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Effects of Conventional Ultrafiltration During Cardiopulmonary Bypass on Serum Lactatemia in Patients Undergoing Cardiac Surgery

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ABSTRACT

Background: Cardiopulmonary bypass (CPB) is a crucial technique in cardiac surgeries to maintain systemic circulation and oxygenation. However, it can cause physiological changes like fluid overload, hemodilution, inflammatory response, and metabolic abnormalities. Monitoring serum lactate levels is essential for peri-operative management and patient outcomes. Conventional ultrafiltration (CUF) is utilized to reduce fluids, but understanding its impact on lactatemia is crucial.

Aim: To study the effects of conventional ultrafiltration throughout CPB on serum lactatemia in patients partaking cardiac surgery.

Methods: The study was a retrospective single-center study done at Sri Ramachandra Institute of Higher Education and Research (SRIHER), involving 30 patients who underwent cardiac valvular and coronary artery bypass grafting with valvular surgeries using CPB from March 2022 to July 2022. The patients were split into two groups: Group A (CPB with hemofiltration) and Group B (CPB without hemofiltration). Data measurements included hemoglobin, serum lactate, creatinine, blood urea nitrogen (BUN), and urine output. Statistical analysis was done utilizing a t-test along with chi-square test, with a probability value (PV) of $P < 0.005$ considered noteworthy.

Results and Discussion: Throughout cardiac bypass surgery (CPB), serum lactate levels are lower in Group A (mean- 1.87mmol/L) compared to Group B (mean-5.34mmol/L), and hemoglobin levels increase in Group A (mean-11.4 g/dL) compared to Group B (mean-8.3 g/dL). The incorporation of an ultrafilter during CPB significantly increases hemoglobin levels, reducing the need for blood transfusions. Postoperatively, serum lactate levels gradually increase in Group B (mean-4.9 mmol/L) and hemoglobin levels increase in Group A (mean-11.7 g/dL), reducing the need for blood transfusions and mechanical ventilation time. Additionally,

serum creatinine levels decrease in Group A (hemofilter-induced CPB) compared to Group B (mean-3.21 mg/dL). BUN levels slightly increase in Group B.

Conclusion: Conventional ultrafiltration during CPB reduces hyperlactatemia risk, reducing mechanical ventilation time and ICU stay duration. It benefits short-term patients and those with preoperative renal dysfunction in the long run.

Keywords: Cardiac Surgery, Cardiopulmonary Surgery, Ultrafiltration and Serum lactatemia.

INTRODUCTION

Cardiopulmonary bypass (CPB) is an essential technique in cardiac surgeries to maintain systemic circulation and oxygenation during the temporary cessation of heart function. While it plays a crucial role, CPB is linked with an array of physiological changes and outcomes, including fluid overload, hemodilution, systemic inflammatory response, and metabolic abnormalities (1). A prevalent concern during CPB is the onset of hyperlactatemia, which may signify tissue hypoxia, compromised perfusion, or metabolic disturbances. Increased blood lactate levels are not solely a biochemical indicator but are associated with heightened morbidity, extended ICU admissions, and poorer clinical outcomes within patients partaking in heart surgery (2). A lot of factors like hemodilution, vasopressor usage and the inflammatory response that starts when blood contacts non-endothelial surfaces in the bypass circuit. As a peri-operative management monitoring serum lactate levels has become a crucial aspect and an early indicator for circular distress and patient outcomes (3)(4).

Conventional ultrafiltration (CUF) is used to remove excess fluids, thereby reducing the hemodilution and inflammatory response rates. During CUF, the blood passe through the semipermeable membrane, which removes plasma and low molecular weight solutes without disturbing the cell parts (5). Using CUF during CPB has serval advantages better post-operative pulmonary function, decreased tissue edema, and improved hemodynamic stability. The relationship between serum lactatemia and CUF is intricate through improving the levels of hematocrit and blood concentration which enhances the oxygen delivery to the tissues by reducing anerobic metabolism and lactate production (6). If ultrafiltration is not meticulously controlled, it could potentially result in hypovolemia, diminished perfusion, and elevated lactate generation. Removal of certain mediators through ultrafiltration might influence the metabolic pathways thereby affecting the dynamic of lactate (7).

In cardiac surgery, understanding the impact of CUF on lactatemia during CPB is vital for stabilizing the perfusion strategies to improve patient outcomes (8). Some studies have shown positive findings that CUF helps in the reduction of lactate accumulation by enhancing microcirculatory flow and oxygenation while other reports have no significant effect or even a potential risk of worsening lactatemia under certain conditions. This paper aims to assess the impact of conventional ultrafiltration on serum lactate concentrations during CPB in individuals undergoing cardiac surgical procedures.

METHODOLOGY

The present study was a retrospective single-center study done at SRIHER. Thirty patients underwent cardiac valvular and coronary artery bypass grafting with valvular surgeries using CPB from March 2022 to July 2022.

Inclusion criteria: patients of either gender, Patients aged > 18 years, patients who underwent valvular heart surgeries, elective open-heart surgery, patients weighing > 40 kgs, coronary artery bypass grafting with valvular heart surgeries, and cardiac surgery.

Exclusion criteria: patients with renal or hepatic failure preoperatively, emergency cases, and CPB time less than 60 minutes.

Per the inclusion criteria, current study patients are classified into two groups:

1. Group A: Patients undergoing CPB with hemofiltration with 7 female and 8 male patients.
2. Group B: Patients undergoing CPB without hemofiltration with 8 female and 7 male patients.

Data Measurements

Hemoglobin, serum lactate, creatinine, blood urea nitrogen (BUN), and urine output were monitored, and arterial blood gas samples were taken preoperatively during induction. Intraoperatively (10 minutes post-administration of cardioplegia) and postoperatively (24 and 48 hours following patient transfer to the ICU).

Operative Techniques

Anesthesia

Anesthetic techniques are uniformly applied across all patients. Induction of general anesthesia was accomplished using midazolam and fentanyl, while vecuronium was utilized to achieve muscle relaxation. Fentanyl is utilized to sustain intravenous anesthesia during the entire procedure. All patients in our study receive standard valvular heart surgeries via a median sternotomy.

Cardiopulmonary Bypass

During cardiopulmonary bypass, an intravenous administration of heparin at a dosage of 400 IU/kg is performed. CPB commences when the activated clotting time surpasses 480 seconds.

Perfusion and Ultrafiltration Techniques

The procedure of extracorporeal circulation utilizes a Sorin inspire adult membrane oxygenator, a Sarns 8000 perfusion pump, and a Spictra AF arterial line filter. Non-pulsatile perfusion is sustained at a flow rate of 2.2–2.4 l/m/min. Patients are assigned randomly by the perfusionist, utilizing a computer-created random number chart for the inclusion of 10% mannitol in the priming solution. The bypass circuit is prepared with a 1-liter solution of Plasmalyte – A, 20% mannitol, and 10,000 IU of heparin for the study group. The bypass circuit is prepared with a 1-liter Plasmalyte-A solution and 10,000 IU of heparin for the control group. The hematocrit level is sustained within the range of 20% to 25%, with packed red cells administered as needed. The mean arterial pressure (MAP) is sustained within the range of 40-60 mmHg during cardiopulmonary bypass. The controlling of acid-base balance is guided by the alpha-stat principle.

Postoperative Care

All patients are then cooled to a nasopharyngeal temperature of 28°C. Following the application of the aortic cross-clamp, and then myocardial protection was successfully attained using intermittent antegrade cold blood cardioplegia, administered at a temperature of 40°C. Initiate rewarming 10 minutes before the release of the aortic cross-clamp. Patients are then rewarmed to 37°C. Patients are brought to a temperature of 37°C. The reversal of heparinization is achieved through the administration of protamine sulphate, at a dosage of 1 to 1.3 mg for each 100 IU of heparin used. Patients are transitioned from CPB while maintaining stable hemodynamics. Following surgery, patients are moved to the cardiac ICU for further monitoring and care.

Statistical analysis

We statistically described the data concerning mean, and standard deviation, and median, along with range, or in terms of frequencies (number of cases) and percentages when appropriate. We used a t-test to determine the significant difference across paired groups (PREOP, POST-OP, and PERI-OP). We used a chi-square test to configure data's significance. In all given statistical tools, the PV of $P < 0.005$ is considered the noteworthy level. All statistical calculations were done using the computer program SPSS for Microsoft Windows.

RESULTS AND DISCUSSION

Hematologic Variable

During the perioperative period, Group A, which used conventional ultrafiltration, had stable hemoglobin levels. Values dropped slightly from

11.59 g/dL before surgery to 11.4 g/dL during surgery but then rose to 11.7 g/dL and then 11.6 g/dL 24 and 48 hours after surgery with (p=0.005) respectively. Conversely, Group B had a notable decline from 11.9 g/dL preoperatively to 8.3 g/dL intraoperatively, followed by consistently reduced levels of 8.0 g/dL along with 7.9 g/dL at 24 and 48 hours postoperatively (Table 1, Fig. 1). It is clear from the results that regular ultrafiltration helps to keep hemoglobin levels stable, which may make oxygen delivery easier by lowering hypoxia and raising lactate production. In the end, keeping hemoglobin levels high, like what was seen in Group A, may be linked to lower serum lactate levels. This shows how beneficial ultrafiltration is for therapy during cardiopulmonary bypass (9).

Table 1. Levels of Hemoglobin

HEMOGLOBIN	GROUP A	GROUP B
Pre Operative	11.59	11.9
Peri Operative	11.4	8.3
Post Operative After 24 Hours	11.7	8
Post Operative After 48 Hours	11.6	7.9

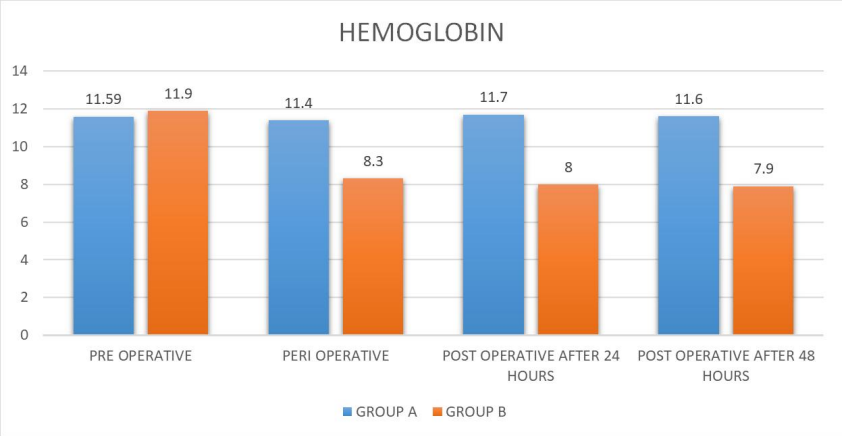

Fig 1. Comparison of Hemoglobin between groups

Serum Lactate

Pre-operatively, both groups had equivalent baseline lactate concentrations (1.32 mmol/L). Peri-operatively, Group B demonstrated a significant elevation in lactate levels (5.34 mmol/L), while Group A exhibited just a minor increase (1.87 mmol/L) (p= 0.004). The significant rise in Group B indicates an elevated level of tissue hypoxia during cardiopulmonary bypass, perhaps resulting from insufficient perfusion or metabolic anomalies. Post-operatively, Group A exhibited a consistent lactate level, peaking at 2.0 mmol/L after 24 hours and decreasing to 0.95 mmol/L after 48 hours, signifying effective lactate clearance and metabolic recovery. Conversely, Group B exhibited consistently high lactate levels (4.9 mmol/L at 24 hours and 3.68 mmol/L at 48 hours), indicating sustained metabolic stress and impaired clearance. The findings underscore the advantageous effects of CUF in Group A, likely promoting hemodynamic stability, diminishing hemodilution, and facilitating lactate clearance, while the lack or reduced application of CUF in Group B may have led to metabolic acidosis and extended lactatemia (Table 2, Fig. 2).

Hyperlactatemia is defined as a condition in which the average lactate level in blood serum surpasses 2 mmol/L. The incidence of this phenomenon during or following CPB elevates the risk of postoperative complications, including infections. Numerous studies indicate that factors such as age, sex, type 2 diabetes mellitus, and anemia can contribute to the occurrence of lactic acidosis prior to surgical

procedures. During CPB, various factors influence the outcomes, including the duration of ultrafiltration, the extent of hemodilution, the volume of oxygen intake and utilization, as well as the rates of oxygen extraction and the duration of CPB (7) (10). The lowering of serum lactate decreases the duration of artificial breathing in patients having heart surgery with cardiopulmonary bypass. Consequently, the duration of stay inside the ICU was markedly decreased, since a surgical intubation period beyond 12 hours correlates directly with an extended length of stay (11).

Table 2. Levels of Serum Lactate

SERUM LACTATE	GROUP A	GROUP B
Pre Operative	1.32	1.32
Peri Operative	1.87	5.34
Post Operative After 24 Hours	2	4.9
Post Operative After 48 Hours	0.95	3.68

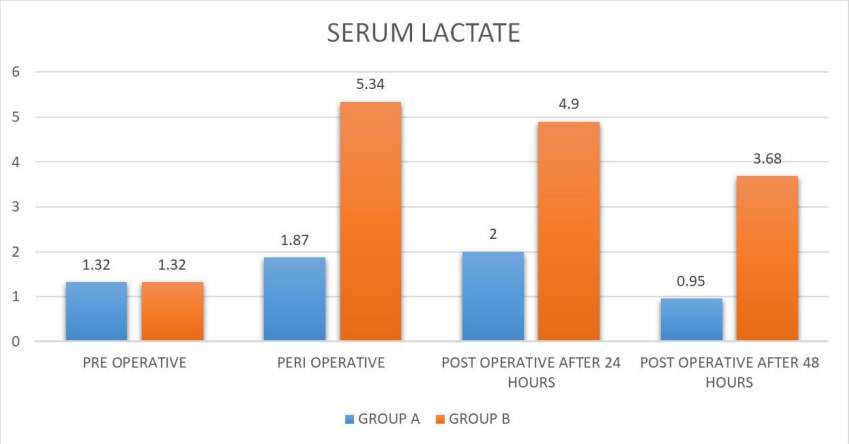

Fig 2. Comparison of Serum Lactate between Groups

RENAL PARAMETERS

Serum Creatinine

Preoperatively, both groups show comparable baseline renal function (Group A: 0.98 mg/dL, Group B: 0.84 mg/dL). However, 24 hours postoperatively, Group B exhibits a significant rise in serum creatinine to 3.21 mg/dL, indicating impaired renal function, while Group A shows a drop to 0.65 mg/dL, showing an improved renal clearance possibly due to effective ultrafiltration. By 48 hours postoperatively, Group B's creatinine level backs to baseline (0.92 mg/dL), while Group A stabilizes at 0.89 mg/dL These findings suggest that CUF may have contributed to better fluid and metabolic balance in Group A, potentially reducing renal stress and preserving kidney function. In contrast, Group B experienced transient renal impairment, which could correlate with increased serum lactate levels due to impaired perfusion and metabolic clearance during CPB without effective ultrafiltration (Table 3, Fig.3).

As demonstrated by higher peak postoperative creatinine levels inside 48 hours of arrival in the ICU linked to persistent acute kidney injury, an elevated preoperative creatinine level is the most noteworthy predictive threat factor for postoperative acute kidney injury following CPB (13) (14). Preoperative creatinine levels above 2.5 mg/dL not only prolong hospital stay after CPB surgery but also increase mortality risk and induce the development of acute kidney injury (15). All of these findings point to the importance of keeping an eye on elevated creatinine levels throughout the perioperative phase.

Table 3. Levels of Serum Creatinine

SERUM CREATNINE	GROUP A	GROUP B
Pre Operative	0.98	0.84
Post Operative After 24 Hours	0.65	3.21
Post Operative After 48 Hours	0.89	0.92

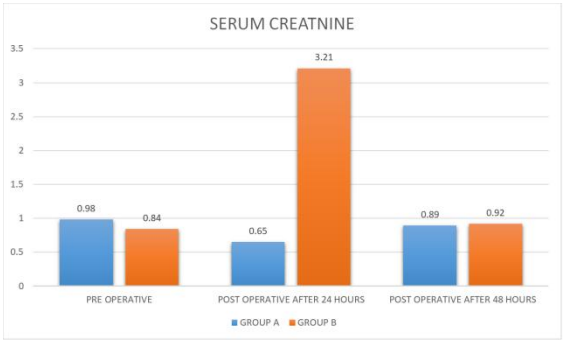

Fig 3. Comparison of Serum Creatinine between the groups

Blood Urea Nitrogen (BUN)

Pre-operatively, the BUN levels were comparable across the two groups (Group A: 11.73 mg/dL, Group B: 11.33 mg/dL). Post-operatively, Group B demonstrated a significant increase, attaining 16.1 mg/dL in 24 hours and sustaining this elevation at 48 hours. In contrast, Group A exhibited a more gradual increase, reaching 13.1 mg/dL at 24 hours and 13.8 mg/dL at 48 hours (Table 4, Fig.4)

The increase in the levels of BUN in Group B indicates diminished renal clearance, likely resulting from increased hemoconcentration, reduced renal perfusion, or an elevated metabolic burden linked to lactate accumulation. This trend corresponds with the potential CUF in Group A, which may have led to enhanced fluid balance, improved renal function, and diminished metabolic derangement following cardiopulmonary bypass. The results indicate that CUF may reduce elevated BUN levels, thus improving post-operative recovery and stabilizing renal function in patients undergoing cardiac surgery (16).

Table 4. Levels of Blood Urea Nitrogen

Blood Urea Nitrogen	Group A	Group B
Pre Operative	11.73	11.33
Post Operative After 24 Hours	13.1	16.1
Post Operative After 48 Hours	13.8	16.1

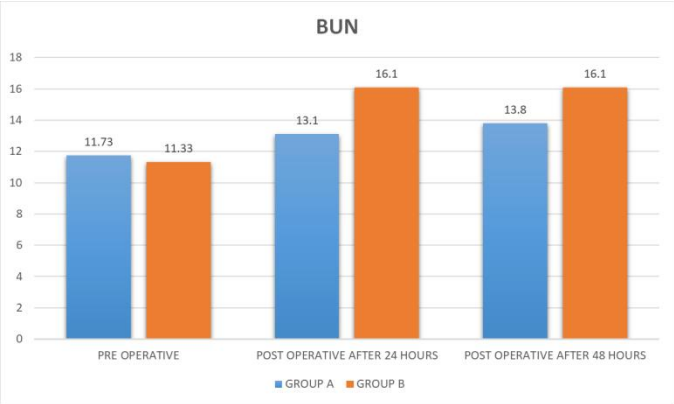

Fig 4. Comparison of Blood Urea nitrogen between Groups

Urine Output

The peri-operative urine output in Group A was 336.3 mL, whereas Group B exhibited a significantly higher output of 519 mL (Table 5, Fig. 5). This discrepancy shows that Group B experienced more diuresis during the perioperative phase. The higher urine output in Group B and the effect of CUF during CPB on serum lactatemia in heart surgery patients may point to a more aggressive process for removing fluids, most likely because ultrafiltration techniques were used. CUF effectively minimizes fluid overload, concentrates blood, and regulates serum lactate levels. The increased urine production in Group B may reflect increased fluid clearance or renal response; however, it could also result in intravascular volume depletion, which is consistent with the considerable fall in hemoglobin levels found in this group. This emphasizes the impact of CUF on fluid balance and hemodynamics, which may affect serum lactate levels and patient recovery after heart surgery (16).

Table 5. Urine Output between groups

URINE OUTPUT	GROUP A	GROUP B
Peri Operative	336.3	519

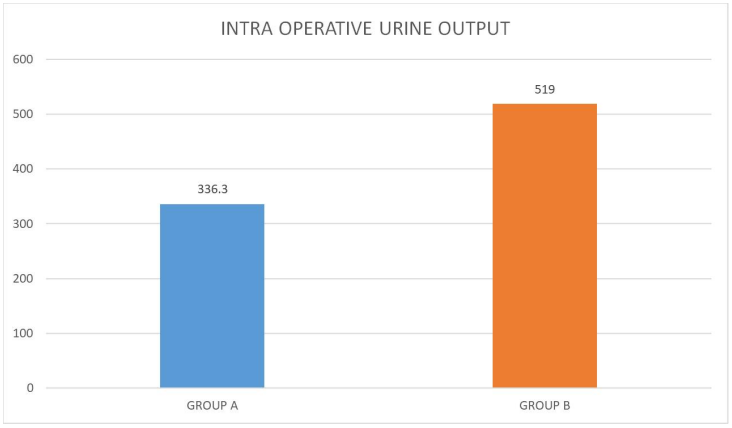

Fig 5. Comparison of Urine Output between Groups

CONCLUSION

This study's findings indicate that traditional ultrafiltration during CPB offers multiple benefits.

CUF seems to reduce the risks linked to tissue hypoxia and metabolic acidosis, established factors in postoperative complications, by stabilizing hemoglobin levels, improving lactate clearance, and maintaining renal function. These results support the utilization of CUF as an effective therapy to mitigate the risk of hyperlactatemia after heart surgery by enhancing hemodynamic stability and facilitating patient recovery.

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