The Effect of Hypothermic and Normothermic Cardiopulmonary Bypass on Metabolic and Haemodynamic Parameters

Mahmut Padak[1], *Reşat Dikme*[1]

1 Harran University Vocational School of Health Services, Department of Perfusion Technology, Şanlıurfa, Türkiye

Abstract

Aim: The aim of this study is to investigate the changes in metabolic and haemodynamic parameters over time in patients undergoing coronary artery bypass grafting with hypothermic and normothermic cardiopulmonary bypass.

Methods: A total of 126 patients were included in the study: 64 patients who underwent normothermic (35–37 °C) CPB and 62 patients who underwent hypothermic (28–34 °C) CPB. Statistical analyses were performed using SPSS 25.0 and Python software, with $p<0.05$ accepted as the level of significance.

Results: During CPB, a decrease in albumin levels and an increase in AST, ALT, CRP, glucose, lactate, sodium, and total bilirubin levels were observed ($p<0.05$). However, no significant differences were found between the normothermic and hypothermic groups for most parameters ($p>0.05$).

Conclusions: In this retrospective study, the incidence of PoAF did not differ significantly between hypothermic and normothermic CPB. Although higher intraoperative temperature and prolonged CPB duration showed a tendency toward increased PoAF, these trends were not statistically significant. The findings indicate that temperature management strategy alone is unlikely to be a decisive factor, and further prospective studies are required to clarify its role in PoAF prevention.

Keywords: *Cardiopulmonary bypass; Normothermia; Hypothermia; Metabolic parameters; Systemic inflammation*

1. Introduction

Coronary artery disease (CAD) is one of the leading causes of cardiovascular morbidity and mortality worldwide.[1] Coronary artery bypass grafting (CABG) is an effective surgical method used in the treatment of advanced CAD and is often performed with cardiopulmonary bypass (CPB) support. During CPB, bodily functions are maintained through an external circulation system, and the thermal management strategy employed during this process can directly affect the patient's metabolic and haemodynamic responses.[2,3]

During cardiopulmonary bypass (CPB), two primary thermal management approaches are typically employed: normothermia (35–37 °C) and hypothermia (28–34 °C).[4] The effects of normothermia and hypothermia during CPB play a significant role in surgical outcomes. Management of body temperature during CPB is critically important in terms of surgical outcomes and patient survival. Normothermia, i.e. maintaining body temperature above 35°C, is generally the preferred method in adult patients, and this approach has been shown to yield favourable outcomes such as improved tissue perfusion and shorter intensive care unit stays postoperatively.[4] Hypothermia is thought to protect organs from ischaemic damage by slowing metabolic rate, reducing the inflammatory response, and decreasing oxygen consumption.[5] Some studies have reported that hypothermia increases short- and long-term survival rates.[2] However, hypothermia also has adverse effects, such as post-operative renal failure and longer intensive care unit stays.[5] In neonatal patients, persistent hypothermia has been reported to increase the risk of serious complications and may be a clinically useful indicator for assessing patient stability.[6]

However, there are conflicting data in the literature regarding the effect of normothermic and hypothermic perfusion on clinical outcomes. While some studies highlight the organ-protective effects of hypothermia, others report that normothermia is at least as safe.[7,8] In particular, how metabolic parameters such as inflammation markers (CRP), liver enzymes (AST, ALT), serum albumin levels, electrolyte balance, and lactate respond to these two perfusion strategies is still being investigated.

The aim of this study is to compare metabolic and haemodynamic parameters in CABG patients undergoing hypothermic and normothermic CPB during the pre-bypass, post-bypass, and postoperative periods, to analyse changes over time, and to determine whether there are clinically significant differences between the two strategies.

Corresponding Author: Resat Dikme, rdikme@harran.edu.tr, *Received: 29.09.2025, Accepted: 17.12.2025, Available Online Date: 31.12.2025* *Harran University Vocational School of Health Services, Department of Perfusion Technology, Şanlıurfa, Türkiye.* *https://doi.org/10.36516/jocass.1793221*

2. Materials and Methods

2.1. Patients and study design

This study was conducted using a retrospective cross-sectional design, evaluating data from a total of 126 patients who underwent CABG surgery between 2010 and 2025. The patients included in the study were divided into two groups: normothermic (n=64) and hypothermic (n=62) CPB. The normothermic group was perfused at a body temperature range of 35–37 °C, while the hypothermic group was perfused at a range of 28–34 °C. The patients were similar in terms of age, gender, comorbidities, and type of surgery. Data for each patient were collected at three different time points: Pre-bypass: Preoperative period (after induction, before bypass); Post-bypass: Immediately after CPB (after disconnection); Postop: Early postoperative period (within the first 24 hours in intensive care).

2.2. Data collection

Metabolic (albumin, AST, ALT, CRP, glucose, lactate, electrolytes, etc.) and haemodynamic (systolic, diastolic blood pressure, pH, pCO_2, pO_2, etc.) parameters obtained during these time periods were analysed. Data were obtained retrospectively from the hospital information management system and perfusion-surgery-anaesthesia records.

2.5. Statistical analysis

IBM SPSS Statistics 25.0 software and Python software were used for data analysis. The normality distribution of the data set was tested for each group and time period using the Shapiro-Wilk test. Parametric tests were used for data meeting the assumption of normal distribution, while non-parametric tests were used for data not meeting this assumption. Differences between normothermic and hypothermic groups in each time period (Prebypass, Postbypass, Postop) were assessed using the independent samples t-test or Mann-Whitney U test. The effect of time within the same group was analysed using Repeated Measures ANOVA or the Friedman test, depending on the distribution of the data. For parameters where time showed a significant effect, pairwise comparisons between the three time periods were performed using the Tukey HSD test, and pairs with significant differences were coded with letters in the table accordingly. In the tables, significant differences between time points within the same group are indicated by capital letters (A, B, C), while differences between groups within the same time period are indicated by lowercase letters (a, b). All data are presented as mean ± standard deviation (SD); statistical significance was set at $p < 0.05$.

3. Results

The demographic characteristics of the 126 patients included in the study are presented in Table 1.

The hypothermic group included in the study comprised 38 men and 26 women, while the normothermic group comprised 34 men and 28 women. The mean age, height, weight, and BSA were similar between the groups. The mean age in the hypothermic group was 60.76 ± 9.71 years, while in the normothermic group it was 59.73 ± 11.29 years. Height and BSA values were similar in both groups, and no significant differences were found between the groups in terms of demographic characteristics.

The clinical and biochemical data of the normothermic and hypothermic patients included in the study were evaluated at three time points (pre-bypass, post-bypass, and postoperative). The findings are presented to include the effect of time, differences between groups, and detailed comparisons of these differences. The mean ± SD values for the normothermic and hypothermic groups according to the Prebypass, Postbypass, and Postoperative time periods are given in Table 2.

Table 1 above shows the mean±SD values for all clinical parameters in the normothermic and hypothermic groups across three time periods (Pre-bypass, Post-bypass, Postoperative) and the statistical results regarding the effect of time.

According to the table, parameters showing significant changes over time in both groups include albumin, AST, CRP, calcium, glucose, sodium, lactate, and total bilirubin levels ($p<0.05$). Significant changes in some parameters were observed in only one group. For example, significant changes in ALT and pH levels were detected only in the hypothermic group, while changes in creatinine, potassium, and GGT levels were detected only in the normothermic group. In contrast, no significant change over time was observed in parameters such as systolic and diastolic blood pressure, HCT, PO_2, and direct bilirubin ($p>0.05$).

In terms of the effect of time, a significant decrease in albumin levels ($p<0.001$) was observed in both groups, while significant increases in AST, ALT, and CRP levels ($p<0.001$) were detected in the postoperative period. Furthermore, sodium (Na) levels increased in both groups ($p<0.001$), while creatinine and lactate (LAC) levels rose significantly, particularly in the postoperative period ($p<0.05$). Time-dependent significant changes in PCO_2 and pH values were also observed in the hypothermic group ($p<0.05$).

The pairwise comparisons of each parameter over time (Prebypass–Postbypass and Prebypass–Postoperative) in normothermic and hypothermic CPB patients are shown in Table 3.

Table 3 shows the statistical significance levels for pairwise comparisons between the Pre-bypass-Post-bypass and Pre-bypass-Postoperative periods for each parameter in patients undergoing normothermic and hypothermic cardiopulmonary bypass (CPB). Statistical analyses were supported by post hoc analyses following Repeated Measures ANOVA or Friedman tests.

According to Table 3, there was a significant change effect between the preoperative and postoperative periods in each parameter within the Normothermic and Hypothermic groups. Significant changes were observed in the postoperative periods for both groups in parameters such as albumin, AST, CRP, glucose, and sodium ($p<0.001$).

Table 1

Demographic data of the study group

Group	Sex	Age (Year)	height (cm)	weight (kg)	BSA (m^2)
Hypothermic	38 Male+ 26 Female	60.76 ± 9.71	164.33 ± 9.61	73.96 ± 13.71	1.83 ± 0.18
Normothermic	34 Male+ 28 Female	59.73 ± 11.29	164.8 ± 8.74	77.44 ± 15.92	1.87 ± 0.18

BSA: body surface area

Table 2

Mean ± SD values for the normothermic and hypothermic groups according to the pre-bypass, post-bypass and postoperative time periods.

Parameter	Normothermic			Hypothermic			Normothermic	Hypothermic
	Pre-bypass	Post-bypass	Postoperative	Pre-bypass	Post-bypass	Postoperative	p	p
Systolic	63.45±7.24	63.15±5.83	64.57±7.45	62.19±7.94	63.25±6.28	63.56±6.83	p>0.05	p>0.05
Diastolic	54.37±6.21	54.29±5.61	54.89±6.47	53.64±7.65	54.21±6.50	54.20±6.43	p>0.05	p>0.05
Albumin (g/dl)	38.74±7.46	29.51±5.89	32.63±4.33	37.18±6.43	30.19±5.90	32.45±4.33	*p<0.001	*p<0.001
ALT (U/L)	25.92±23.92	25.83±19.95	39.28±51.76	26.12±32.88	26.05±17.26	38.46±47.77	p>0.05	*p=0.003
AST (U/L)	35.08±34.58	42.21±18.21	85.85±142.10	43.75±94.62	48.67±40.51	81.96±115.10	*p<0.001	*p<0.001
BE	0.32±2.70	0.48±2.43	0.07±2.26	0.46±2.55	0.28±2.36	-0.08±2.23	p>0.05	p>0.05
CRP (mg/L)	22.68±44.64	32.10±61.70	104.98±64.92	33.03±53.54	38.68±57.61	120.35±88.37	*p<0.001	*p<0.001
Ca (mg/dL)	8.98±0.68	8.26±0.63	8.01±0.55	9.58±5.98	8.93±5.76	10.97±24.25	*p<0.001	*p<0.001
D.Bil. (mg/dL)	0.54±2.87	0.28±0.48	0.50±0.64	0.56±2.87	0.26±0.25	0.56±0.71	p>0.05	*p<0.001
GGT (U/L)	31.33±26.63	23.75±13.22	30.36±18.23	33.01±28.88	28.89±20.01	33.04±21.92	*p=0.033	p>0.05
Glucose (mg/dL)	151.73±45.53	169.27±47.90	189.09±44.79	145.47±36.41	170.15±39.30	190.33±39.62	*p=0.003	*p<0.001
HCT (%)	23.04±3.63	23.49±3.27	22.97±3.08	21.85±3.09	22.32±2.68	22.24±2.81	p>0.05	p>0.05
K (mEq/L)	4.39±0.44	4.58±0.48	4.33±0.50	4.54±0.52	4.55±0.64	4.46±0.67	*p=0.011	p>0.05
Creatinine (mg/dL)	0.91±0.27	0.99±0.37	1.52±2.83	1.35±1.64	1.19±1.08	1.40±1.19	*p=0.006	p>0.05
Lactate (mmol/L)	1.80±0.98	1.93±1.01	2.13±1.10	1.78±0.83	1.94±0.98	2.22±1.26	*p=0.013	*p=0.022
Na (mmol/L)	139.37±3.46	141.61±3.89	141.80±3.91	137.13±15.80	141.76±4.17	141.73±5.49	*p<0.001	*p<0.001
PCO_2 (mmHg)	37.99±5.10	38.17±4.29	37.52±4.04	35.85±4.13	36.87±2.69	37.99±3.26	p>0.05	*p<0.001
PH	7.42±0.07	7.41±0.06	7.41±0.04	7.44±0.06	7.43±0.06	7.41±0.05	p>0.05	*p=0.005
PO_2 (mmHg)	301.93±71.51	286.63±59.40	303.19±67.84	302.71±62.95	283.73±38.78	301.99±61.23	p>0.05	p>0.05
T.Bil. (mg/dL)	0.63±0.37	0.91±0.79	1.16±1.29	0.64±0.56	0.86±0.60	1.16±1.07	*p=0.003	*p<0.001
Üre (mg/dL)	37.55±11.07	41.91±16.22	46.09±19.20	47.76±27.68	46.44±23.57	48.05±23.94	*p=0.005	p>0.05

ALT: alanine aminotransferase, AST: aspartate aminotransferase, BE: base excess. CRP: C-reactive protein, Ca: calcium, D.Bil.: direct bilirubin, GGT: gamma-glutamyl transferase, HCT: Haematocrit, K: Potassium, Na: Sodium, PCO_2: Partial carbon dioxide pressure, pH: Power of Hydrogen, PO_2: Partial oxygen pressure, T.Bil.: Total bilirubin.

Table 3

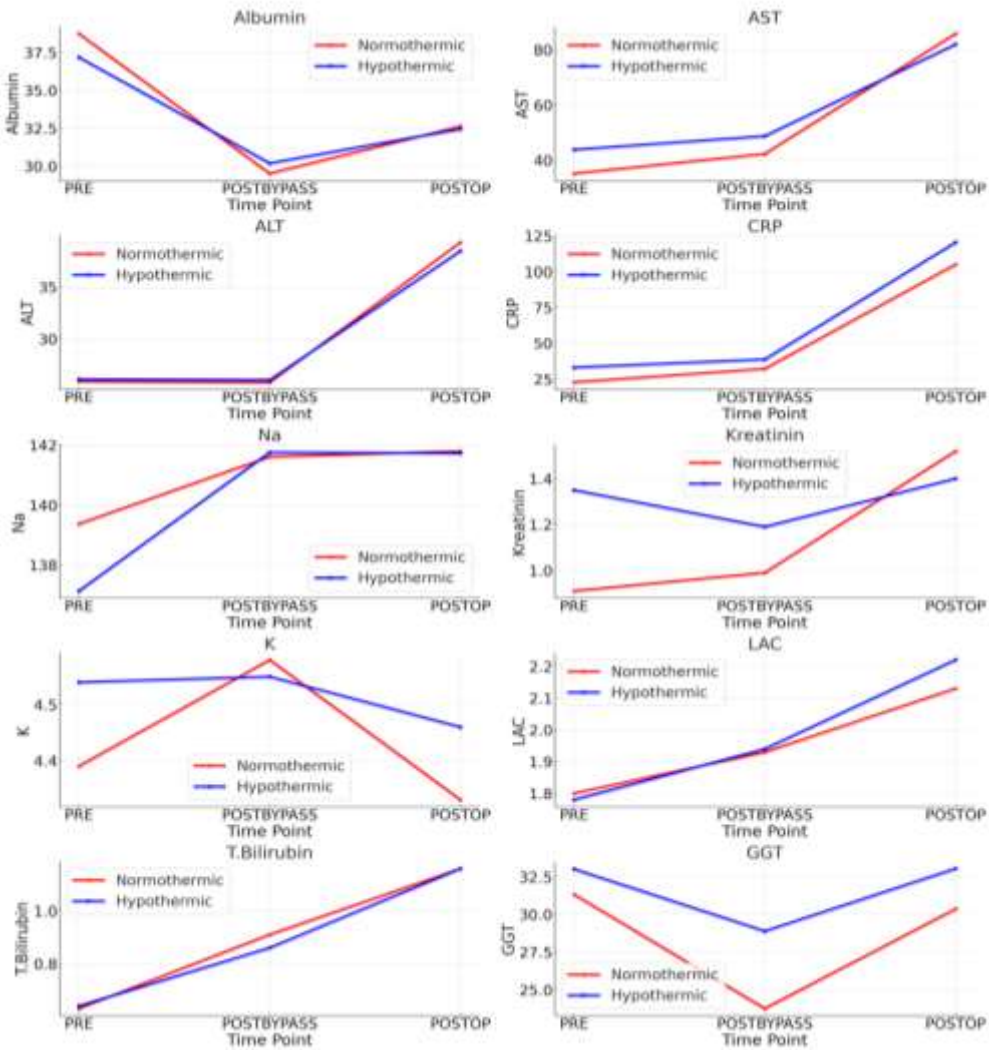
Results of the Time Effect on Clinical Parameters

	Normothermic		Hypothermic	
Parameter	Prebypass vs postbypass	Prebypass vs postoperative	Prebypass vs postbypass	Prebypass vs postoperative
Albumin (g/dl)	* p < 0.001	* p < 0.001	* p < 0.001	* p < 0.001
ALT (U/L)	✕ p = 0.7795	* p = 0.0039	✕ p = 0.1064	* p = 0.0032
AST (U/L)	* p < 0.001	* p < 0.001	* p < 0.001	* p < 0.001
CRP (mg/L)	✕ p = 0.9192	* p < 0.001	✕ p = 0.3210	* p < 0.001
Ca (mg/L)	* p < 0.001	* p < 0.001	* p < 0.001	* p < 0.001
D.Bilirubin (mg/L)	✕ p = 0.4143	* p < 0.001	✕ p = 0.3253	* p < 0.001
GGT (U/L)	* p = 0.0328	✕ p = 0.6572	✕ p = 0.3708	✕ p = 0.6410
Glucose (mg/dL)	* p = 0.0025	* p < 0.001	* p < 0.001	* p < 0.001
K (mEq/L)	* p = 0.0110	✕ p = 0.2547	✕ p = 0.9499	✕ p = 0.1183
Kreatinin (mg/L)	✕ p = 0.5741	* p = 0.0056	✕ p = 0.7042	✕ p = 0.2032
Lactate (mmol/L)	✕ p = 0.2725	* p = 0.0128	✕ p = 0.4227	* p = 0.0221
Na (mmol/L)	* p < 0.001	* p < 0.001	* p < 0.001	* p < 0.001
PCO_2 (mmHg)	✕ p = 0.8234	✕ p = 0.5310	✕ p = 0.0734	* p < 0.001
PH	✕ p = 0.4065	✕ p = 0.3512	✕ p = 0.1603	* p = 0.0048
T.Bilirubin (mg/L)	* p = 0.0026	* p < 0.001	* p < 0.001	* p < 0.001
Urea (mg/dL)	✕ p = 0.1796	* p = 0.0049	✕ p = 0.7968	✕ p = 0.6013

ALT: alanine aminotransferase, AST: aspartate aminotransferase, CRP: C-reactive protein, Ca: calcium, D.Bil.: direct bilirubin, GGT: gamma-glutamyl transferase, K: Potassium, Na: Sodium, PCO_2: Partial carbon dioxide pressure, pH: Power of Hydrogen, T.Bil.: Total bilirubin.

Figure 1

Time-dependent changes in certain clinical and biochemical parameters in the normothermic and hypothermic groups



However, a significant difference was only observed in parameters such as CRP and creatinine during the pre-bypass to post-operative transition. On the other hand, no significant change over time was detected in some parameters such as blood pressure, pO_2, BE, and HCT. Furthermore, some changes, such as pH and PCO_2, were only found to be significant in the hypothermic group. The time-dependent changes in some clinical and biochemical parameters in the normothermic and hypothermic groups are shown in Figure 1.

Figure 1 shows how parameters exhibiting significant changes over time differ between the Normothermic and Hypothermic groups. In particular, a decrease in albumin and an increase in CRP and AST are noteworthy. Among the parameters that decreased over time, albumin and sodium (Na) levels stand out. In contrast, significant increases over time were observed in parameters such as AST, ALT, CRP, creatinine, lactate (LAC), and total bilirubin.

The results of intergroup comparisons of clinical and biochemical parameters measured during the same time period (pre-bypass, post-bypass, postoperative) in normothermic and hypothermic CPB are summarised in Table 4.

No statistically significant difference was detected between the normothermic and hypothermic groups in most parameters ($p>0.05$). However, statistical significance was observed at certain time points for some parameters. Calcium (Ca) levels showed a significant difference between the two groups in the postoperative period ($p=0.039$). The haematocrit (HCT) level was found to be significantly different between the groups only in the post-bypass period ($p=0.0452$). The PCO_2 level showed significant differences between the groups in both the pre-bypass and post-bypass periods ($p=0.0052$ and $p=0.035$). No significant differences were found between the normothermic and hypothermic groups at any time point for all other parameters (e.g., albumin, AST, CRP, glucose, creatinine, lactate, PO_2, systolic and diastolic pressure). The results of multiple comparisons (Tukey HSD test) between the three time periods (Prebypass, Postbypass, Postop) for statistically significant parameters are shown in Table 5.

Different capital letters within the same column (A–C) indicate a significant difference between time points within the group (Normothermic or Hypothermic); lowercase letters within the same row (a–b) indicate a difference between the two groups (Normothermic or Hypothermic) at the same time point ($p < 0.05$). Both the normothermic and hypothermic groups showed a significant postoperative decrease in albumin levels and increases in AST and ALT levels. CRP levels increased significantly over time in both groups. Parameters such as Na, Lactate, Creatinine, and T. Bilirubin also showed an increasing trend over time.

Table 4

Time-Based Normothermic and Hypothermic Group Comparisons

Parameter	Pre-bypass	Post-bypass	Postoperative
Ca (mg/dL)	✕ p = 0.2691	✕ p = 0.6425	* p = 0.0390
HCT (%)	✕ p = 0.0968	* p = 0.0452	✕ p = 0.2165
PCO_2 (mm/hg)	* p = 0.0052	* p = 0.0350	✕ p = 0.7484

Ca: calcium, HCT: Haematocrit, PCO2: Partial carbon dioxide.

Table 5

Post Hoc Analysis (Tukey HSD) for Parameters Showing Time Effect

Parameter	Time	Normothermic	Hypothermic
	Pre-bypass	38.74 ± 7.46C,a	37.18 ± 6.43C,a
Albumin (g/dl)	Post-bypass	29.51 ± 5.89A,a	30.19 ± 5.90A,a
	Postoperative	32.63 ± 4.33B,a	32.45 ± 4.33B,a
	Pre-bypass	25.92 ± 23.92B,a	26.12 ± 32.88B,a
ALT (U/L)	Post-bypass	25.83 ± 19.95A,a	26.05 ± 17.26A,a
	Postoperative	39.28 ± 51.76C,a	38.46 ± 47.77C,a
	Pre-bypass	35.08 ± 34.58A,a	43.75 ± 94.62A,a
AST (U/L)	Post-bypass	42.21 ± 18.21B,a	48.67 ± 40.51B,a
	Postoperative	85.85 ± 142.10C,a	81.96 ± 115.10C,a
	Pre-bypass	0.32 ± 2.70B,a	0.46 ± 2.55C,a
BE	Post-bypass	0.48 ± 2.43C,a	0.28 ± 2.36B,a
	Postoperative	0.07 ± 2.26A,a	-0.08 ± 2.23A,a
	Pre-bypass	22.68 ± 44.64A,a	33.03 ± 53.54A,a
CRP (mg/L)	Post-bypass	32.10 ± 61.70B,a	38.68 ± 57.61B,a
	Postoperative	104.98 ± 64.92C,a	120.35 ± 88.37C,a
	Pre-bypass	8.98 ± 0.68C,a	9.58 ± 5.98B,a
Ca (mg/dL)	Post-bypass	8.26 ± 0.63B,a	8.93 ± 5.76A,a
	Postoperative	8.01 ± 0.55A,a	10.97 ± 24.25C,a
	Pre-bypass	0.54 ± 2.87C,a	0.56 ± 2.87B,a
D.Bilirubin (U/L)	Post-bypass	0.28 ± 0.48A,a	0.26 ± 0.25A,a
	Postoperative	0.50 ± 0.64B,a	0.56 ± 0.71C,a
	Pre-bypass	31.33 ± 26.63C,a	33.01 ± 28.88B,a
GGT (U/L)	Post-bypass	23.75 ± 13.22A,a	28.89 ± 20.01A,a
	Postoperative	30.36 ± 18.23B,a	33.04 ± 21.92C,a
	Pre-bypass	151.73 ± 45.53A,a	145.47 ± 36.41A,a
Glukose (mg/dL)	Post-bypass	169.27 ± 47.90B,a	170.15 ± 39.30B,a
	Postoperative	189.09 ± 44.79C,a	190.33 ± 39.62C,a
	Pre-bypass	4.39 ± 0.44B,a	4.54 ± 0.52B,a
K (mEq/L)	Post-bypass	4.58 ± 0.48C,a	4.55 ± 0.64C,a
	Postoperative	4.33 ± 0.50A,a	4.46 ± 0.67A,a
	Prebypass	0.91 ± 0.27A,b	1.35 ± 1.64B,a
Creatinine (mg/L)	Postbypass	0.99 ± 0.37B,a	1.19 ± 1.08A,a
	Postoperatif	1.52 ± 2.83C,a	1.40 ± 1.19C,a
	Prebypass	1.80 ± 0.98A,a	1.78 ± 0.83A,a
Lactate (mmol/L)	Postbypass	1.93 ± 1.01B,a	1.94 ± 0.98B,a
	Postoperatif	2.13 ± 1.10C,a	2.22 ± 1.26C,a
	Prebypass	139.37 ± 3.46A,a	137.13 ± 15.80A,a
Na (mmol/L)	Postbypass	141.61 ± 3.89B,a	141.76 ± 4.17C,a
	Postoperatif	141.80 ± 3.91C,a	141.73 ± 5.49B,a
	Prebypass	37.99 ± 5.10B,a	35.85 ± 4.13A,b
PCO_2 (mmHg)	Postbypass	38.17 ± 4.29C,a	36.87 ± 2.69B,b
	Postoperatif	37.52 ± 4.04A,a	37.99 ± 3.26C,a
	Prebypass	7.42 ± 0.07C,a	7.44 ± 0.06C,a
PH	Postbypass	7.41 ± 0.06B,a	7.43 ± 0.06B,a
	Postoperatif	7.41 ± 0.04A,a	7.41 ± 0.05A,a
	Prebypass	301.93 ± 71.51B,a	302.71 ± 62.95C,a
PO_2 (mmHg)	Postbypass	286.63 ± 59.40A,a	283.73 ± 38.78A,a
	Postoperatif	303.19 ± 67.84C,a	301.99 ± 61.23B,a
	Prebypass	0.63 ± 0.37A,a	0.64 ± 0.56A,a
T.Bilirubin (U/L)	Postbypass	0.91 ± 0.79B,a	0.86 ± 0.60B,a
	Postoperatif	1.16 ± 1.29C,a	1.16 ± 1.07C,a
	Prebypass	37.55 ± 11.07A,b	47.76 ± 27.68B,a
Urea (mg/dL)	Postbypass	41.91 ± 16.22B,a	46.44 ± 23.57A,a
	Postoperatif	46.09 ± 19.20C,a	48.05 ± 23.94C,a

ALT: alanine aminotransferase, AST: aspartate aminotransferase, BE: base excess. CRP: C-reactive protein, Ca: calcium, D.Bil.: direct bilirubin, GGT: gamma-glutamyl transferase, HCT: Haematocrit, K: Potassium, Na: Sodium, PCO_2: Partial carbon dioxide pressure, pH: Power of Hydrogen, PO_2: Partial oxygen pressure, T.Bil.: Total bilirubin.

BE fluctuated at different time points in both groups, but the values remained within normal limits. Statistically significant differences were found between the normothermic and hypothermic groups in creatinine and urea levels at certain time points. PCO_2 was lower in the hypothermic group during the post-bypass period, while no significant difference was observed in the normothermic group. No significant differences were found between the two groups for most other parameters during the same time period.

4. Discussion

This study evaluated the effects of normothermic and hypothermic cardiopulmonary bypass (CPB) applications on key metabolic and haemodynamic parameters in patients undergoing coronary artery bypass grafting (CABG) surgery. The findings showed that both CPB applications caused statistically significant changes over time, particularly in albumin, ALT, AST, and CRP levels; however, no significant differences were detected between the groups at specific time points. These results suggest that normothermic and hypothermic perfusion strategies have similar effects on metabolic and inflammatory processes during the CPB process.

A significant and consistent decrease in albumin levels was observed at all time points in both groups. This state of hypoalbuminaemia, frequently encountered during and after CPB, is thought to be related to increased capillary permeability, haemodilution, and systemic inflammatory response syndrome (SIRS) resulting from contact between blood and extracorporeal circuit surfaces. [9, 10, 11] Although hypoalbuminaemia can adversely affect oncotic pressure and tissue perfusion, the similar degree of decrease observed in both temperature groups indicates that perfusion temperature does not play a decisive role in this phenomenon.

Significant increases in ALT and AST liver enzyme levels were also observed in the postoperative period, reflecting transient hepatic damage. This elevation in transaminases is thought to be associated with processes such as hepatic hypoperfusion, ischaemia-reperfusion injury, and haemolysis; these mechanisms are often exacerbated by the non-pulsatile flow applied during CPB.[12] Although it has been suggested that hypothermia may alleviate ischaemic damage by reducing metabolic demands, our study found that it did not provide a significant advantage over normothermia in preventing increases in liver enzymes. This finding is consistent with previous studies reporting similar biochemical changes independent of thermal strategy.[13, 14] Indeed, the similarity in the elevation of liver enzymes is consistent with findings in the literature that the thermal strategy during CPB does not significantly affect liver function tests.[15]

Increases in lactate and creatinine levels are interpreted as indicators of hypoperfusion and renal dysfunction.[16] In particular, a significant increase in lactate in the postoperative period may indicate that peripheral tissue perfusion was inadequate during the bypass procedure. At the same time, changes in electrolytes such as Na and K can be explained by both haemodilution and the effect of replacement fluids.[17]

CRP, an acute phase reactant and marker of systemic inflammation, showed a marked increase in both groups after surgery. This finding is consistent with current knowledge regarding the activation of inflammatory cascades triggered by complement system activation, cytokine release, and leukocyte-endothelial interactions during CPB.[18] The absence of a significant difference between the normothermic and hypothermic groups supports the view that inflammation is primarily triggered by extracorporeal circulation itself rather than perfusion temperature. Similarly, it has previously been reported in neonatal and paediatric patient groups that normothermic and hypothermic CPB lead to largely similar effects in terms of inflammatory markers and clinical outcomes.[19] Furthermore, it has been demonstrated that the release of systemic inflammatory mediators is unaffected by mild hypothermia (≈32°C) or normothermia (≈36°C) administered during CPB.[20,21]

Hypothermia has traditionally been the preferred strategy due to its potential to preserve organ function by reducing cellular metabolism; however, increasing evidence in recent years has demonstrated that normothermic CPB is at least as safe and effective as hypothermia, particularly in adult cardiac surgery.[4] The findings of our study are consistent with this literature, demonstrating that hypothermia does not provide a clinically significant advantage over normothermia in terms of inflammatory or metabolic outcomes.

Although time-dependent changes were statistically significant, no significant differences were found between the normothermic and hypothermic groups in most parameters.[7, 22] This indicates that the two different temperature strategies produced similar physiological responses in terms of metabolic and haemodynamic effects. However, the detection of limited but statistically significant differences between groups in certain parameters, such as PCO2 and creatinine, may raise the possibility of individual patient variations or the influence of intraoperative factors.

5. Conclusion

In our study, although significant time-dependent changes were observed in the metabolic and haemodynamic parameters examined in cases undergoing hypothermic and normothermic CPB (e.g. decrease in albumin levels, increase in AST/ALT and CRP levels), these changes were found not to constitute a statistically significant difference between the two groups. The similar course of the measured parameters in both groups suggests that the effects of CPB, such as systemic inflammatory response and haemodilution, developed independently of the applied temperature management. In light of these findings, it is understood that the normothermic cardiopulmonary bypass method does not create a significant disadvantage compared to the hypothermic method in terms of metabolism and haemodynamics and can be applied as safely as the latter. In conclusion, our study demonstrated that hypothermic and normothermic CPB applications did not produce clinically significant differences in the metabolic and haemodynamic parameters evaluated.

Statement of ethics

It was approved by the decision numbered 12 dated 30.06.2025 of the Clinical Research Ethics Committee of Harran University Faculty of Medicine. This study was conducted in accordance with the Declaration of Helsinki, as revised in 1989. All participants were informed in detail about the study's purpose and procedures, and written informed consent was obtained from each participant in accordance with the Declaration of Helsinki.

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest statement
The authors declare that they have no conflict of interest.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions
MP, RD: Study conception and design; study conduction, the analysis and interpretation of the results; first draft of the manuscript, and all authors edited, reviewed, and approved the final version of the manuscript. MP, RD: First draft of the manuscript, and all authors edited, reviewed, and approved the final version of the manuscript. MJM: Study conception and design; final version of the manuscript revision, with important contributions to the discussion.

References
1.Ralapanawa U, & Sivakanesan, R. Epidemiology and the Magnitude of Coronary Artery Disease and Acute Coronary Syndrome: A Narrative Review. Journal of Epidemiology and Global Health, 2021;11:169 - 177. [Crossref]
2.Hendriks KDW, Castela Forte JN, Kok WF, Mungroop HE, Bouma HR, Scheeren TWL, et al. Mild hypothermia during cardiopulmonary bypass assisted CABG is associated with improved short- and long-term survival, a 18-year cohort study. PLoS One. 2022; 25;17(8):e0273370. [Crossref]
3.Stern M, Kok WF, Doorduin J, Jongman RM, Jainandunsing J, Nieuwenhuijs-Moeke GJ, et al. Mild and deep hypothermia differentially affect cerebral neuroinflammatory and cold shock response following cardiopulmonary bypass in rat. Brain Behav Immun. 2024;119:96-104. [Crossref]
4.Amer GF, Elawady MS, ElDerie A, Sanad M. Normothermia versus Hypothermia during Cardiopulmonary Bypass in Cases of Repair of Atrioventricular Septal Defect. Anesth Essays Res. 2020;14(1):112-118. [Crossref]
5.Bianco V, Kilic A, Aranda-Michel E, Dunn-Lewis C, Serna-Gallegos D, Chen S, et al. Mild hypothermia versus normothermia in patients undergoing cardiac surgery. JTCVS Open. 2021 (17);7:230-242. [Crossref]
6.Helman SM, Sereika S, Hravnak M, Henker R, Gaynor JW, Herrup E, et al. Association Between Persistent Hypothermia After Cardiopulmonary Bypass in Neonates and Odds of Serious Complications. Crit Care Explor. 2024;20;6(8):e1137. [Crossref]
7.Keizman E, Mishaly D, Ram E, Urtaev S, Tejman-Yarden S, Tirosh Wagner T, et al. Normothermic Versus Hypothermic Norwood Procedure. World J Pediatr Congenit Heart Surg. 2023;14(2):125-132. [Crossref]
8.Dankiewicz J, Cronberg T, Lilja G, Jakobsen JC, Levin H, Ullén S, et al. TTM2 Trial Investigators. Hypothermia versus Normothermia after Out-of-Hospital Cardiac Arrest. N Engl J Med. 2021;17;384(24):2283-2294.
9.Enayet K, Hussain M, Islam M, Karim T, Jahan T, Das P, et al. Serum Albumin and Its Influence on Immediate Outcomes in Children with Congenital Heart Disease Undergoing Cardiac Surgery. Bangladesh Heart Journal. 2024;75794. [Crossref]
10.Karki S, Gajjar R, Bittar-Carlini G, Jha V, Yadav N. Association of Hypoalbuminemia With Clinical Outcomes in Patients Admitted With Acute Heart Failure. Curr Probl Cardiol. 2023;48(11):101916. [Crossref]
11.Martin KR, Gamell C, Tai TY, Bonelli R, Hansen J, Tatoulis J, et al. Whole blood transcriptomics reveals granulocyte colony-stimulating factor as a mediator of cardiopulmonary bypass-induced systemic inflammatory response syndrome. Clin Transl Immunology. 2024;19;13(2):e1490. [Crossref]
12.Reddy D, Sunitha Y, Thangavel D, Ramkumar J & Miller, S. Effects of cardiopulmonary bypass on liver function in patients undergoing cardiac surgery. CARDIOMETRY. [Crossref]
13.Kumar R, Bansal M, Nath SS, Kumar V, Malviya D, Srivastava D. N-Acetylcysteine Supplementation for the Prevention of Postoperative Liver Dysfunction after On-Pump Cardiac Surgery. Turk J Anaesthesiol Reanim. 2021;49(6):460-469. [Crossref]
14.Zakkar M, Amirak E & Bryan AJ. The effects of cardiopulmonary bypass on the liver: a review. Eur J Cardiothorac Surg, 2014;45(4): 661-667.
15.Sabzi F, Faraji R. Liver Function Tests Following Open Cardiac Surgery. J Cardiovasc Thorac Res. 2015;7(2):49-54. [Crossref]
16.Deininger S, Hoenicka M, Müller-Eising K, Rupp P, Liebold A, Koenig W, et al. Renal Function and Urinary Biomarkers in Cardiac Bypass Surgery: A Prospective Randomized Trial Comparing Three Surgical Techniques. Thorac Cardiovasc Surg. 2016;64(7):561-568. [Crossref]
17.Leong XF, Cheng M, Jong B, Hwang NC, Roscoe A. Sodium Abnormalities in Cardiac Surgery With Cardiopulmonary Bypass in Adults: A Narrative Review. J Cardiothorac Vasc Anesth. 2021;35(11):3374-3384. [Crossref]
18.He Y, Liu S, Luo Y, Wu H, Yu Y & Chen, H. Elevation of C-reactive protein early after cardiopulmonary bypass surgery is associated with occurrence of postoperative atrial fibrillation. Nan fang yi ke da xue xue bao = Journal of Southern Medical University, 2022;42 (3): 443-447.
19.Milam AJ, Liang C, Mi J, Mascha EJ, Halvorson S, Yan M, et al. Derivation and Validation of Clinical Phenotypes of the Cardiopulmonary Bypass-Induced Inflammatory Response. Anesth Analg. 2023;1;136(3):507-517. [Crossref]
20.Li S, Nordick KV, Murrieta-Álvarez I, Kirby RP, Bhattacharya R, Garcia I, et al. Prolonged Cardiopulmonary Bypass Time-Induced Endothelial Dysfunction via Glypican-1 Shedding, Inflammation, and Matrix Metalloproteinase 9 in Patients Undergoing Cardiac Surgery. Biomedicines. 2024;27;13(1):33. [Crossref]
21.Ghasemzade B, Ghodrati M, Kachuian N, Banakar Y, Gorjipour F, Zarei A, & Zaree, H. Fibrinogen and Fibrin Degradation Products' Levels in Cardiopulmonary Bypass with Mild-Hypothermia versus Normothermia. 2020;V5I3.30324.
22.Linassi F, Maran E, De Laurenzis A, Tellaroli P, Kreuzer M, Schneider G, et al. Targeted temperature management in cardiac surgery: a systematic review and meta-analysis on postoperative cognitive outcomes. Br J Anaesth. 2022;128(1):11-25. [Crossref]