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TO ASSESS THE EFFECTS OF DURATION OF CARDIOPULMONARY BYPASS ON POST-OPERATIVE RENAL FUNCTION

Original Research

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ABSTRACT

Background: Cardiopulmonary bypass (CPB) is essential for many cardiac surgeries, yet its physiological impact on renal function remains a persistent clinical concern. Prolonged exposure to extracorporeal circulation can increase renal stress due to altered perfusion, inflammatory activation, and hemodynamic fluctuations. Understanding how CPB duration influences early postoperative renal markers is crucial for preventing complications such as acute kidney injury and ensuring better recovery outcomes for cardiac patients.

Objective: To evaluate the association between CPB duration and postoperative renal function among adult cardiac surgery patients.

Methods: A total of 109 patients undergoing cardiac surgery with CPB were included. Renal parameters were recorded after the first 24 postoperative hours in the ICU. The primary variables measured were CPB duration, serum creatinine, blood urea levels, and urine output. Data analysis was performed using SPSS version 23. Mean values and standard deviations were calculated for all quantitative variables. Correlation analysis was employed to determine the strength and significance of the association between CPB duration and renal markers, with $p < 0.05$ considered statistically significant.

Results: The mean CPB duration was 102.00 ± 33.85 minutes. The mean postoperative creatinine level was 1.1661 ± 0.56801 mg/dl, and the mean urea level was 32.63 ± 10.73 mg/dl. A significant positive correlation was found between CPB duration and both creatinine ($r = 0.287$, $p = 0.003$) and urea ($r = 0.330$, $p = 0.001$). The mean urine output was 2142.66 ± 392.04 ml, showing a weak negative and non-significant correlation with CPB duration ($r = -0.016$, $p = 0.867$).

Conclusion: Longer CPB duration was associated with higher postoperative creatinine and urea levels, reflecting increased renal strain, while urine output showed no significant association. Minimizing CPB duration where clinically feasible may support renal preservation and contribute to improved postoperative outcomes.

Keywords: Acute Kidney Injury; Cardiopulmonary Bypass; Creatinine; Kidney Function Tests; Postoperative Complications; Renal Insufficiency; Urea.

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INTRODUCTION

Cardiopulmonary bypass (CPB) is a cornerstone of modern cardiac surgery, enabling complex procedures by temporarily diverting blood flow away from the heart and lungs through an extracorporeal circuit that oxygenates and circulates blood back to the body. This system, commonly referred to as the heart–lung machine, creates a motionless and bloodless operative field while maintaining physiological stability (1). Since the first successful human cardiac surgery on CPB performed by Gibbon in 1952 to repair an atrial septal defect, its evolution has transformed surgical care and markedly improved survival outcomes. Despite these advancements, CPB is well recognized for its potential adverse effects on vital organs, particularly the kidneys, where its influence remains a major clinical concern (2,3). Renal dysfunction following CPB ranges from subtle biochemical disturbances to severe acute kidney injury (AKI), a complication associated with high morbidity and mortality. AKI is defined as a sudden decline in renal function resulting in a rise in serum creatinine greater than 0.5 mg/dl from baseline or reduced urine output within 48 hours, and may progress to the need for dialysis, especially in individuals with pre-existing chronic kidney disease. Mortality rates in patients who develop AKI after cardiac surgery may reach 30%, and increase up to 50% when dialysis becomes necessary, largely due to complications such as sepsis, wound infection, and nutritional impairment (4,5). The susceptibility of the kidneys to hypoxic injury, combined with the systemic inflammatory response syndrome (SIRS) triggered by blood contact with non-biological surfaces during CPB, further heightens the risk. Inflammatory mediators and endotoxins released during this process contribute to renal tubular damage through cytokine-driven pathways, intensifying the risk of postoperative renal deterioration (6,7).

Multiple patient- and procedure-related factors influence the development of AKI, with pre-existing chronic kidney disease being the most significant predictor. Patients with baseline serum creatinine levels of 2–4 mg/dl have an approximate 20% risk of postoperative dialysis, which rises to nearly 28% when serum creatinine exceeds 4 mg/dl. Additional risk factors include diabetes mellitus, advanced age, female sex, peripheral vascular disease, preoperative heart failure, chronic obstructive pulmonary disease, anemia, and the need for intra-aortic balloon pump support. Procedure-related contributors such as prolonged CPB duration, reduced perfusion pressure, extended aortic cross-clamp time, and inadequate intraoperative oxygen delivery further compound renal vulnerability (8). Evidence from prior studies consistently suggests that longer CPB times are associated with greater postoperative renal impairment, prolonged ICU stay, increased infectious complications, and higher likelihood of AKI requiring dialysis. Existing literature has explored CPB-related renal dysfunction, yet variations in methodology, sample demographics, surgical procedures, and monitoring parameters leave important gaps in understanding the specific contribution of CPB duration to postoperative renal outcomes. Studies support the association between prolonged CPB and deteriorating renal indices (9,10), while others, highlight the protective role of optimized perfusion pressures in preventing renal compromise (11). Despite these insights, inconsistencies remain regarding the degree to which CPB duration alone predicts renal injury independent of patient comorbidities and intraoperative management strategies. Given the clinical significance of AKI and the growing population of cardiac patients with multiple comorbidities, there is a compelling need to better delineate the extent to which CPB duration affects postoperative renal parameters, including serum creatinine, urea levels, and urine output. Clarifying this relationship may guide perioperative strategies aimed at minimizing renal insult and improving short- and long-term outcomes in cardiac surgery patients. Therefore, this study aims to systematically assess the influence of CPB duration on postoperative renal function, with the objective of determining whether prolonged bypass time significantly increases the risk of renal impairment and AKI, thereby informing safer clinical practice and more effective management protocols.

METHODS

The study was conducted as an analytical observational investigation designed to assess the effect of cardiopulmonary bypass (CPB) duration on postoperative renal parameters in adult cardiac surgery patients. It was carried out in the Department of Cardiac Surgery at Chaudhary Pervaiz Elahi Institute of Cardiology (CPEIC), Multan, over a period of approximately four months. A total of 109 patients were included using non-probability consecutive sampling, chosen primarily due to the feasibility of patient recruitment within the limited study duration and the restricted availability of eligible cases. All participants who met the predefined inclusion criteria underwent cardiac surgery requiring CPB and were subsequently monitored postoperatively in the intensive care unit (ICU). Eligible participants included male and female cardiac surgery patients aged 40 to 60 years with an ejection fraction greater than 35%, and with

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controlled diabetes mellitus and controlled hypertension. Exclusion criteria comprised patients younger than 40 or older than 60 years, those with an ejection fraction below 35%, redo or repeat cardiac surgeries, preoperative renal disease, off-pump cardiac procedures, preexisting end-organ failure, and pregnant patients (3,4). These criteria were selected to ensure a relatively homogenous cohort and to minimize confounding factors that could independently influence renal function. Data collection was performed through postoperative renal assessments documented in the ICU. Renal parameters, including serum creatinine, blood urea levels, and total urine output during the first 24 hours following surgery, were extracted from patient records and manually recorded on predefined data sheets. CPB duration for each patient was taken from the operative record. No direct patient interaction or intervention occurred, and no additional diagnostic procedures were required beyond routine clinical care. All procedures adhered to ethical standards. Permission to conduct the study was granted by the Institutional Ethical Review Board of CPEIC, Multan. Patient confidentiality was maintained throughout the study by anonymizing all data, which were used solely for academic and statistical purposes. As the study involved retrospective review of clinical records without direct patient contact, informed consent requirements followed institutional policy; however, the section would benefit from clarification regarding whether waivers for informed consent were formally approved. Data analysis was carried out using IBM SPSS version 23. Quantitative variables were summarized using means and standard deviations. Inferential analysis was conducted through correlation testing to evaluate the relationship between CPB duration and postoperative renal parameters. A p-value of less than 0.05 was considered statistically significant at a 95% confidence interval with a 5% margin of error. The analytical approach was selected to determine the extent to which variations in CPB duration corresponded with measurable postoperative renal changes.

RESULTS

A total of 109 patients were assessed to determine the relationship between cardiopulmonary bypass (CPB) duration and postoperative renal parameters. The mean CPB duration was 102.00 minutes with a standard deviation of 33.85 minutes. The mean postoperative serum creatinine level recorded after the first 24 hours in the ICU was 1.1661 mg/dl (SD = 0.56801). Correlation analysis demonstrated a positive association between CPB duration and serum creatinine, with a correlation coefficient of r = 0.287 and a statistically significant p-value of 0.003, indicating that higher CPB duration corresponded with higher postoperative creatinine levels. Similarly, the mean postoperative blood urea level was 32.63 mg/dl (SD = 10.73). The correlation between CPB duration and blood urea revealed a positive coefficient of r = 0.330 with a p-value of 0.001, denoting statistical significance. This indicates that patients with longer CPB times tended to exhibit higher postoperative urea levels. Postoperative urine output in the first 24 hours averaged 2142.66 ml (SD = 392.04). Correlation analysis between CPB duration and urine output showed a weak negative association, with r = –0.016 and a non-significant p-value of 0.867, demonstrating no meaningful relationship between bypass time and early postoperative urine volume.

Table 1: Correlation of CPB Duration with Creatinine level

Variables	N	Mean Value	Standard Deviation	r	Level of Significance
CPB Duration (mins)	109	102.00	33.854	0.287	0.003
Creatinine Level (mg/dl)	**109**	**1.1661**	**.56801**		

Table 2: Correlation of CPB Duration with Urea level

Variables	N	Mean Value	Standard Deviation	r	Level of significance
CPB Duration (mins)	109	102.00	33.85	0.330	0.001
Urea Level (mg/dl)	**109**	**32.63**	**10.73**		

Table 3: Correlation of CPB Duration with Urine value

Variables	N	Mean	Standard Deviation	r	Level of Significance
CPB Duration (mins)	109	102.00	33.85	-0.016	0.867
Urine Volume (ml)	**109**	**2142.66**	**392.04**		

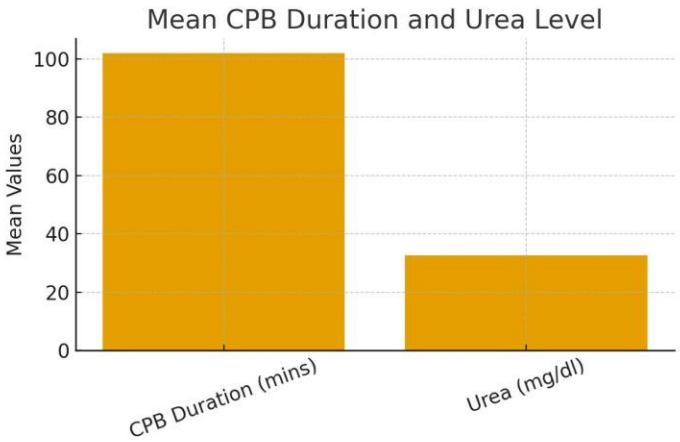

Figure 2 Mean CPB Duration and Urea Level

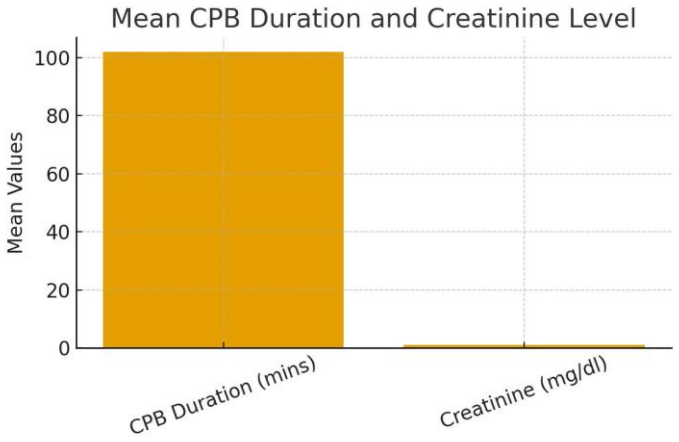

Figure 2 Mean CPB Duration and Creatinine Level

DISCUSSION

The study demonstrated that the duration of cardiopulmonary bypass (CPB) during cardiac surgery had a measurable impact on postoperative renal function, as reflected by changes in serum creatinine and urea levels. A statistically significant positive correlation was observed between CPB duration and both creatinine and urea, indicating that longer bypass times were associated with higher postoperative values of these biomarkers. Patients with modest prolongation of CPB generally exhibited only transient biochemical disturbances that responded to medical management, whereas those exposed to substantially longer bypass durations tended to develop more pronounced renal dysfunction and, in a small number of cases, required dialysis. These findings supported the concept that CPB duration acted as an important procedural determinant of renal stress in the early postoperative period (12,13). The absence of a significant association between CPB duration and urine output, despite a weak negative correlation, provided an important nuance to the interpretation of renal status. Early postoperative urine volume can be influenced by multiple factors, including perioperative fluid administration, use of diuretics, vasopressor therapy, and hemodynamic management in the intensive care unit (14). As a result, urine output alone may not have reflected the full extent of renal injury in this cohort, whereas biochemical markers such as creatinine and urea appeared more sensitive to the cumulative impact of prolonged bypass. The pattern observed in this study aligned with the broader understanding that acute kidney injury in the context of CPB often manifests initially as subtle biochemical changes before overt oliguria becomes evident (15,16). When placed in the context of existing literature, the findings from this study were broadly consistent with previous work indicating that extended CPB duration is associated with higher risk of postoperative renal dysfunction and acute kidney injury (17).

Earlier studies reported that prolonged bypass time contributed to renal impairment through mechanisms such as reduced renal perfusion, ischemia–reperfusion injury, systemic inflammatory response, hemolysis, and microembolic phenomena. Other research emphasized the importance of intraoperative factors such as perfusion pressure, temperature management, and hemodilution, suggesting that CPB duration represented one component of a multifactorial risk profile rather than an isolated cause (18,19). The present study reinforced the role of CPB time as a clinically relevant marker of renal risk, while also implying that it may function as a surrogate for overall procedural complexity and physiological burden. The clinical implications of these findings were meaningful for perioperative management. The observed relationship between longer CPB duration and deranged renal parameters supported strategies aimed at

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minimizing bypass time wherever safely possible, through meticulous surgical planning, efficient conduct of the procedure, and close coordination between the surgical, anesthetic, and perfusion teams. At the same time, the occasional need for dialysis among patients with markedly prolonged CPB highlighted the importance of early identification of high-risk individuals, optimization of preoperative renal function, and implementation of renal-protective measures such as adequate hydration, avoidance of nephrotoxic agents, and maintenance of stable hemodynamics and perfusion pressures during surgery. The potential for recovery in patients with moderate elevations in creatinine and urea also indicated that timely supportive care could modify the trajectory of renal injury, especially when CPB exposure was not excessively prolonged (20-22). This study possessed several strengths. It focused on a clearly defined cohort of adult cardiac surgery patients within a specific age and ejection fraction range, thereby reducing heterogeneity related to extremes of age or severe ventricular dysfunction. Renal parameters were measured in a standardized manner in the first 24 hours postoperatively, and the use of correlation analysis provided a direct quantitative assessment of the relationship between CPB duration and renal biomarkers. The work added locally relevant data from a high-volume cardiac centre and contributed to the growing body of evidence that procedural factors continue to shape renal outcomes even in the era of improved perfusion technology and perioperative care.

However, important limitations needed to be acknowledged. The study was conducted at a single centre with a relatively small sample size of 109 patients and used a non-probability consecutive sampling technique, which limited generalizability and introduced potential selection bias. The observational design prevented any causal inference; CPB duration could not be separated fully from other intraoperative and patient-related factors that may have contributed to renal dysfunction. Detailed information on baseline renal function trends, comorbidities, type and complexity of cardiac procedures, intraoperative perfusion pressures, temperature profiles, fluid balance, diuretic use, and postoperative hemodynamics was not incorporated into the analysis. These omissions reduced the ability to adjust for confounding variables that may have influenced renal outcomes. Furthermore, the study did not report the incidence or staging of acute kidney injury based on standardized criteria, nor did it provide long-term renal follow-up, which limited the understanding of the persistence or reversibility of renal dysfunction beyond the immediate postoperative period. The constraints of time, small sample size, and single-centre setting were acknowledged and represented practical limitations rather than methodological defects alone. Nonetheless, future studies would benefit from larger, multicentre cohorts with probability-based sampling, incorporation of multivariable regression models, and stratification of outcomes by established acute kidney injury definitions. Inclusion of detailed intraoperative data and longer-term follow-up of renal function would provide a more comprehensive picture of how CPB duration interacts with other clinical variables to shape both short- and long-term renal outcomes. Despite these limitations, the present study contributed valuable evidence supporting the notion that prolonged CPB duration remained an important and modifiable risk factor for postoperative renal impairment, underscoring the need for ongoing efforts to optimize surgical efficiency and perioperative renal protection in cardiac surgery patients.

CONCLUSION

The study concluded that the duration of cardiopulmonary bypass played a meaningful role in shaping early postoperative renal function, with longer bypass times associated with greater biochemical evidence of renal stress. By examining postoperative creatinine, urea, and urine output patterns, the findings highlighted that minimizing CPB duration, wherever surgically feasible, may contribute to preserving renal integrity and reducing the likelihood of complications such as acute kidney injury. These insights underscore the practical importance of optimizing intraoperative efficiency and adopting renal-protective strategies to enhance patient outcomes following cardiac surgery.

AUTHOR CONTRIBUTION

Author	Contribution
Shehryar Ghauri*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Fizah Subhani	Substantial Contribution to study design, acquisition and interpretation of Data

Author	Contribution
	Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Tayyab Ali	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Sumayya Urooj	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Saba Saif	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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