, 15). A logical solution to avoid this ischemia is to deliver oxygenated substrate enhanced blood cardioplegia continuously and simultaneously via antegrade and retrograde routes. At St. Michael's Hospital, Toronto, Canada, a normothermic simultaneous antegrade/retrograde continuous method has been developed, refined, and employed clinically on 164 patients over the past eighteen months with exceptionally good and gratifying results.

MATERIALS AND METHODS

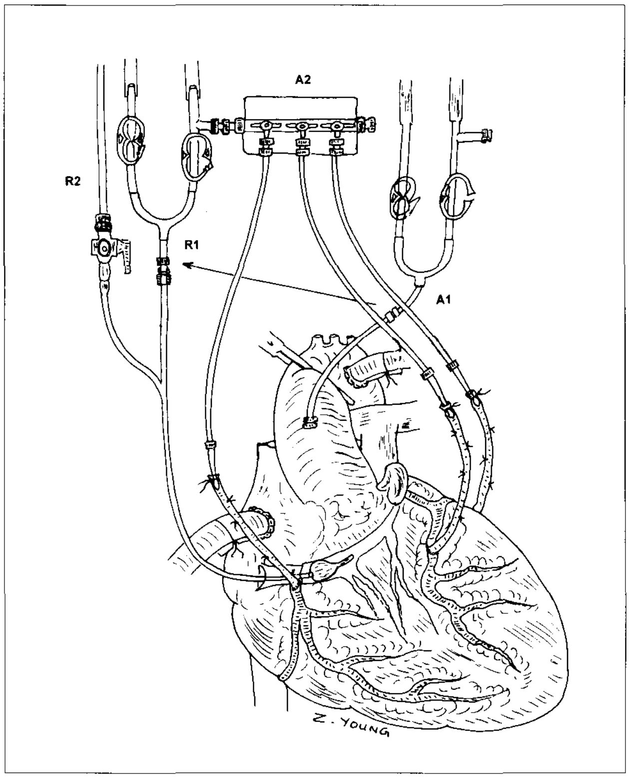
On completion of arterial and venous cannulation for cardiopulmonary bypass (CPB), a pursestring is placed in the wall of the right atrium (RA). In preparation for insertion, the retrograde cannula[a] is connected to a transducer and zeroed at the height of the RA to provide continuous coronary sinus (CS) pressures. The cannula is then digitally inserted into the RA and advanced into the CS. With the stylus removed, desaturated blood flow via the central lumen should be visualized. A phasic pressure trace on the monitor will confirm the accurate placement of the CS catheter. This is *essential* and the most important step in the procedure. Absence of cardiac drainage anomalies should be confirmed at this point, as this may prevent adequate cardioplegia delivery (1). CPB is initiated in the usual manner, and when a cardiac index of ≥ 2.5 l/m²/min is achieved, ventillatory support is discontinued. The cardioplegia delivery line[b] is attached to a Y adapter with a side port[c]. This cardioplegia line is flushed prior to connection to the aortic root needle[d]. The arm of the Y adapter without the side port is clamped. The aortic crossclamp is applied as normothermic high potassium Fremes/ blood cardioplegia solution (ratio 8:1) (Table 1) is initiated via the aortic root. Flows of 250-300 ml/min are delivered until cardiac arrest is achieved, usually within one to two minutes. The cardioplegia line is then disconnected from the aortic root needle and transferred to the CS catheter (Figure 1). To facilitate transition, cardioplegia flow must first be decreased to 30-50 ml/min and then gradually increased to a maintenance flow of 250-300 ml/min. Awareness of the continually transduced CS pressure is mandatory, with 40 mmHg being ideal and 50 mmHg

Table 1: Fremes' High Potassium Cardioplegic Solution

8:1 Dilution Blood: Crystalloid

	Total Volume D5W	250 ml
Additives	Potassium Chloride	60 mmol
	Magnesium Sulfate	4.5 mmol
	THAM	6 mmol
	CPDA Solution	10 ml
	Approx. osmolality	583 mosm
	Approx. pH	8.45
	Approx. Total Volume	313 ml

Figure 1: Continuous simultaneous antegrade/retrograde cardioplegia



A1 - Antegrade via aortic root for initial arrest
R1 - Disconnect at A1 and move to R1 for retrograde via coronary sinus

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a Normothermic retrograde coronary sinus cannula with textured self inflating balloon 14 Fr. NPC-014T, Research Medical Inc., Midvale, Utah
b BCD ADV 8:1, Sorin Biomedical, Irvine CA 92713
c Y Type Adapter #10003, DLP, Grand Rapids, MI 49501
d Aortic root needle 12 gauge, 10014, DLP, Grand Rapids MI 49501

Table 2: Fremes' Low Potassium Cardioplegic Solution

8:1 Dilution Blood: Crystalloid

	Total Volume D5W	500 ml
Additives	Potassium Chloride	30 mmol
	Magnesium Sulfate	7 mmol
	THAM	12 mmol
	CPDA Solution	20 ml
	Approx. osmolality	385 mosm
	Approx. pH	8.45
	Approx. Total Volume	580 ml

being a maximum. Line pressure transduced from the cardioplegia delivery system should be ≤ 200 mmHg. With a successful arrest achieved, continuous delivery of low potassium Fremes/blood solution (Table 2) provides maintenance. On confirmation of electromechanical arrest, crystalloid may be eliminated from the blood, allowing only oxygenated blood to reperfuse through the CS. This can be achieved simply in one of two ways. One can clamp the outlet and the inlet sides of the crystalloid raceway tubing, or as with some cardioplegia delivery systems integral shunts are utilized[e]. The perfusionist has the necessary flexibility to respond to the electromechanical status of the patient by being able to readily alternate between high potassium, low potassium, or all blood without interruption to delivery. Utilizing higher blood to crystalloid ratios markedly reduces hyperglycemia and hemodilution. Attention to the volume of crystalloid infused combined with utilizing blood only will control incidence of hyperkalemia.

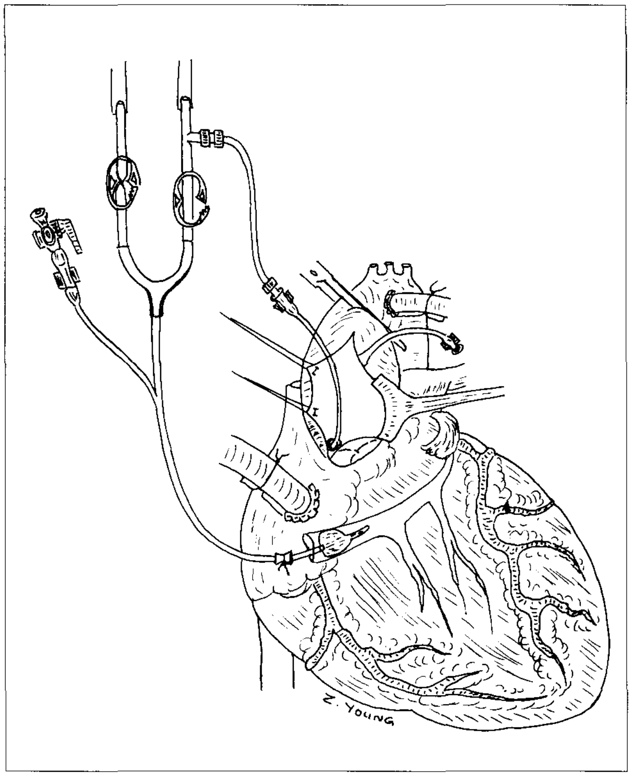
Coronary Artery Bypass Grafts

On completion of each distal anastomosis, the vein is attached via a heparin needle and 1 foot pressure line to a three-hole manifold port[f] (Figure 1). Simultaneous antegrade/retrograde cardioplegia is now infused. The graft to the right coronary artery is ideally completed first to maximize delivery to the right ventricle. Surgeons familiar with the clear field of vision which intermittent cardioplegia provides may want to utilize a humidified jet blower (16, 17) with this technique. It blows the infusion cardioplegia away from the anastomosis being constructed.

Aortic Valve Replacement

Initial arrest is achieved with antegrade high potassium cardioplegia delivery. After transition to retrograde low potassium cardioplegia is complete, the aorta is opened, the right coronary ostium is cannulated, and simultaneous antegrade/retrograde flow commences (Figure 2). This is to provide maximum protection to the right side of the heart.

Figure 2: Continuous retrograde/antegrade cardioplegia for aortic valve surgery (antegrade via direct right coronary cannulation)



Initial antegrade arrest may not be possible in patients with severe aortic insufficiency. In these cases, retrograde cardioplegia is solely utilized until the right ostium is cannulated.

Combined Procedures

Combined valve and coronary bypass graft procedures are done with a combination of these techniques, as deemed necessary and practical.

DISCUSSION

Electromechanical arrest decreases metabolism and therefore myocardial oxygen consumption by 90%. Hypothermia may reduce this by a further 5-7% (2), i.e., heart rate and electromechanical work are greater factors than metabolism.

Although hypothermia decreases overall cellular metabolism and thus oxygen requirements, there are a number of recognized disadvantages associated with its use (5). There is a reduction in the rate of activity of sodium/potassium and calcium adenosine triphosphate ATP-ase systems in the sarcolemma and sarcoplasmic reticulum (18), it has been suggested that cell membrane stability, coagulation defects, mitochondrial rupture, and alternation of membrane bound enzyme systems (19) are affected

e BCD ADV 8C, Sorin Biomedical, Irvine, CA 92713
f MX7096, Medex, Inc., Hillard OH 43026

by hypothermia. Oxygen delivery to tissue is reduced due to a left shift of the oxygen dissociation curve. During hypothermia and intermittent cardioplegia administration technique, glucose utilization is limited to anaerobic glycolysis (4).

Cardioplegia that sustains a normothermic aerobic arrest leaves the metabolic, enzyme and biologic functions near normal (5, 20). As simultaneous continuous antegrade/retrograde cardioplegia prevents ischemia, reperfusion injury is avoided (1). Approximately 75% of the myocardial venous return comes from the following network of cardiac veins draining into the coronary sinus: subepicardial, anterior descending, posterior left ventricular, oblique vein of Marshall, the small cardiac vein, and the middle interior-ventricular vein. The other 25% is the intramural drainage system made up of Thebesian veins and sinusoids which drain directly into the cardiac chambers. Therefore, it would seem that areas distal and possibly those proximal to occlusion would be well perfused through the retrograde route.

The perfusionist will find delivery of simultaneous antegrade/retrograde cardioplegia more technically demanding. The cardioplegia circuit requires as much if not more attention than the arterial circuit. Constant awareness of CS pressures and flow is imperative. Communication regarding adequacy of delivery between the surgeon and perfusionist is mandatory. Questions, concerns or doubts must be clarified immediately. Notification prior to repositioning of the heart allows the perfusionist to safely adjust cardioplegia flow and avoid unsafe CS pressures.

Much depends on the perfusionist's ability to recognize any problems in thc continuous delivery through the retrograde route. Often they are the first to notice resumption of electromechanical activity on the electrocardiogram or CS pressure trace. In most instances, removal of the aortic crossclamp is accompanied by a spontaneous resumption of sinus rhythm. As no reperfusion period is required, CPB is terminated within minutes thereafter.

We have noted over the last 18 months that patients with NYHA III-IV ventricles appeared to benefit most from this technique. Post CPB they require significantly less pharmacologic or mechanical support relative to comparable patients receiving intermittent cardioplegia delivery.

CONCLUSION

Continuous normothermic simultaneous antegrade/retrograde blood cardioplegia provides excellent myocardial protection. The continuous homogeneous distribution of enhanced substrate throughout the myocardium, promotes and maintains normal physiology for the duration of the procedure. Ischemic conditions and therefore reperfusion injury is avoided. The benefit of this technique is evident in those who are most compromised, namely patients in cardiogenic shock or with severe cardiac disease. Type A dissection of the aorta and coronary patients with severe proximal lesions benefit most from this technique. Redo coronary bypass patients may additionally benefit from retrograde perfusion as the risk of distal embolization of atheromatous material from previous vein grafts is avoided. This technique reduces the risk of ischemia and reperfusion as encountered with intermittent delivery technique.

ACKNOWLEDGEMENT

We would like to thank Patricia Anning, RN, CPC, CCP, and Peter Naismith, BSc for their help and support in preparation of this manuscript.

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