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The Hemodynamic Responses to Hypothermic and Normothermic Cardiopulmonary Bypass

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Abstract : This prospective randomized clinical study was designed to assess and compare the effects of normothermic and hypothermic nonpulsative cardiopulmonary bypass in patients with mitral valve replacement. Forty patients undergoing elective mitral valve replacement were randomly divided into two groups according to the temperature of perfusion. Group N (15 patients) underwent normothermic cardiopulmonary perfusion and Group H (25 patients) underwent hypothermic cardiopulmonary perfusion. These groups were compared using clinical and electrocardiographic criteria and cardiovascular evaluation parameters. Quantitative data were analyzed using the paired Student t test.

While there was a significant increment in heart rate in Group N in relation to preoperative values, there was no change in heart rate in Group H. Increasing values in systemic vascular resistance (SVR) parameters were detected in both groups. Oxygen consumption (VO_2) values decreased in Group N in relation to Group H. There was no significant change in alveolar-arterial O_2 difference (DO_2) values between these two groups.

These results indicate that the temperature of cardiopulmonary perfusion had no effect on the immediate postoperative values but did cause an increase in heart rate in the normothermic group.

Key Words: normothermia, cardiopulmonary bypass

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Introduction

There is a growing body of evidence showing that perfusion temperature during cardiopulmonary bypass (CPB) influences postoperative cardiac hemodynamic measurements. Myocardial hypothermia has long been used as an important modality for myocardial preservation during cardiac operations. The concept of myocardial protection with systemic hypothermia has been described by many authors (1). However, normothermic systemic perfusion in patients undergoing CPB may compromise myocardial hypothermia since this aids the preservation of ventricular function during operative cardiac arrest. Consequently, several studies have suggested that normothermic (warm) bypass techniques may improve myocardial outcomes for patients undergoing cardiac operations (2).

In order to compare hemodynamic responses to normothermic and hypothermic CPB 40, adult patients undergoing mitral valve replacement operation were

studied. Hemodynamic measurements were taken from the preoperative period to the first postoperative hour.

It is known that cardiopulmonary bypass produces hemodynamic and inflammatory disorders involving changes in vascular permeability and regional blood flow and alterations to the coagulation and complement systems (3). The aim of this study was to investigate whether any hemodynamic changes occur after CPB according to temperature. Forty patients undergoing mitral valve replacement were studied. In 15 patients (Group N), systemic normothermic CPB and antegrade warm intermittent cardioplegia were used. The remaining 25 cases (Group H) underwent surgery under systemic hypothermic CPB and with antegrade cold intermittent blood cardioplegia.

Patients and Methods

To evaluate the influence of perfusion temperature on the systemic effects of cardiopulmonary perfusion 40, the patients undergoing elective mitral valve replacement

were randomly assigned to undergo either normothermic (warm, N=15, 36 degrees C) or hypothermic (cold, N=25, 28 degrees C) cardiopulmonary bypass.

In Group N there were 3 males and 12 females, and the mean age was 37.4 +/- 13 years. In Group H there were 7 males and 18 females, and the mean age was 43.6 +/- 15 years (p>0.05). (Table 1).

Table 1. Preoperative values.

	Normothermic CPB	Hypothermic CPB	p value
Age	37.45+/-13.09	43.64+/-15.01	>0.05
Height	159.36+/-6.32	161.67+/-9.09	>0.05
Weight	60.54+/-9.66	63.38+/-15.03	>0.05
BSA	1.65+/-0.14	1.68+/-0.21	>0.05
CPB duration	98+/-50	118+/-60	>0.05

Legends:
 CPB: cardiopulmonary bypass
 BSA: body surface area

Ethical approval and informed consent were obtained at Atatürk State Hospital in İzmir. Standard anesthetic and operative procedures were performed in all patients.

The chest was entered through a median sternotomy incision, and both the aorta and right atrium were cannulated. Two separate venous cannulae were used to cannulate the vena cavae. After heparinization (3 mg/kg heparin sulphate) so as to obtain an activated clotting time of at least 450 seconds the patient was connected to the heart lung machine using a membrane blood oxygenator. Once bypass was established normothermic perfusion (36°C) was established in Group N and systemic hypothermia (28°C) in Group H. The aorta was clamped, 10 ml/kg of patient cardioplegia was infused primarily and valve replacement was performed. Cardioplegia was infused with a roller pump and a half dose of the primary amount (5 ml/kg). Cardioplegic infusion was repeated every 10 minutes. The cardioplegic temperatures were 36 and 28-30 degrees respectively. After declamping and after complete hemodynamic stability was obtained, decannulation was carried out and heparin was neutralized with protamine sulphate.

Serial hemodynamic measurements and blood samples were obtained before anesthetic procedure and after the

CPB procedure and first postoperative hour in the intensive care unit.

Statistical Analysis

Statistical analysis was performed using the SPSS program. Quantitative data were analyzed using the paired Student t test. A p value of less than 0.05 was considered significant. Data were expressed as mean +/- standard deviation.

Results

There was no statistical difference between the two groups when assessed according to age, sex and cross-clamping time (p>0.05). The comparison of preoperative and early postoperative cardiac measurements between groups N and H failed to demonstrate that perfusion with warm solution offered any definite advantage over hypothermic perfusion. This failure to demonstrate any advantage or disadvantage resulting from temperature control may lead us not to cool patients for valve surgery in the future. The CPB and operation times were not significantly different between the groups.

During CPB there was no difference between the 2 groups in the need for vasopressors, urinary output or fluid balance. During the postoperative period normothermic CPB patients had a significantly lower right ventricular stroke work index (RVSWI) and higher heart rate (HR) (Table 2). Systemic vascular resistances increased in both groups. Heart rate values did not change in the hypothermic group (Table 3). Blood loss was significantly higher in the patients after hypothermic CPB.

These two groups were given similar amounts of anesthetics. Systemic vascular resistance was found to be similar in both groups and heart rate was higher in only the normothermic group. The postoperative central venous pressure (CVP) and pulmonary capillary wedge pressure (PCWP) were not different between the groups. Oxygen consumption decreased significantly after normothermic CPB, and the alveolar-arterial O₂ difference (DO₂) did not change significantly in the two groups. The urine output was similar in the two groups.

A right ventricular-pulmonary artery catheter was used to assess right ventricular function by measuring the right ventricular stroke work index, pulmonary arterial pressure and PCWP in the pre-bypass and post-bypass

		Awake	Entubation	After CPB	Intensive care
LVSWI	Normo	35.9+/-19.28	21.54+/-11.8	24+/-9	22.54+/-9.08
	Hypo	43.64+/-15.01	28.96+/-18	30.67+/-16	27.03+/-12.54
MAP	Normo	89.18+/-10.36	60.09+/-10	79.45+/-22.08	91.63+/-15.45
	Hypo	92.61+/-15.15	65.38+/-15	87+/-20.39	93.25+/-19.77
CVP	Normo	3+/-3.2	4+/-4	6+/-3.4	2.5+/-2
	Hypo	4+/-4	6+/-5	6.29+/-2.96	4+/-3.1
MPAP	Normo	24.54+/-12.62	17.18+/-6.6	19.72+/-6.34	18+/-5.79
	Hypo	24.74+/-11.19	17.22+/-6.9	18.77+/-6.46	18.22+/-7.18
PCWP	Normo	16.09+/-11.07	11.54+/-6.59	11.36+/-6.24	8.27+/-6.57
	Hypo	15.67+/-8.59	12+/-6.25	12.29+/-5.24	10.83+/-6.3
CI	Normo	3.65+/-1.64	3.18+/-1.18	3.2+/-0.77	2.41+/-0.57
	Hypo	3.56+/-1.9	3.02+/-1.32	2.85+/-0.95	2.38+/-0.68
SVRI	Normo	2150+/-797	1506+/-513	1987+/-952	3088+/-835
	Hypo	2207+/-1193	1680+/-967	2315+/-1277	3033+/-1578
PVRI	Normo	238+/-230	166+/-137	240+/-194	341+/-195
	Hypo	226+/-144	141+/-99	190+/-138	252+/-189
RVSWI	Normo	10+/-8	6.27+/-4.94	4.54+/-1.86	4+/-1.5
	Hypo	10+/-6	5.09+/-3.08	5.46+/-3.65	4.69+/-2.8
SVI	Normo	35.45+/-15.38	32.72+/-13.34	26.72+/-10	19.63+/-6.6
	Hypo	39.38+/-20.46	36.38+/-17.82	31.19+/-12.95	24.77+/-9.52

Table 2. Postoperative values.

Legends:

CPB : cardiopulmonary bypass
 LVSWI : left ventricular stroke work index
 mAP : mean arterial pressure
 CVP : central venous pressure
 mPAP : mean pulmonary arterial pressure
 PCWP : pulmonary capillary wedge pressure
 CI : cardiac index
 SVRI : systemic vascular resistance index
 PVRI : pulmonary vascular resistance index
 RVSWI : right ventricular stroke work index
 SVI : stroke volume index

HR	Normo	106+/-22	105+/-33	126+/-28	128+/-23
	Hypo	95+/-20	90+/-23	98+/-19	102+/-20
VO ₂	Normo	326+/-121	311+/-94	277+/-118	142+/-48
	Hypo	271+/-131	273+/-114	219+/-66	185+/-77
DO ₂	Normo	1006+/-400	931+/-326	940+/-326	500+/-164
	Hypo	999+/-532	881+/-400	736+/-298	559+/-226

Table 3. Postoperative heart rate values.

Legends:

HR : heart rate
 VO₂ : oxygen consumption
 DO₂ : alveolar-arterial O₂ difference

periods. RVSWI decreased during the postoperative period.

There were no differences between the two groups in terms of postoperative hepatic and renal functions. Normothermic CPB was not associated with adverse effects on postoperative metabolic and cardiac recovery (Table 4).

There were no changes in the mean arterial pressure (mAP), left ventricular stroke work index (LVSWI), systemic vascular resistance index (SVRI), mPAP, PCWP, cardiac index (CI), pulmonary vascular resistance index (PVRI), stroke volume index (SVI), oxygen consumption (VO₂) or DO₂ after CPB in the normothermic group; but some decreases were observed in RVSWI (p<0.05) in

addition to rises in CVP and heart rate (p<0.05)

According to the values of Group H; there were no changes in mAP, CVP, SVRI, PVRI, HR or VO₂ after the cardiopulmonary bypass (p>0.05). However, there were significant reductions in the levels of LVSWI, mean pulmonary arterial pressure (mPAP), PCWP, CI, RVSWI, SVI, and DO₂ (p<0.05).

In the early postoperative period (first hour) this significant reduction in LVWSI, RVSWI, CI, mPAP, PCWP, SVI, VO₂, DO₂ continued in both groups. In that period the normothermic CPB patients exhibited a significantly higher heart rate (p<0.05). There was no significant change in heart rate in the hypothermic group in the intensive care unit. There were significant rises in the

	GROUP N		GROUP H	
	Preop - after CPB	First postop hour	Preop - after CPB	First postop. hour
mAP	Same	Same as pre-CPB	Same	Same as pre-CPB
LVSWI	Same	Decrease	Decrease	Decrease
SVRI	Same	Increase	Same	Increase
PVRI	Same	Same as pre-CPB	Same	Same as pre-CPB
SVI	Same	Decrease	Decrease	Decrease
VO ₂	Same	Decrease	Same	Decrease
DO ₂	Same	Decrease	Decrease	Decrease
RVSWI	Decrease	Decrease	Decrease	Decrease
CVP	Increase	Same as pre-CPB	Same	Same as pre-CPB
HR	Increase	Increase	Same	Same as pre-CPB
mPAP	Same	Decrease	Decrease	Decrease
PCWP	Same	Decrease	Decrease	Decrease
CI	Same	Decrease	Decrease	Decrease

Table 4. Changes between preoperative and postoperative parameters.

- Legends:
- CPB : cardiopulmonary bypass
 - mAP : mean arterial pressure
 - LVSWI : left ventricular stroke work index
 - SVRI : systemic vascular resistance index
 - PVRI : pulmonary vascular resistance index
 - SVI : stroke volume index
 - VO₂ : oxygen consumption
 - DO₂ : alveolar-arterial O₂ difference
 - RVSWI : right ventricular stroke work index
 - CVP : central venous pressure
 - HR : heart rate
 - mPAP : mean pulmonary arterial pressure
 - PCWP : pulmonary capillary wedge pressure
 - CI : cardiac index

levels of VO₂ (p<0.05) and DO₂ (p<0.05) in Group N after CPB but the VO₂ values decreased in the postoperative period in relation to Group H (p<0.05). The DO₂ values did not differ significantly between the two groups in the first postoperative hour. The normothermic group did not require the administration of larger volumes of cardioplegia or crystalloid infusion than the hypothermic group.

Normothermic CPB is not associated with additional systemic adverse effects.

There was no mortality, no necessity for intraaortic balloon pump nor any neurological events in any of the patients of either group.

In contrast to some studies, which have suggested that hypothermic heart surgery could be a safer procedure, we conclude that there were no differences between the two procedures.

No differences between the warm and cold groups were observed.

Discussion

Although it has been said that temperature should be lowered in order to reduce metabolic rate (4), normothermia optimizes the rate of cellular repair, and enrichment of the oxygenated cardioplegic solution improves the oxygen utilization capacity (5).

Our operations did not need to be prolonged for warm induction and warm perfusion.

It is known that post-ischemic reperfusion damage after global ischemia can be avoided or minimized by giving a brief warm (36°C) blood cardioplegic infusion during the initial phase of reoxygenation (6). We are observing the beneficial effects of this procedure in our open heart surgery patients.

The higher SVR during hypothermic CPB is not caused by hormonal changes, but might be caused by other factors such as greater blood viscosity. There are some limitations to performing hypothermic cardiopulmonary bypass. The right ventricle is the area of the heart most susceptible to rewarming (7). This event probably causes right ventricular dysfunction that could be encountered postoperatively. Normothermic temperatures during CPB may, however, decrease the brain’s tolerance to the ischemic damage that accompanies all cardiac procedures. Some studies have shown that patients undergoing normothermic CPB are at greater risk of cerebral desaturation for neurologic injury. In some studies, warming during CPB to maintain systemic temperatures equal to or above 35 degrees C increased the risk of perioperative neurologic deficit in patients undergoing elective coronary revascularization (8). However, we did not encounter any neurologic disorders after our cardiac operations, in contrast to some studies, which did not show any protective effects of hypothermia (9).

There was no evidence of increased morbidity due to normothermic CPB.

Conclusion

This study did not demonstrate that CPB temperature had any significant effect on postoperative hemodynamics, except in terms of heart rate. It can be estimated that normothermic CPB is not associated with additional systemic adverse effects except for increasing heart rate.

We conclude that normothermic CPB might compromise right ventricular preservation in patients undergoing cardiac operations.

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