

Influence of Total vs. Partial Cardiopulmonary Bypass on Myocardial Preservation: A Clinical Study

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INTRODUCTION

Aortic root infusion of a cold potassium solution and topical hypothermia is a widely accepted means of providing myocardial cooling during aortic cross-clamping. While the nature of cardioplegic solutions and methods of administration have been the subjects of considerable debate, little attention has been paid the role of venous cannulation techniques in helping to assure myocardial protection.

Rosenfeldt and Watson conducted a careful study of the heat exchange occurring through the myocardium during ischemia in an excised pig heart. They found that the most potent factor interfering with myocardial cooling was the presence of warm fluid inside the heart, the source of which is systemic venous blood. Double cannulation and occlusive caval clamps isolate the heart from this heat source.¹ A study by Hood et al. using a canine model showed that myocardial cooling was better sustained under conditions of total bypass (double cannulation and occlusive caval clamps).²

Early in our clinical experience with cardioplegia, we observed that patients having valve replacement done on total cardiopulmonary bypass (CPB) required intraaortic balloon counterpulsation (IABCP) less frequently than did those patients having aorto-coronary bypasses which were performed on partial bypass. In order to determine the effect of total bypass on myocardial preservation in comparable patient populations, operations were performed on a group of coronary bypass patients using total bypass and compared with a similar group on whom partial bypass had been used.

In a retrospective review of coronary bypass patients we found that myocardial preservation, based on the need for IABCP post-perfusion, was superior using total bypass.

CLINICAL MATERIAL

This study concerns 144 consecutive aorto-coronary bypass operations performed between April 1977 and May 1978. Excluded from the study were all cases of valve re-

placement or repair of congenital defects whether coronary bypass was performed or not. Also excluded were those cases so unstable in the pre-bypass period that IABCP or precipitous initiation of CPB was required. By these criteria, five cases in the partial bypass group and no cases in the total bypass group were eliminated. Operative and anesthesia techniques were essentially the same for all patients included in the review.

METHODS

In all patients a median sternotomy was performed, the ascending aorta cannulated, and ventricular decompression accomplished through a venting catheter in the pulmonary artery. Proximal anastomoses were routinely done prior to CPB and distal anastomoses were done under cardioplegic arrest. After initiating CPB using a bubble oxygenator systemic temperatures were reduced to 28–30 degrees Celsius. Patients were rewarmed to 33–35 degrees Celsius 15 to 20 minutes prior to the release of the aortic cross-clamp. Bypass was terminated 15 to 30 minutes following the removal of the aortic clamp. If the patient did not maintain a stable rhythm and a systolic blood pressure of 80 mm Hg, IABCP was initiated. Except for the one intra-operative death, every patient requiring IABCP was stable within 24 hours and the balloon was removed.

The technique used to cool the myocardium was the same for all patients. The aortic root was cannulated with a 14 gauge Jelco needle through which a cold (0–4 degrees) Hartmann's solution was infused. Potassium chloride was added to make a total of 23.5 mEq per liter. The solution was delivered with a Tycos pressure infuser. Administration pressures were not monitored. Immediately following application of the aortic cross-clamp, 400 ml of solution was infused over a period of three to five minutes. Supplemental infusions of 200 ml were administered at 20 minute intervals until the aortic clamp was removed. This procedure was repeated with each application of the aortic clamp. In addition, topical cooling was provided by a continuous bath of cold Hartmann's solution into the pericardial sac.

The cases were divided into two groups based on cannulation technique:

- I. Cannulation of the right atrium with a single 51 Fr. cannula.
98 cases (April, 1977 to January, 1978)
- II. Cannulation of inferior and superior vena cavae with 36 Fr. and 34 Fr. cannulae, respectively, using caval clamps to accomplish total bypass. 46 cases (January, 1978 through May, 1978)

The following pre-operative data were recorded for each case in both groups:

1. age
2. sex
3. use of Inderal within 24 hours prior to surgery
4. estimate of ventricular function
 - a) good—estimated ejection fraction over .6
 - b) fair—estimated ejection fraction between .3 and .6
 - c) poor—estimated ejection fraction less than .3

TABLE I
Myocardial Preservation

Variable	I		II		p
	(mean)	IABCP	(mean)	IABCP	
1. Total clamp time	71.8 min	(12/98)	80.6 min	(0/46)	.012
2. Maximum clamp time	57.8 min	(12/98)	50.6 min	(0/46)	
3. Revised maximum time	54.0 min	(8/88)	50.6 min	(0/46)	.031
4. Multiple clampings	46.9%	(6/46)	82.6%	(0/38)	.023

Details of each operation noted were:

1. maximum cross-clamp time
2. total cross-clamp time
3. number of cross-clampings
4. number of coronary artery bypass grafts
5. number of endarterectomies
6. need for IABCP post-bypass

Following operation pre-operative and post-operative electrocardiograms were compared to determine the incidence of perioperative infarction based on the appearance of a new Q wave or loss of the R wave. Post-operative survival was also noted.

RESULTS

Group I and Group II were comparable with regard to age and sex distribution, pre-operative cardiac function and number of coronary bypass grafts (average number of grafts per patient: 3.4 in Group I, 3.3 in Group II).

The need for IABCP was less frequent in Group II (0/46) than in Group I (12/98).

Comparisons between the two groups were made controlling the variables of maximum cross-clamp times, total cross-clamp times, and single vs. multiple cross-clampings of the aorta.

The Group I population contained more cases with long maximum cross-clamp times (mean 57.8 min) than in Group II (mean 50.6 min). Therefore, in order to make the two groups comparable with respect to maximum cross-clamp times, the segment of the Group I population with maximum cross-clamp time over 83 minutes (the longest time in Group II) was eliminated. With the revised Group I population, the use of IABCP was 8/88, significantly more than 0/46 in Group II ($p = .031$). (Table I)

The average total cross-clamp time for Group I was 71.8 minutes and 80.6 minutes for Group II. The use of IABCP was 12/98 in Group I and 0/46 in Group II ($p = .012$). (Table I) When Group I cases were analyzed separately, it was found that there was an increased need for IABCP with the longer total clamp times.

In Group I, 13% (6/46) of the patients subjected to multiple cross-clampings required IABCP whereas none of the 38 patients in Group II did. (Table I)

TABLE II
Myocardial Preservation

	I	IABCP	II	IABCP
Inderal	53%	5/32	70%	0/46
No Inderal	67%	7/66	30%	0/46
Infarct	19%	3/17	11%	0/46
No infarct	81%	9/81	89%	0/46
Endarterectomy	47%	9/47	57%	0/46
No endarterectomy	53%	5/51	43%	0/46

It is therefore concluded that the observed differences in IABCP utilization cannot be explained by maximum cross-clamp times, total cross-clamp times, or number of cross-clampings per case.

Thirty-three percent (32/98) of the patients in Group I received Inderal within 24 hours prior to surgery. Of these, 16% (5/32) required IABCP. Eleven percent (7/66) of those not receiving Inderal required IABCP. This difference is insignificant. In Group II, 70% received Inderal and none required IABCP. (Table II)

The incidence of perioperative infarct was not significantly different between the two groups (19% Group I; 11% Group II). Of the patients exhibiting evidence of infarction in Group I, 18% (3/17) required IABCP. IABCP was needed in 11% (9/81) of the Group I patients without infarction. None of the Group II patients required IABCP. (Table II)

One or more endarterectomies were performed in 47% of the cases in Group I and 57% of the cases in Group II. Of the patients having endarterectomy in Group I, 19% (9/47) required IABCP; 6% (3/51) needed IABCP who had not had an endarterectomy. (Table II)

There was one death in Group I and one in Group II. The death that occurred in Group I was perhaps attributable to insufficient myocardial protection in that the patient could not be weaned from bypass even with IABCP, despite the fact that the patient did not present an unusual risk. The death in Group II occurred two days post-operatively and was clearly not related to the problem of myocardial preservation.

DISCUSSION

In temperature studies by Hood et al. it was found that myocardial temperatures dropped to an acceptable level with initial applications of topical hypothermia and aortic root infusion regardless of the venous cannulation technique. However, the temperatures were better sustained using double cannulation and occlusive caval clamps.² Rosenfeldt and Watson found that systemic venous blood had a greater warming effect on the ventricular septum than pulmonary venous blood.¹ Double cannulation using occlusive caval clamps isolates the hypothermic heart from this heat source.¹ Our clinical observations support these findings. With the single cannula technique ventricular fibrillation was occasionally noted within 20 minutes of an injection of cold solution and atrial activity was frequent. These phenomena were rare using double cannulae and caval occlusion suggesting that in manipulating a heart with a single atrial cannula, the right side of the

heart and the interventricular septum may be exposed to warm caval blood. This warmer blood decreases cooling efficiency, as shown by Rosenfeldt and Watson, and presumably reduces myocardial preservation during aortic cross-clamping.

Our current practice is to monitor myocardial temperature with a 22 gauge thermistor* placed in the interventricular septum. With double cannulation, occlusive caval clamps and effective venting, temperatures are maintained below 20° Celsius (preferably at 15° C) by periodic application of topical hypothermia and aortic root infusion of a cold potassium solution. The aortic cross-clamp is applied only once. The need for IABCP is only occasional and is usually associated with a sizable perioperative infarct or failure to maintain adequate myocardial temperatures.

REFERENCES

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* Yellow Springs Instruments, Yellow Springs, Ohio