Temperature management of intraoperative cardiopulmonary bypass in valve replacement surgery: a retrospective analysis of the impact on postoperative organ function

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Abstract. – OBJECTIVE: **This study aimed to systematically analyze the effects of cardiopulmonary bypass (CPB) at different temperatures on the function of different organs in patients after heart valve replacement and to investigate its safety and feasibility.**

PATIENTS AND METHODS: The data of 275 heart valve replacement surgery patients who underwent static suction compound anesthesia under CPB between February 2018 and October 2019 were retrospectively analyzed and divided into normothermic CPB anesthesia group (group 0), shallow hypothermic CPB anesthesia group (group 1), medium hypothermic CPB anesthesia group (group 2), and deep hypothermic CPB anesthesia group (group 3) according to the different intraoperative CPB temperatures. The basic preoperative conditions, cardiac resuscitation, number of defibrillations, postoperative ICU stay, postoperative hospital stay, and postoperative evaluation of different organ functions, such as heart, lung, and kidney functions, were analyzed and studied in each group.

RESULTS: The comparison of preoperative and postoperative pulmonary artery pressure and left ventricular internal diameter (LVD) was statistically significant in each group (*p* < 0.05), the postoperative pulmonary artery pressure was statistically significant in group 0 compared with groups 1 and 2 (*p* < 0.05), and the postoperative LVD between groups 1 and 2 were statistically significant (*p* < 0.05). The preoperative glomerular filtration rate (eGFR) and the eGFR on the first postoperative day were statistically significant in all the groups (*p* < 0.05), and the eGFR on the first postoperative day in groups 1 and 2 were statistically significant (*p* < 0.05).

CONCLUSIONS: The control of appropriate temperature during CPB was associated with the recovery of organ function in patients after valve replacement. Intravenous compound general anesthesia with superficial hypothermic CPB might be more beneficial in recovering cardiac, pulmonary, and renal functions.

Key Words:
Heart valve replacement, Cardiopulmonary bypass, Temperature, Cardiopulmonary function, Renal function.

Introduction

Heart valve disease (HVD) is a common cardiac surgical condition characterized by damage to the anatomical structure or physiological function of the valves[1]. As life expectancy increases and the population ages, the incidence of HVD increases[2-4]. Cardiac valve replacement (CVR) with cardiopulmonary bypass (CPB) is one of the most common types of heart valve surgery. Temperature management of the cardiopulmonary bypass during cardiac surgery

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may have different effects on the patient's postoperative organs and plays an important role in both perioperative management and the long-term prognosis of the patient.

Hypothermia has been used in cardiac surgery to reduce metabolic rates and oxygen requirements during cardiopulmonary bypass, protect the brain, heart, and other organs, and improve patient tolerance to ischemic episodes. In addition, a low temperature facilitates the inhibition of free radicals, inhibits destructive enzymatic reactions, inhibits biosynthesis, and affects the release and uptake of excitatory neurotransmitters in the body[5-9]. CPB is a non-physiological body cycle that may adversely affect the patient's neurological and urinary systems because of ischemic and reperfusion injury, hypothermic and deep hypothermic arrest cycles, inflammatory and immune responses, and non-pulsatile perfusion factors, and may even produce serious cardiopulmonary complications[10]. Moreover, the perfusion of organs under hypothermia during the CPB phase may affect the assessment of the depth of anesthesia, leading to under- or over-dosing of opioids and increased postoperative pain. The longer exposure of organs to higher temperatures (T > 37°C) during the rewarming of CPB may also exacerbate the impairment of organ function in patients after surgery[11]. In particular, the brain's autoregulatory mechanisms may not be able to cope with the sudden increase in metabolic activity during a temperature rise, leading to an imbalance in the oxygen supply and demand in the areas of cerebral ischemia, resulting in other complications, such as delayed awakening[12]. In addition, lower temperatures can lead to higher lactate levels and decreased immune defenses, increasing the incidence of adverse events. Therefore, strict intraoperative temperature control is very testing for anesthesiologists, and maintaining the optimal temperature intraoperatively poses a considerable challenge for us.

The use of CPB for heart valve replacement surgery at the most appropriate body temperature may provide a new reference and a new means for the clinical development of heart valve replacement surgery. This study retrospectively analyzed and compared the effects of different CPB temperatures on the cardiac, pulmonary, and renal functions in patients after heart valve replacement, intending to determine the feasibility and safety of optimal CPB temperature during heart valve replacement.

Patients and Methods

This retrospective study was approved by the Institutional Review Board of the First Affiliated Hospital of Anhui Medical University (IRB number: PJ-2022-021-528). This Institutional Review Board waived the requirement for written informed consent because the data were anonymous, and the study did not involve patient privacy or treatment. All experimental procedures and methods were performed in accordance with relevant guidelines and regulations (Declaration of Helsinki).

Patients

Totally, 275 patients who underwent CPB heart valve replacement surgery in the First Affiliated Hospital of Anhui Medical University between February 2018 and October 2019 were selected for the study. According to the different temperatures during intraoperative CPB, they were divided into the static inhalation compound anesthesia normothermia group (group 0), static inhalation compound shallow hypothermia CPB anesthesia group (group 1), static inhalation compound medium hypothermia CPB anesthesia group (group 2), and static inhalation compound deep hypothermia stopped circulation CPB anesthesia group (group 3).

Inclusion and Exclusion Criteria

Inclusion criteria: patients who underwent cardiac valve replacement surgery with CPB under static suction compound general anesthesia.

Exclusion criteria: (1) previous history of coronary heart disease; (2) concomitant COPD, diabetes mellitus, and/or heart failure; (3) preoperative renal insufficiency, cerebrovascular disease, and/or immune dysfunction; (4) contraindication to surgery; (5) previous history of psychiatric disease; (6) incomplete clinical data; (7) combined with other procedures, such as simultaneous application of coronary artery bypass grafting; (8) another surgery within 90 days before surgery; and (9) history of drug allergy.

Anesthesia Method

Throughout the anesthesia process, all the patients were uniformly managed according to the same anesthesia management. Patients were admitted to the room 30 min before the induction of anesthesia, connected to cardiac monitoring, and opened to intravenous access. Sedation with midazolam was performed, and radial artery puncture placement was performed under local anesthesia. Tracheal intubation and esophageal ultrasound placement were performed after induction of anesthesia, followed by right internal jugular vein puncture placement and monitoring of invasive arterial blood pressure and central venous pressure. After the induction of anesthesia, an esophageal temperature probe was placed in the patient's esophagus to monitor and control the body temperature throughout.

(1) Anesthesia induction: all the groups were slowly administered an intravenous injection of etomidate 0.3 mg/kg, vecuronium 0.1-0.2 mg/kg, and sufentanil 1 μg/kg; after 3-5 min, the trachea was intubated and connected to the anesthesia machine for mechanical ventilation, in which the oxygen inhalation concentration was maintained at 60%-80%, the RR was maintained at 10-12 times/min, the flow rate was controlled at 2 L/min, $PetCO_2$ was maintained at 35-45 mmHg, and the respiratory ratio was controlled at 1:2.

(2) Anesthesia maintenance: propofol, sufentanil, and vecuronium were pumped intravenously for maintenance, and sevoflurane was inhaled at a concentration of 1%-2% (inhaled anesthetics were stopped during CPB, and intravenous anesthetics were maintained). The perfusion flow of CPB had to meet the requirements of tissue metabolism, and the mean arterial pressure had to be above 55 mmHg. The patient's vital signs were closely observed during the operation. The surgeons routinely opened the chest, exposed the heart, injected 400 IU/kg of heparin in the patient's right neck by intravenous injection, performed arterial and vena cava placement at ACT 280 s, started CPB at 480 s, and performed blood flow cooling after the start of diversion. The temperature during CPB was divided into normal temperature (34-36°C), shallow low temperature (30-34°C), middle low temperature (28-30°C), and deep low temperature (below 20°C). After aortic opening, 3-10 μg/kg dopamine was routinely applied to control SBP at 90-120 mmHg and heart rate at about 80 beats / min to maintain hemodynamic stability, water, electrolytes and blood sugar. After surgery, the patient was routinely reheated and transferred to CCU for further observation. All the surgical operations were managed by the same team of cardiac surgeons and CPB, anesthesia, and postoperative CCU doctors who worked well together.

Observation Indices

The main observation indices were the patients' postoperative cardiopulmonary function evaluation indices (cardiac ejection fraction LVEF, left ventricular internal diameter LVD, and pulmonary artery pressure) and renal function evaluation indicators (urea nitrogen BUN, creatinine CRE, and glomerular filtration rate eGFR) on the first postoperative days.

The secondary observation indices were the intraoperative cardiac resuscitation time, the number of defibrillations, postoperative ICU stay, and postoperative hospitalization days.

Statistical Analysis

The SPSS 26.0 software was used for the statistical analysis (IBM Corp., Armonk, NY, USA). The measurement data were expressed as medians (interquartile range), and the categorical data were expressed as instances (%). Furthermore, the χ^2 test was used for the comparison between groups. An independent samples *t*-test was used for comparing data between two groups, and a paired *t*-test was used for the intra-group comparison before and after the treatment. Next, a one-way ANOVA and an LSD post-test were used to compare multiple groups. The GraphPad Prism 8.0 software was used to plot the different curves (LaJolla, CA, USA). Differences were considered statistically significant at $p < 0.05$.

Results

The study included 275 patients with valve surgery, who were divided into four groups according to the temperature of CPB, and there was no statistically significant difference in the clinical baseline data of each group ($p > 0.05$), as displayed in Table I.

Comparison of Basic Postoperative Conditions

All the patients were successfully discharged from CPB, and all the hearts resumed beating after aortic opening. Moreover, no complications related to CPB, and anesthesia occurred. The intraoperative cardiac resuscitation time, number of defibrillations, postoperative ICU stay, and postoperative hospitalization days were all indicators with no statistically significant difference ($p > 0.05$), as illustrated in Table II.

Assessment of Cardiopulmonary Function

No statistically significant differences were observed in the preoperative pulmonary artery pressure, LVEF, and LVD between the groups of patients ($p > 0.05$). The preoperative and postop-

Table I. Baseline and perioperative data of four groups.

	Group 0 (n=23)	Group 1 (n=195)	Group 2 (n=56)	Group 3 (n=1)	*p*-value
Female	7(30.0%)	109 (55.9%)	26 (46.4%)	1 (100%)	0.064
Age, yrs	56.6 (52.3,63.7)	55.1 (49.7,63.3)	57.4 (52.1,65.4)	64.0	0.100
Height, cm	165.2 (159.0,170.4)	162.6 (158.7,169.2)	164.3 (158.9,170.1)	152.0	0.652
Weight, kg	60.8 (56.3,64.2)	60.4 (52.0,68.2)	61.7 (53.5,68.7)	50.0	0.525
BMI	22.8 (21.1,24.5)	22.7 (20.0,25.0)	22.2 (20.4,24.1)	21.4	0.753
NYHA, median	3	3	3	4	0.646
ASA, median	4	4	4	4	0.090
Smoking (n)					
Yes	1	11	3	0	0.967
No	22	184	53	1	

Values are median (interquartile range); BMI, Body Mass Index; NYHA, New York Heart Association Class; ASA, American Society of Anesthesiologists.

Table II. Comparison of the basic post-operative conditions of four groups (mean).

	Group 0 (n=23)	Group 1 (n=195)	Group 2 (n=56)	Group 3 (n=1)	*p*-value
Resumption time, min	5.6	4.4	4.6	3	0.326
Number of defibrillations, median	0	0	0	0	0.146
postoperative ICU stay, d	3.78	3.28	3.30	6	0.853
Postoperative hospital days, d	15.60	18.28	16.98	20	0.551

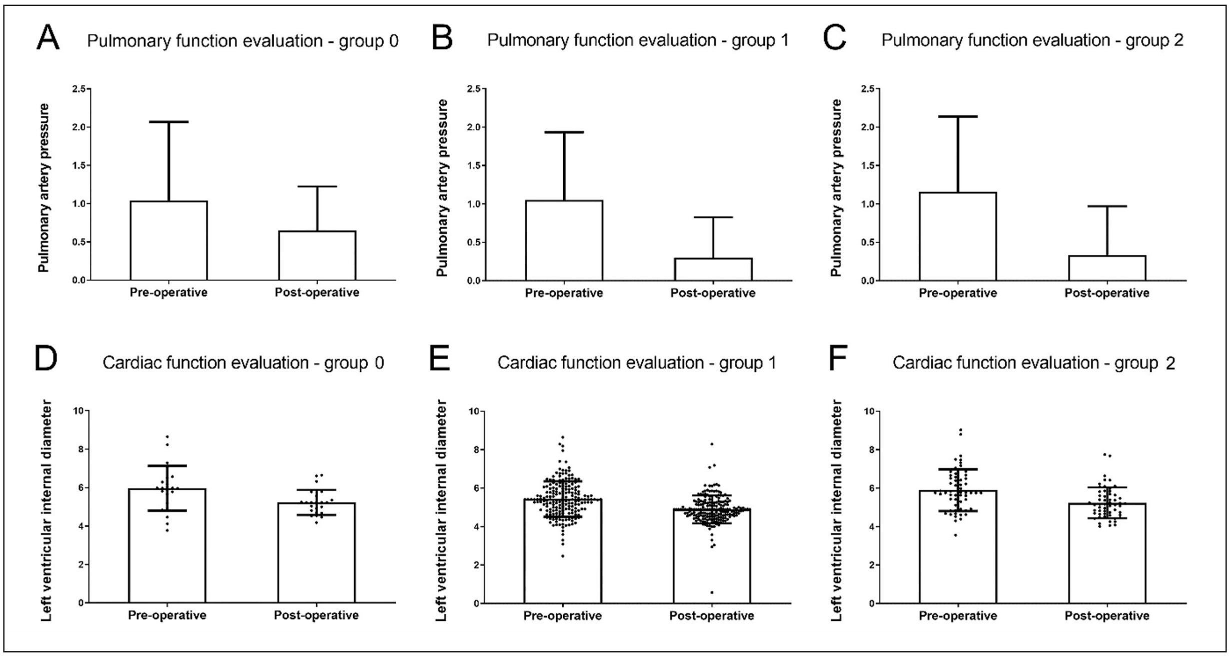

Figure 1. The horizontal coordinates of the graph represent preoperative and postoperative, and the vertical coordinates of the **A-C**, graphs represent the different grades of pulmonary artery pressure, with 0 representing normal pulmonary artery pressure, 1 representing mild pulmonary hypertension, 2 representing moderate pulmonary hypertension, and 3 representing severe pulmonary hypertension, with statistically significant differences between the preoperative and the postoperative pulmonary artery pressure in each group ($p < 0.05$). The vertical coordinates of the **D-F**, plots represent the left ventricular internal diameter (LVD), which was statistically significantly different in each group of patients before and after surgery ($p < 0.05$).

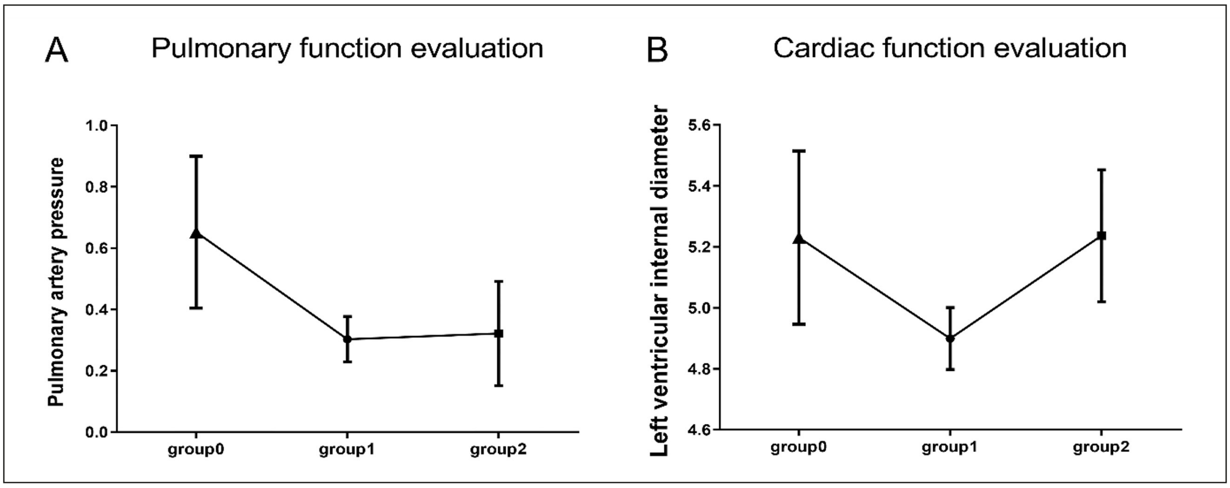

Figure 2. Horizontal coordinates represent the groups, and the vertical coordinates of figure **A**, represent the different grades of pulmonary artery pressure. The difference between the postoperative pulmonary artery pressure of patients in group 0 and those in groups 1 and 2 was statistically significant ($p < 0.05$), and the pulmonary artery pressure of patients in group 1 was more advantageous. The vertical coordinate of the figure **B**, represents the left ventricular internal diameter (LVD), and a statistically significant difference in LVD was observed between patients in groups 1 and 2 ($p < 0.05$).

erative pulmonary artery pressure (Figures 1A, B, and C) and LVD (Figures 1D, E, and F) of the patients in each group were statistically significant ($p < 0.05$); the postoperative pulmonary artery pressure of patients in group 0 was statistically different from that of patients in groups 1 and 2 ($p < 0.05$), and the patients in group 1 had more advantageous pulmonary artery pressure, as revealed in Figure 2A. A statistically significant difference ($p < 0.05$) in the LVD of patients in groups 1 and 2 was observed, as depicted in Figure 2B.

Assessment of Renal Function

Serum Cr and BUN were within the normal range at each time point in each group, and no statistically significant changes were observed before and after CPB. There was a statistically significant difference between the preoperative glomerular filtration rate (eGFR) and the glomerular filtration rate on the first postoperative day in each group ($p < 0.05$), as displayed in Figure 3. Meanwhile, a statistically significant difference between the glomerular filtration rate (eGFR) on the first postoperative day was observed in groups 1 and 2 ($p < 0.05$), as illustrated in Figure 4.

Special Patients

According to the inclusion and exclusion criteria of patients in the retrospective data, only one patient was anesthetized by static inhalation compounded with deep hypothermic stopped circulation CPB, so the data of this patient's group were not analyzed and compared with those of the other three groups.

Discussion

The most appropriate temperature for CPB during cardiac surgery is still controversial. In clinical practice, hypothermia has been used in cardiac surgery, which protects organ function through mechanisms related to the reduction of metabolic rate, blocking the release of glutamate, reducing the inward calcium flow, accelerating the recovery of protein synthesis, reducing the formation of reactive oxygen species, increasing the tolerance of the brain to an insufficient oxygen supply, or regulating the expression of inflammatory factors[3,6,7,13,14]. CPB temperatures at moderate and deep hypothermia can cause platelet dysfunction and inhibition of activated coagulation factors, causing coagulation in the organism; however, patients receiving shallow hypothermic CPB exhibited the greatest fibrinolytic activity, and antifibrinolytic drugs could prevent the coagulation dysfunction caused by hypothermia and avoid the adverse effects of platelet aggregation[15,16].

This is the largest sample size report to date on the effects of temperature selection for CPB on the postoperative organs of patients undergo-

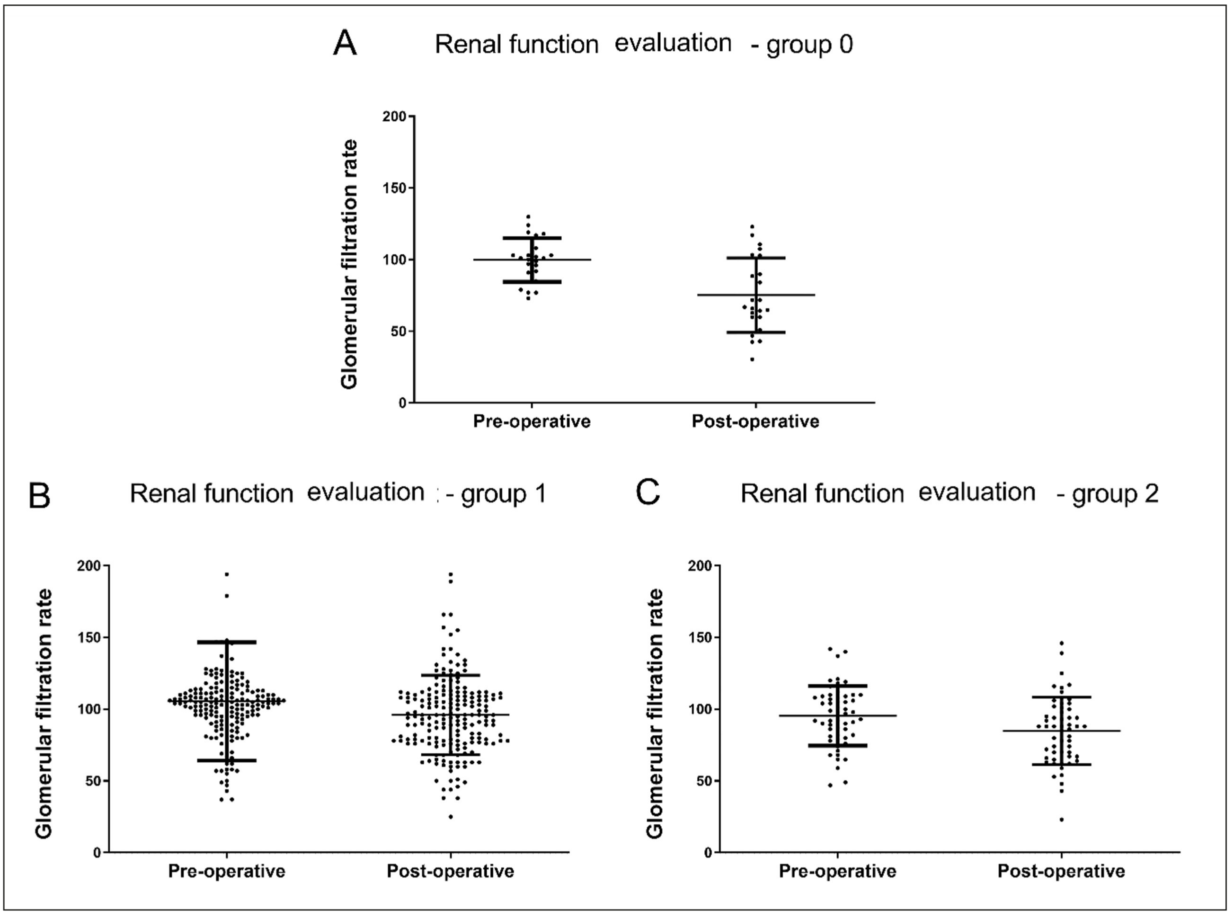

Figure 3. The horizontal coordinates of the graph represent preoperative and postoperative, and the vertical coordinates represent the glomerular filtration rate. The preoperative glomerular filtration rate (eGFR) and the first-day postoperative glomerular filtration rate were statistically significantly different in each group ($p < 0.05$). Figure (**A**) shows the results for the normothermic CPB anesthesia group (group 0), (**B**) shows the results for the shallow hypothermic CPB anesthesia group (group 1), and (**C**) shows the results for the medium hypothermic CPB anesthesia group (group 2).

ing valve replacement. The results of this study suggested that the choice of CPB temperature for heart valve surgery affected the individual organ function after surgery.

No statistically significant differences in the preoperative baseline levels were observed in all the patients, and the postoperative pulmonary artery pressure and left ventricular internal diameter (LVD) were significantly improved in all the groups compared with the preoperative levels. The difference in the choice of CPB temperature resulted in a more significant decrease in the postoperative pulmonary artery pressure in patients in the superficial and moderate hypothermic CPB anesthesia groups than in patients in the normothermic anesthesia group. Postoperative LVD was closer to the normal range in the patients of the superficial hypothermic CPB anesthesia group than in those in the moderate hypothermic CPB anesthesia group, and the data from both groups suggested that shallow hypothermia was more conducive to the recovery of cardiopulmonary function. After heart valve replacement surgery, patients might experience a temporary decrease in renal function because of hemodilution or altered coagulation. Patients who received shallow hypothermia experienced an improvement in the decline in renal function, particularly the glomerular filtration rate (eGFR), compared with those who received normothermia and moderate hypothermia. Therefore, the intraoperative use of shallow hypothermic CPB with static suction compound anesthesia might be more effective in recovering cardiac, pulmonary, and renal functions in patients after surgery.

Adequate myocardial protection during cardiac surgery under CPB is essential for successful clinical outcomes. Doppler echocardiography

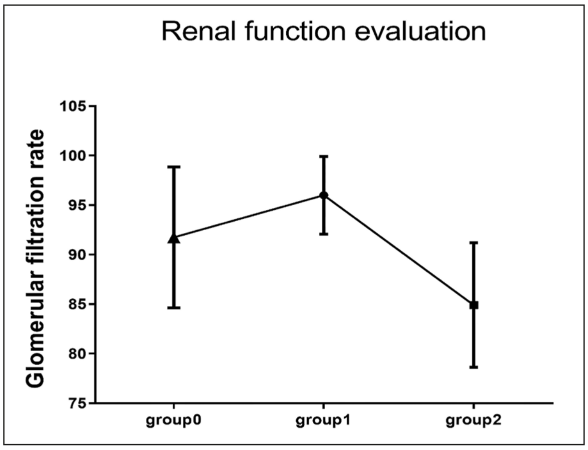

Figure 4. Horizontal coordinates represent the groups, and the vertical coordinates represent the glomerular filtration rate. There was a statistically significant difference in the glomerular filtration rate (eGFR) between groups 1 and 2 on the first postoperative day ($p < 0.05$), and group 1 (static suction combined with shallow hypothermic CPB anesthesia group) demonstrated its superiority.

provides accurate, non-invasive measurement of valve hemodynamics for clinical management[17-19]. Hypothermia may reduce myocardial ischemia-reperfusion injury through several mechanisms, including preserving energy reserves, inhibiting endothelial cell E-selectin expression, and altering mitochondrial function[20,21]. In addition, the cardioprotective properties of hypothermia may be attributed to the expression of heat shock proteins in the myocardium[22] and the increased levels of anti-inflammatory cytokines[23]. Systemic hypothermia may attenuate organ damage, including myocardium, because of the lower plasma and myocardial tumor necrosis factor-α concentrations[24,25]. Although many experimental studies[20-23] have demonstrated a clear cardioprotective effect of hypothermia, the results of clinical studies[24-26] suggest otherwise. Birdi et al[24] reported that in low-risk patients undergoing coronary artery bypass grafting, the use of hypothermic perfusion did not provide additional cardioprotection. Moreover, hypothermic CPB increases apoptosis in patients with aortic valve lesions[26]. It has been depicted that the heart rate increases at the end of CPB in patients in both the hypothermic and the normothermic groups, with a greater increase in the hypothermic group. Although the plasma levels of catecholamines are lower during hypothermic CPB, systemic vascular resistance (SVR) is higher; this difference may be attributed to the increased blood viscosity during hypothermic CPB. Left ventricular ejection fraction (LVEF) is the most effective and commonly used echocardiographic measure of cardiac systolic function, and LVD, or left ventricular internal diameter, is the primary measure of the end-diastolic internal diameter of the left ventricle. Both are key assessment indicators of postoperative cardiac function and are important for the postoperative risk assessment and follow-up of cardiac patients[27]. In general, a smaller left ventricular end diastolic (LVD) internal diameter is associated with a higher ejection fraction and represents improved cardiac function. Interestingly, however, LVEF, an important index for evaluating the patients' LV function, was not found to be significantly different preoperatively and postoperatively in this study, whereas LVD, which has a consistent correlation with LVEF, showed statistically significant differences preoperatively and postoperatively, which may be related to the timing and sequence of improvement in the cardiac function after LVD and LVEF, and needs to be further investigated.

The pathogenesis of pulmonary dysfunction after cardiac surgery is generally considered to be multifactorial[28], and the activation and isolation of neutrophils are usually one of the main causes of pulmonary dysfunction after CPB[29]. Unfortunately, the study lacked data on the inflammatory response in patients with valvular heart disease during normothermic and hypothermic CPB[30]. It has been demonstrated that the degree of depletion of pulmonary surface-active substances after CPB is statistically correlated with the degree of deterioration of pulmonary function[31]. Numerous experimental studies[32,33] have demonstrated that hypothermia protects adult animals from acute lung injury caused by endotoxin exposure. The use of echocardiography to estimate pulmonary artery pressure as an indirect reflection of lung function is one of the current, reliable modalities. Pulmonary arterial hypertension (PAH) is a progressive disease with complex pathophysiological mechanisms[34]. Elevated pulmonary artery pressure is strongly associated with poor patient prognosis, and even mildly elevated pulmonary artery pressure is associated with increased mortality in patients[35-37]. Therefore, it is crucial to improve postoperative pulmonary hypertension in patients undergoing cardiac surgery. In this study, we demonstrated that the postoperative pulmonary artery pressure in the shallow hypothermic CPB anesthesia group and the medium hypothermic CPB anesthesia group was more favorable for the patient's pulmonary function recovery than that in the patients of the normothermic anesthesia group, and the change in the pulmonary artery pressure was more pronounced in patients with shallow hypothermic CPB anesthesia, suggesting that shallow hypothermic CPB anesthesia might be more effective in restoring the patients' postoperative cardiopulmonary circulation.

Accurate measurement of glomerular filtration rate (GFR) is an important component of assessing renal function and is a dynamic indicator that helps to make an early diagnosis of renal insufficiency and guide treatment. Renal insufficiency after cardiac surgery is a major factor contributing to the poor long-term prognosis of patients, and even moderate renal insufficiency can lead to a more complicated postoperative course, longer hospital stays and increased long-term mortality[38-42]. The risk of renal insufficiency is higher after valve replacement surgery, aortic surgery, and combined procedures than after coronary artery bypass grafting (CABG) alone[43-45]. The deterioration of the renal excretory function, i.e., a decrease in the glomerular filtration rate (GFR), leads to the retention of nitrogen metabolic waste products, which increases the detected serum creatinine concentration. As renal autoregulation does not function during hypothermic non-pulsatile blood flow, the hemodilution of the CPB decreases the capillary viscosity and the capillary density, thus redistributing the blood from the cortex to the medulla of the kidney. As the physiology of the renal medulla makes it a hypoxic environment, this part of the kidney appears to be especially at risk for hypoxic damage caused by a hemodilution-induced lowered oxygen transport and oxygen delivery[46]. In addition, Ramkumar et al[47] demonstrated that CPB with moderate hypothermia for valvular heart surgeries can be performed safely in patients with adequate renal functional reserve. Therefore, in order to minimize the impact of CPB temperature changes on renal function and to reduce metabolic and hypoxic injury, reasonable measures include lowering body temperature to reduce the metabolic rate, increasing the patient's GFR to prevent renal insufficiency and avoiding hypoxic injury caused by hypothermia.

Hypothermia in CPB is associated with several deleterious physiological effects, such as impaired coagulation, cerebral blood flow autoregulation, prolonged CPB time[48], the leftward shift of the oxyhemoglobin dissociation curve, and induction of the inflammatory response[49], which adversely affect the recovery of the organism. Hypothermia leads to significantly impaired coagulation, reducing the enzyme volume and enzyme activity, while increased intraoperative blood loss reduces the amount of coagulation factors in the blood, further aggravating the degree of blood loss and affecting the recovery of postoperative organ function. A systematic evaluation of major surgical cases revealed that even mild hypothermia (<1°C) significantly increased blood loss by 16% and the relative risk of transfusion by 22%, thereby increasing the incidence of postoperative complications in patients[50]. In addition, hypothermia has been associated with developing emotional distress in patients after surgery, which is particularly harmful to depressed patients[51]. The results of studies[52] in laboratory settings have depicted that hypothermia can stimulate neuronal death. For perioperative anesthetic management, hypothermia decreases the clearance of opioids and propofol. Under CPB conditions, even a 2°C temperature change may enhance the effect of inotropic drugs and double the duration of action of vecuronium bromide. In addition, low temperature increases the solubility of the inhaled anesthetics, thereby prolonging their duration of action[53,54]. A study published by Insler et al[55] revealed that hypothermic CPB is associated with higher in-hospital mortality and higher rates of intraoperative or postoperative use of intra-aortic balloon pumps. However, Nathan et al[56] performed a randomized trial in which they observed no statistically significant differences between hypothermia and normothermia throughout the intraoperative phase of CPB cardiac surgery concerning the use of blood products, intubation time, length of hospital stays, and incidence of myocardial infarction in patients. Interestingly, in this study, the hypothermia group (mean: 3.3 days) spent a mean of 12 h less in the intensive care unit as compared to the normothermia group (mean: 3.8 days), which, even though not constituting a statistically significant difference, suggests, to some extent, a trend that shallow hypothermia may be more beneficial for patients' postoperative organ function recovery, with more findings to be further investigated.

Limitations

Although the study has encouraging results, it still has the following limitations. First, this study was a retrospective analysis based on the available data, and the number of cases and organ function-related evaluation indices need to be further improved; second, hypothermic CPB affects all systems of the body to varyious degrees, and this study did not address the effects on the brain, liver, infection, and coagulation; third, all the patients might experience an effect on the postoperative organ function depending on the amount of fluids administered. Third, the difference in the intraoperative fluid intake and output in all the patients might affect the postoperative organ function recovery. However, we followed a uniform standard of anesthesia and fluid management for regulation, and we believe that our results are sufficiently accurate to assess the differences between the different temperatures of CPB. Fourth, this study excluded patients with previous cardiopulmonary and renal dysfunction and cerebral-psychiatric lesions. Therefore, the benefits and risks of CPB temperature selection may not be extrapolated to these patients.

Conclusions

The temperature of CPB was related to the recovery of each organ function in patients after valve replacement, and the use of intravenous complex general anesthesia with shallow hypothermic CPB was more favorable to the recovery of cardiac and pulmonary functions. Postoperative renal function was temporarily decreased, but the choice of shallow hypothermic CPB improved the decrease in the postoperative glomerular filtration rate to some extent compared with that in patients with normothermia and moderate hypothermia. Thus, our study suggested that the use of shallow hypothermic CPB in valve replacement surgery might have more significant advantages, providing a new reference for the optimal management of the CPB temperature and enabling clinicians to make more scientific decisions.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethics Approval

This retrospective study was approved by the Institutional Review Board of the First Affiliated Hospital of Anhui Medical University (IRB number: PJ-2022-021-528). All experimental procedures and methods were performed in accordance with relevant guidelines and regulations (Declaration of Helsinki).

Informed Consent

This Institutional Review Board waived the requirement for written informed consent because the data were anonymous, and the study did not involve patient privacy or treatment.

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Authors' Contribution

YY, LQ, CS, ZZ, and LYH were involved in topic selection. YY, LQ, LXF, and LYH were involved in result screening. YY, CMY, DXY, and LXF were involved in data collection. YY, LQ, CS, and QZH were involved in analysis of the data. YY and LQ wrote the manuscript. All authors contributed to the revision and approved the final version of the manuscript.

Availability of Data and Materials

All data are available by the corresponding author upon reasonable request.

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