Reperfusion Modification with a Simplified Blood Cardioplegia System Compared with Oxygenated Crystalloid Cardioplegia

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Abstract

A simplified system was developed for administration of blood cardioplegia with reperfusion modification. This system utilizes a single pass stainless steel coil to eliminate the need for a separate heat exchanger circuit. This system was compared with an oxygenated crystalloid cardioplegia system which was utilized in a manner which allowed warm blood perfusion of the heart for the last three minutes of the crossclamp interval. Both of these systems were compared with regard to mortality, spontaneous defibrillation, myocardial temperature, blood usage and peak CK-MB levels. In this series of patients, no significant advantage of either system could be identified.

Introduction

Reperfusion modification by infusion of warm hyperkalemic blood into the aortic root prior to crossclamp removal may lead to improved recovery of myocardium which has been compromised either prior to crossclamping or during the crossclamp interval.[1] This study is an attempt to compare two simplified systems of reperfusion modification.

A simplified system of blood cardioplegia was developed utilizing a single pass stainless steel coil (Figure 1).[a] The coil is placed in an ice bath for infusion of cold solution and in a warm water bath for delivery of warm blood during the reperfusion phase.

An oxygenated crystalloid cardioplegia system[b] has been described which utilizes a recirculating aluminum coil with a cardioplegia filter.[2] This coil delivers cold (4°C) oxygenated crystalloid cardioplegia (Figure 2). At the end of the crossclamp interval, the aluminum coil is removed from the ice water bath, air is evacuated from the heart and ascending aorta and room temperature cardioplegia solution is infused into the aorta at a rate of 70-100 ml/min. Simultaneously, the aortic crossclamp is partially removed allowing blood to flow into the ascending aorta, mixing with the cardioplegia solution. A variable mixture of cardioplegia and blood (approximately one third cardioplegia and two thirds warm blood) is therefore delivered into the coronary circulation for three minutes. After this three minute interval, the crossclamp is completely removed.

These two systems were designed to allow reperfusion modification with a very simple system with an equipment cost of less than $100.

Methods

Ninety one cardiac surgery patients were prospectively assigned to either a crystalloid (Table 1) or blood (Table 2) cardioplegia solution. The blood solution was slightly more complex[3] and required more time for mixing in the pharmacy. Therefore, a randomized trial was not possible, but groups of patients were alternated. That is, six to eight crystalloid patients would be followed by six to eight blood cardioplegia patients.

Anesthesia was provided with a standardized system utilizing diazepam and sufentanyl. Cardiopulmonary bypass was accomplished with a roller pump and a COBE® microporous membrane (C.M.L.®).[c]

The patients were heparinized (4 mg/kg) and placed on bypass with core cooling to 25°C. Mean systemic blood pressure was maintained at 50-90 mm Hg. Cardiac indices on cardiopulmonary bypass were maintained between 2-2.5 L/min/m^2.

After the aortic crossclamp was applied, antegrade infusion of one liter of blood solution (a 4:1 mixture of

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a) Gish Biomedical, Santa Ana, CA 92705
b) Baxter Healthcare, Irvine, CA 92714
c) Cobe Laboratories, Arvada, CA 80213

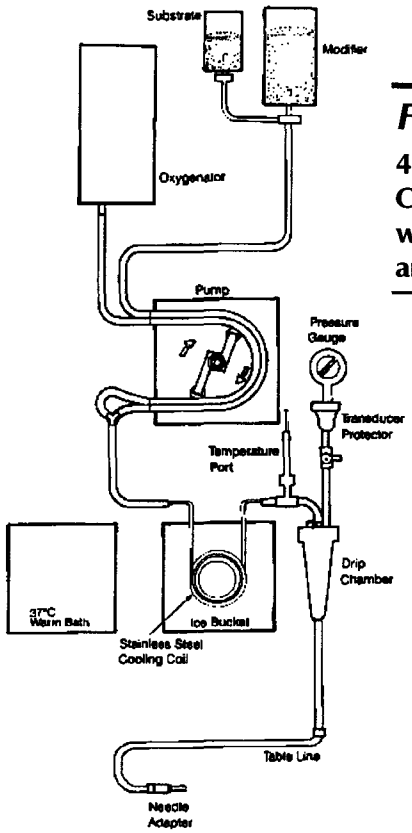


Figure 1
4:1 Blood Cardioplegia Set with Warm Bath and Ice Bath

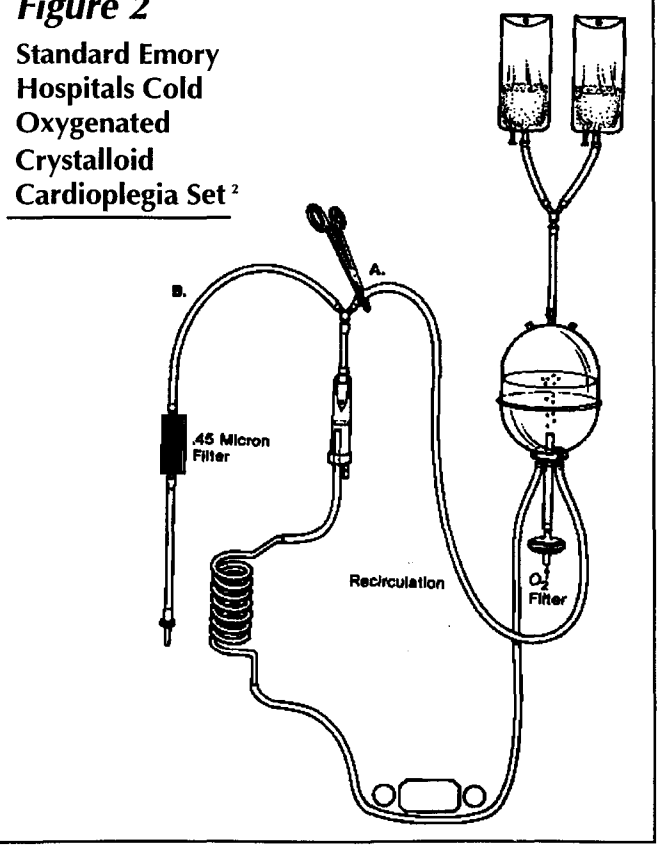


Figure 2
Standard Emory Hospitals Cold Oxygenated Crystalloid Cardioplegia Set [2]

Table 1. Crystalloid Cardioplegia Solution Formulation

Isolyte® pH 7.4	1000 ml.
8.4% Sodium Bicarbonate	20 ml.
Potassium Chloride (2 mEq/ml.)	10 ml.
50% Dextrose	3 ml.

100% oxygen bubbled into Oxy-Hi® reservoir

blood and the cardioplegia additive) or oxygenated crystalloid solution was administered. The stainless steel or aluminum coils were placed in ice water baths for this infusion. After each coronary bypass graft was completed, 200 ml of additional cardioplegia was infused down each bypass graft. After all proximal and distal anastomoses had been completed, air was evacuated from the ascending aorta. In the case of the blood cardioplegia patients, the stainless steel coil was placed in a 39°C water bath and additional cardioplegia was infused into the aortic root at a rate of 150-200 ml/min prior to crossclamp removal. In the case of the crystalloid solution, the aluminum coil was removed from the water bath and oxygenated crystalloid solution was infused into the ascending aorta at a rate of 75 ml/min. Simultaneously, the crossclamp was partially removed, allowing blood to flow into the ascending aorta for mixture with the crystalloid solution. The crossclamp was completely removed after the three minute interval. Myocardial temperatures and temperature of the cardioplegic solutions were measured. Spontaneous defibrillation was noted and the use of postoperative catecholamines was recorded. Hematocrits were monitored before bypass, on bypass, upon arrival in the ICU and one day after operation. The requirement for blood infusion was also recorded. Serum CK levels were checked at eight, 16 and 24 hours after crossclamp removal.

Results

There was no significant difference in the preoperative status of patients in either the blood group or the crystalloid group. (Table 3) The average age in the blood group was 56.9 ± 1.7. The average age of the crystalloid group was 60.4 ± 1.6. The average crossclamp and bypass times for the blood group were 45.1 ± 3.1 and 86.3±4.9, respectively. The average crossclamp and bypass times for the crystalloid group were 38.2 ± 2.1 and 74.2 ± 4.2, respectively. Blood utilization was also nearly identical. In the crystalloid group, 31 of 49 patients (63 percent) required no blood. The 18 patients who did receive blood received an average of 0.8 ± 0.2 units of blood. In the blood group, 27 of 42 patients (64

Table 2. Buckberg Cardioplegia Formulation[5]

SUBSTRATE PORTION		MODIFIER PORTION	
*Monosodium Monohydrate Glutamate	10.97 gm	THAM	258 ml
*Monosodium Monohydrate Aspartate	10.06 gm		
Sterile	322 ml	Citrate Phosphate Dextrose	65 ml
		Potassium Chloride 2 mEq/L	25 ml
		5% Dextrose in water	323 ml
		Sodium Hydroxide	10 ml

*Ajinomoto USA, Teaneck, N.J.

Table 3. Clinical Data: Blood Cardioplegia vs. Oxygenated Crystalloid Cardioplegia*

DATA	Blood	Crystalloid	Significance (P) (t-test)
PREOPERATIVE DATA			
No. of patients	42	49	-
Age	56.9 ± 1.7	60.4 ± 1.6	n.s.
Sex (M/F)	29/14	35/13	-
Hct. pre-op	37.3 ± .7	37.1 ± .8	n.s.
OPERATIVE DATA			
Cabg's/Redo/Valve/Other	34/4/3/1	41/4/4/1	-
IMA's (Y/N)	28/12	28/19	-
Pump-Bypass Time (mins)	86.3 ± 4.9	74.2 ± 4.2	n.s.
Cross-Clamp Time (mins)	45.1 ± 3.1	38.2 ± 2.1	n.s.
Hct on Bypass	22.4 ± .6	20.9 ± .6	n.s.
Cardioplegia Temp °C	6.0 ± .4	5.0 ± 0.3	p < .05
Myocardial Temp °C	11.1 ± 0.7	12.0 ± 1.7	n.s.
Single or Double Cannulation	39/5	45/2	-
Cardioverted (Y/N)	18/24	25/24	-
POSTOPERATIVE DATA			
No. of Deaths	2	2	-
First Hct. in ICU	29.8 ± .5	29.5 ± .6	n.s.
Maximum MB-CK Post-op (IU/L)	29.9 ± .5	22.3 ± 3.6	n.s.
Catechols at 12 hrs. (Y/N)	7/42	7/48	-
Packed Red Blood Cells per Patient (24 hrs. post-op)	0.7 ± .2	0.8 ± .2	n.s.
Percent of Patients Receiving Blood	35.7%	36.7%	-

Cabg's = Coronary Artery Bypass Grafts; IMA's = Internal Mammary Artery Grafts
CPK's = Cardiac Isoenzyme of Creatinine Kinase

* Data given as mean ± SEM

percent) received no blood. The 15 patients who did receive blood received an average of 0.7 ± 0.2 units in the first 24 hours after operation. Hematocrit levels in the patients who did not receive blood were similar.

Initial cardioplegia infusion temperatures were 5 ± 0.3°C in the crystalloid group and 6 ± 0.4°C in the blood group. Myocardial septal temperatures after the initial infusion were 12.0 ± 1.7°C in the crystalloid group and 11.1 ± 0.7°C in the blood group. The temperature of the warm blood reperfusate was 34°C. Spontaneous defibrillation occurred in 51 percent of the crystalloid group and in 42 percent of the blood group. Only seven of 48 patients (16.6 percent) in the crystalloid group and seven of 42 patients (14.3 percent) in the blood group required postoperative inotropic support despite inclusion of valve patients, redo patients and emergency coronary revascularizations. Peak CK-MB levels were compared. For the purposes of comparison, it was necessary to examine only non-redo, scheduled coronary bypass patients to eliminate sources of CK release unrelated to myocardial protection. If only these non-redo, scheduled patients are examined, peak CK-MB levels were similar in the crystalloid group (22.3 ± 3.6 IU/L) (N=31) and in the blood group (29.9 ± 5.0 IU/L) (N=28) (Figure 3).

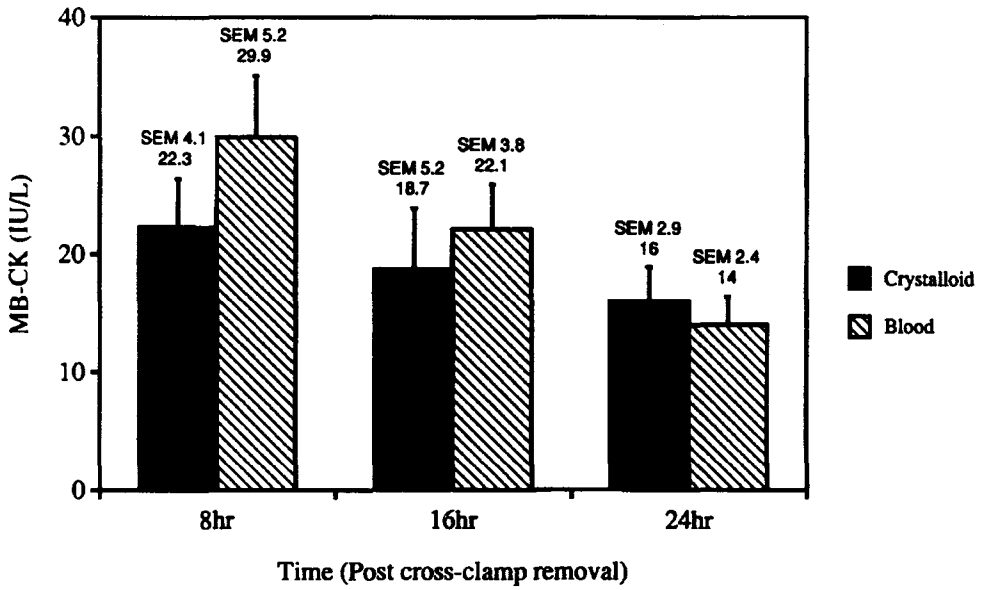
There were two deaths in each group. One death in the crystalloid group was caused by perioperative heart block and postoperative pacing failure. One death in the blood group was caused by malignant ventricular tachycardia. One death in each group was caused by problems related to other organ systems.

Conclusions

This study tested and compared two systems of cardioplegia delivery which were designed to be simple and to allow reperfusion modification. Both the blood and the crystalloid solution allowed adequate cooling of the myocardium. Equivalent clinical results and a low catecholamine requirement were observed in each group, indicating that myocardial protection and recovery of the myocardium was adequate. CK-MB levels revealed a slightly but not significantly higher level of CK values in the blood group. There was no difference between the two groups with regard to blood utilization, postoperative hematocrit, spontaneous defibrillation or patient survival.

Figure 3

Bar Graph of Serum MB-CK levels vs. Time



These simplified systems of cardioplegia delivery and reperfusion modification are less cumbersome and less expensive than the techniques that others have used which require separate heat exchanger circuits. These attributes should prompt further testing of both these systems and consideration for routine clinical use.

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