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Original article

Impact of Cardiopulmonary Bypass on Prothrombin Time: Pre and Post-Operative Variation

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ABSTRACT

Background: Cardiopulmonary bypass (CPB) is an essential component of modern cardiac surgery that temporarily replaces the function of the heart and lungs during complex surgical procedures. Despite its clinical benefits, CPB is associated with haemodilution, systemic inflammatory activation, platelet dysfunction, and coagulation abnormalities that may increase postoperative bleeding risk. Monitoring perioperative coagulation parameters is therefore important for optimizing patient management. Objective: To evaluate the effect of cardiopulmonary bypass on prothrombin time and other coagulation-related laboratory parameters by comparing pre-operative and post-operative measurements in patients undergoing cardiac surgery. Methods: A hospital-based observational study was conducted over four months at Gulab Devi Hospital and the Punjab Institute of Cardiology, Lahore. Seventy-three patients aged 35–55 years undergoing elective coronary artery bypass grafting or valve surgery requiring CPB were enrolled using consecutive sampling. Venous blood samples were obtained before surgery and after completion of CPB for determination of prothrombin time (PT), international normalized ratio (INR), activated partial thromboplastin time (APTT), hemoglobin, red blood cell count, platelet count, total leukocyte count, neutrophils, and lymphocytes. Statistical analysis was performed using paired-sample t-tests in IBM SPSS Statistics version 26.0, with $p < 0.05$ considered statistically significant. Results: Among the 73 participants, 58.9% were male and 41.1% were female. Significant postoperative increases were observed in PT ($p=0.001$), INR ($p=0.003$), and APTT ($p<0.001$), indicating impaired coagulation following CPB. Total leukocyte count increased significantly ($p=0.008$), whereas lymphocyte count decreased significantly ($p=0.032$). Hemoglobin levels also declined significantly ($p<0.001$), consistent with haemodilution. Platelet count showed no statistically significant difference ($p=0.290$). Conclusion: Cardiopulmonary bypass was associated with significant alterations in coagulation parameters, particularly prolonged PT, INR, and APTT, together with perioperative hematological changes. These findings underscore the importance of careful perioperative coagulation monitoring and individualized hemostatic management in patients undergoing cardiac surgery with CPB. Keywords: Cardiopulmonary bypass; Prothrombin time; International normalized ratio; Activated partial thromboplastin time; Cardiac surgery; Coagulation; Haemodilution.

EDITORIAL INFORMATION

Author Contributions: Concept: SS, MRJ, Design: SS, MRJ, MAB, Data Collection: SS, RA, AW, SN, Analysis: MRJ, MAB, Drafting: SS, MRJ, RA, AW, SN, MAB
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INTRODUCTION

Cardiovascular diseases remain one of the leading causes of morbidity and mortality worldwide, and surgical intervention continues to play a crucial role in the management of complex coronary and valvular heart diseases. Cardiopulmonary bypass (CPB) has become an indispensable component of modern cardiac surgery because it temporarily replaces the physiological functions of the heart and lungs, thereby providing a bloodless and motionless operative field that enables surgeons to perform intricate intracardiac procedures with improved precision and safety (1,2). Despite these advantages, exposure of circulating blood to the extracorporeal circuit initiates a cascade of physiological alterations that may adversely affect haemostasis and contribute to perioperative complications (2,3).

Coagulation disturbances following CPB result from multiple interacting mechanisms rather than a single pathological process. Systemic anticoagulation with heparin, haemodilution caused by the

priming solution of the extracorporeal circuit, activation of inflammatory pathways, complement activation, fibrinolysis, platelet activation followed by functional impairment, and consumption of coagulation factors collectively contribute to postoperative coagulopathy (3–6). These alterations may increase the risk of excessive bleeding, blood transfusion, prolonged intensive care unit stay, and postoperative morbidity, thereby emphasizing the importance of careful perioperative hemostatic monitoring (5–8).

Among the routinely available laboratory investigations, prothrombin time (PT) remains one of the most widely used tests for assessing the integrity of the extrinsic and common coagulation pathways. Because the international normalized ratio (INR) is derived from PT, these parameters are valuable for evaluating coagulation status and guiding perioperative anticoagulation management in patients undergoing cardiac surgery (7,8). Activated partial thromboplastin time (APTT), which evaluates the intrinsic coagulation pathway, complements PT assessment by providing additional information regarding coagulation factor activity and the effects of anticoagulant therapy. Together, PT, INR, and APTT provide an accessible laboratory assessment of perioperative coagulation changes and may help identify patients at increased risk of postoperative bleeding (6–9).

Previous investigations have consistently demonstrated that CPB is associated with significant prolongation of PT, INR, and APTT following cardiac surgery, although the magnitude of these changes varies according to patient characteristics, duration of bypass, surgical technique, anticoagulation protocols, and perioperative blood conservation strategies (9–12). Haemodilution occurring during CPB reduces circulating concentrations of coagulation factors and erythrocytes, whereas inflammatory activation further contributes to endothelial dysfunction and hemostatic imbalance (5,7,13). In addition, qualitative platelet dysfunction has been recognized as an important contributor to postoperative bleeding even when platelet counts remain within acceptable ranges, highlighting the complex nature of CPB-induced coagulopathy (8,14,15).

Although numerous international studies have examined coagulation abnormalities associated with cardiopulmonary bypass, evidence from South Asian populations, particularly from Pakistan, remains comparatively limited. Differences in patient demographics, disease characteristics, surgical practices, perioperative management, and healthcare resources may influence coagulation responses and postoperative outcomes, making local evidence essential for optimizing clinical management. Furthermore, relatively few regional studies have simultaneously evaluated changes in PT, INR, APTT, and accompanying hematological parameters using paired pre-operative and post-operative measurements in patients undergoing elective cardiac surgery.

Therefore, the present study aimed to evaluate the impact of cardiopulmonary bypass on prothrombin time and related coagulation parameters by comparing pre-operative and post-operative laboratory findings among patients undergoing cardiac surgery. The findings are expected to improve understanding of perioperative coagulation alterations associated with CPB and provide evidence that may support more effective hemostatic monitoring and individualized perioperative management in routine clinical practice.

MATERIALS AND METHODS

This hospital-based observational study was conducted over four months at Gulab Devi Hospital and the Punjab Institute of Cardiology, Lahore, Pakistan, to evaluate perioperative changes in coagulation and haematological parameters among patients undergoing elective cardiac surgery with cardiopulmonary bypass (CPB), a procedure known to induce significant haemostatic and inflammatory alterations.

A total of 73 patients aged 35–55 years undergoing elective coronary artery bypass grafting (CABG) or valve surgery requiring CPB were enrolled using non-probability consecutive sampling. Patients with congenital or acquired coagulation disorders, chronic liver disease, active infection, inflammatory diseases, or preoperative anticoagulant therapy were excluded. Ethical approval was obtained from the Institutional Review Boards of the participating hospitals, and written informed consent was obtained from all participants before enrolment.

Demographic data, including age and sex, were recorded before surgery. Venous blood samples were collected at two time points: immediately before initiation of CPB and after completion of surgery. Laboratory investigations included prothrombin time (PT), international normalized ratio (INR), activated partial thromboplastin time (APTT), haemoglobin concentration, total leukocyte count (TLC), red blood cell (RBC) count, platelet count, neutrophil count, and lymphocyte count, which are routinely used to assess perioperative coagulation and haematological changes following cardiac surgery. All samples were analysed using standardized laboratory protocols at the participating institutions.

The primary outcome was the perioperative change in prothrombin time, while secondary outcomes included changes in INR, APTT, haemoglobin, TLC, RBC count, platelet count, neutrophil count, and lymphocyte count. Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as frequencies and percentages. Pre-operative and post-operative laboratory parameters were compared using the paired-sample t-test, with a two-tailed p-value <0.05 considered statistically significant. The study was conducted in full compliance with the ethical guidelines of the Ethical Review Committee, Faculty of Allied Health Sciences, The University of Lahore (Ref. No.: DRC/DHPT006/04/25). Written informed consent was obtained from all participants, data were anonymized and securely stored

RESULTS

A total of 73 patients undergoing cardiopulmonary bypass (CPB) were included in the analysis. Male participants constituted 58.9% (43/73) of the cohort, whereas females accounted for 41.1% (30/73) (Table 1; Figure 1). The majority of patients were aged 45–55 years (44/73, 60.3%), while 29 (39.7%) were aged 35–45 years (Table 2; Figure 2).

Table 1: Gender Distribution of Participants

Gender	Frequency (n)	Percentage (%)
Male	43	58.9%
Female	30	41.1%
Total	73	100%

Figure 1: Gender Distribution

Figure 1 visually demonstrates the gender composition of the study cohort, confirming that male patients constituted the majority (58.9%), whereas females represented 41.1% of the participants.

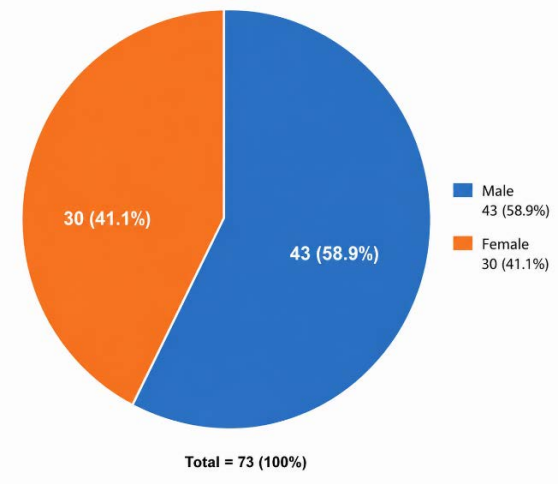


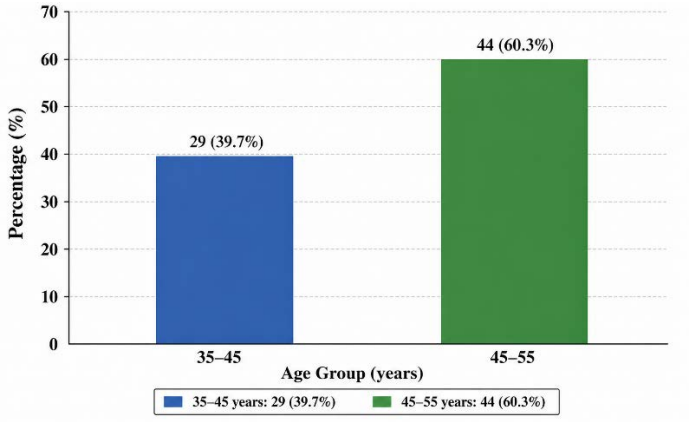
Table 2: Age Distribution of Participants

Most participants belonged to the 45–55-year age group (60.3%), while 39.7% were aged 35–45 years. The findings indicate that cardiopulmonary bypass procedures were performed more frequently among patients in the older age category within the study population.

Age Group (years)	Frequency (n)	Percentage (%)
35–45	29	39.7%
45–55	44	60.3%
Total	73	100%

Figure 2: Age Distribution

The age distribution illustrates that the largest proportion of patients undergoing cardiopulmonary bypass was between 45 and 55 years of age, accounting for approximately three-fifths of the study cohort.



A comparative analysis of pre- and post-operative laboratory parameters revealed significant alterations following cardiopulmonary bypass. Hemoglobin levels showed a statistically significant decrease from 3.04 ± 1.338 pre-operatively to 2.41 ± 0.847 post-operatively ($t = 3.96$, $p < 0.001$), indicating hemodilution associated with CPB. Similarly, red blood cell counts decreased significantly ($t = -3.55$, $p = 0.001$), further supporting the presence of dilutional effects.

Total leukocyte count increased significantly from 1.89 ± 0.560 to 2.26 ± 0.764 ($t = -2.75$, $p = 0.008$), reflecting an inflammatory response induced by extracorporeal circulation. Lymphocyte counts showed a statistically significant decrease ($t = 2.18$, $p = 0.032$), whereas neutrophil counts did not demonstrate a significant change ($p = 0.344$).

Figure 3: Pre- vs Post-Operative PT Comparison

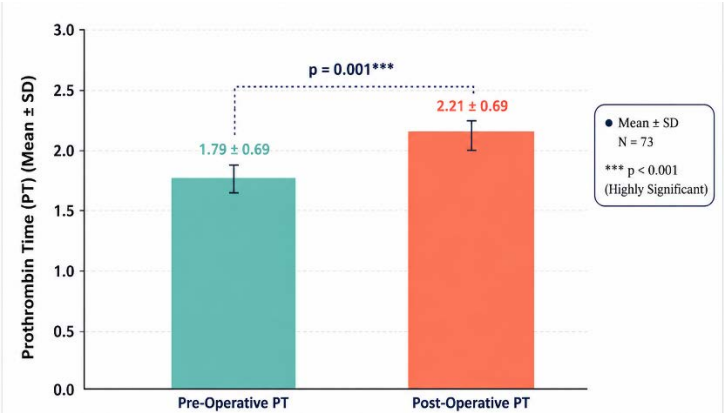


Figure 3 demonstrates a significant increase in mean prothrombin time following cardiopulmonary bypass, rising from 1.79 ± 0.69 pre-operatively to 2.21 ± 0.69 post-operatively ($p = 0.001$), indicating significant prolongation of the extrinsic coagulation pathway after surgery.

With respect to coagulation parameters, prothrombin time (PT) increased significantly from 1.79 ± 0.686 to 2.21 ± 0.686 ($t = -3.51$, $p = 0.001$). Similarly, international normalized ratio (INR) showed a significant rise from 1.70 ± 0.794 to 2.08 ± 0.795 ($t = -3.04$, $p = 0.003$). Activated partial thromboplastin time (APTT) exhibited the most pronounced change, increasing from 1.78 ± 0.768 to 2.52 ± 0.988 ($t = -5.92$, $p < 0.001$). These findings collectively indicate a significant impairment in coagulation following CPB.

Platelet counts showed a slight decrease from 2.12 ± 0.816 to 1.99 ± 0.697; however, this change was not statistically significant ($t = 1.06$, $p = 0.290$), suggesting that platelet function rather than platelet count may be affected during CPB.

Table 3: Pre- and Post-Operative Comparison of Laboratory Parameters

Variable	Pre-Operative (Mean ± SD)	Post-Operative (Mean ± SD)	t-value	p-value
Hemoglobin (Hb)	3.04 ± 1.338	2.41 ± 0.847	3.96	0.000***
Total Leukocyte Count (TLC)	1.89 ± 0.560	2.26 ± 0.764	-2.75	0.008**
Red Blood Cells (RBC)	1.92 ± 0.777	2.36 ± 0.734	-3.55	0.001***
Prothrombin Time (PT)	1.79 ± 0.686	2.21 ± 0.686	-3.51	0.001***
International Normalized Ratio (INR)	1.70 ± 0.794	2.08 ± 0.795	-3.04	0.003**
Activated Partial Thromboplastin Time (APTT)	1.78 ± 0.768	2.52 ± 0.988	-5.92	0.000***
Platelets	2.12 ± 0.816	1.99 ± 0.697	1.06	0.290
Neutrophils	1.99 ± 0.754	2.11 ± 0.809	-0.95	0.344
Lymphocytes	2.08 ± 0.812	1.79 ± 0.745	2.18	0.032*

*Note: *p < 0.05 (significant), **p < 0.01 (moderately significant), ***p < 0.001 (highly significant)*

Comparison of pre- and post-operative laboratory parameters demonstrated significant prolongation of PT, INR, and APTT following cardiopulmonary bypass. Haemoglobin levels decreased significantly, whereas total leukocyte count increased, reflecting perioperative hemodilution and inflammatory activation. Platelet count and neutrophil count did not differ significantly, while lymphocyte counts showed a modest but statistically significant reduction.

Figure 4: Comparison of Coagulation Parameters

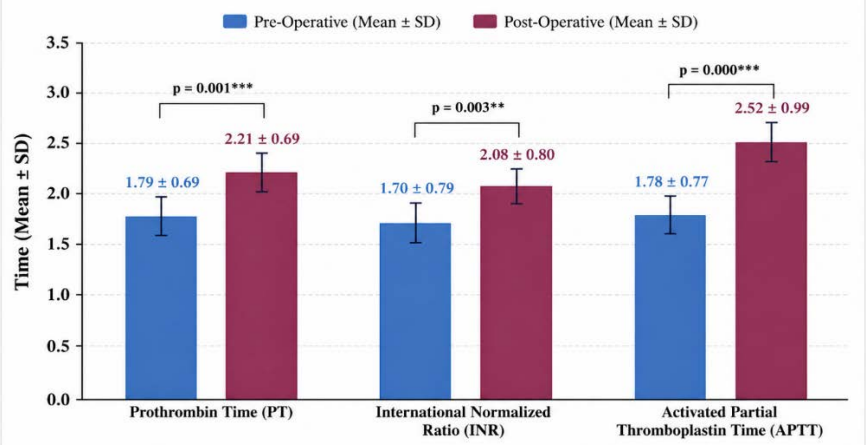


Figure 4 illustrates consistent post-operative increases in all three coagulation indices. Activated partial thromboplastin time exhibited the greatest magnitude of change, followed by prothrombin time and INR, supporting the significant coagulation disturbances associated with cardiopulmonary bypass.

DISCUSSION

The present study evaluated perioperative changes in coagulation and hematological parameters among patients undergoing cardiac surgery with cardiopulmonary bypass (CPB). The findings demonstrated significant postoperative alterations in coagulation profile, characterized by prolonged prothrombin time (PT), international normalized ratio (INR), and activated partial thromboplastin time (APTT). In addition, significant changes were observed in hemoglobin concentration, total leukocyte count, and lymphocyte count, whereas platelet and neutrophil counts did not change significantly. Collectively, these findings indicate that CPB is associated with substantial disturbances in hemostatic function and inflammatory response during the immediate postoperative period.

One of the principal findings of this study was the significant prolongation of PT following CPB. Prothrombin time is a well-established indicator of the integrity of the extrinsic coagulation pathway, and

postoperative prolongation reflects impaired clotting factor activity resulting from haemodilution, consumption of coagulation factors, systemic anticoagulation, and activation of fibrinolytic pathways during extracorporeal circulation (3,5,7). Similar observations have been reported in previous investigations demonstrating that CPB prolongs coagulation times and contributes to increased postoperative bleeding risk (10–12). The present findings therefore support the existing evidence that PT remains an important laboratory parameter for perioperative assessment of coagulation status in patients undergoing cardiac surgery.

Consistent with the PT findings, both INR and APTT increased significantly following surgery. Although INR is derived from PT, its standardized calculation facilitates comparison of coagulation status across laboratories and remains valuable in perioperative hemostatic assessment. The marked prolongation of APTT observed in this study suggests that CPB also substantially affects the intrinsic coagulation pathway. These alterations are likely attributable to systemic heparinization, activation and subsequent consumption of coagulation factors, haemodilution, and inflammatory activation associated with extracorporeal circulation (4,6,13). Previous studies have similarly demonstrated significant postoperative prolongation of INR and APTT following CPB, supporting the consistency of the present findings with established evidence (11,14,18).

The observed reduction in hemoglobin concentration is consistent with the well-recognized phenomenon of haemodilution during cardiopulmonary bypass. Priming solutions used within the extracorporeal circuit increase circulating plasma volume and dilute erythrocytes and coagulation factors, thereby reducing measured hemoglobin concentration during the perioperative period (7,15). Haemodilution, together with intraoperative blood loss and activation of coagulation pathways, contributes to postoperative anemia and may increase the need for blood transfusion in selected patients. Careful perioperative fluid management and individualized transfusion strategies therefore remain important components of modern cardiac surgical practice.

The present study also demonstrated a significant increase in total leukocyte count following CPB, indicating activation of the systemic inflammatory response. Exposure of blood to the artificial surfaces of the extracorporeal circuit initiates activation of complement pathways, leukocytes, cytokines, and endothelial cells, resulting in a generalized inflammatory reaction (6,16). This inflammatory response contributes not only to postoperative immune activation but also to endothelial dysfunction and secondary disturbances in coagulation. The concomitant reduction in lymphocyte count observed in the present study further supports perioperative immunological alterations associated with CPB and is consistent with previous reports describing transient postoperative lymphocyte suppression following major cardiac surgery (16,21).

Although platelet count demonstrated a slight postoperative reduction, the difference did not reach statistical significance. This observation is consistent with studies suggesting that platelet dysfunction, rather than platelet depletion alone, is primarily responsible for CPB-associated bleeding complications (17–20). During extracorporeal circulation, platelet activation, adhesion, and degranulation may impair platelet function despite relatively preserved circulating platelet numbers. Consequently, quantitative platelet counts may underestimate the degree of hemostatic impairment, emphasizing the importance of functional platelet assessment when clinically indicated.

Overall, the findings of the present study are consistent with previous investigations demonstrating that CPB induces multifactorial alterations in hemostasis through haemodilution, anticoagulation, inflammatory activation, platelet dysfunction, and coagulation factor consumption (5,12,18). The agreement between the present results and published literature supports the biological plausibility of the observed perioperative coagulation changes and reinforces the importance of routine coagulation monitoring in patients undergoing cardiac surgery with cardiopulmonary bypass.

From a clinical perspective, early identification of coagulation abnormalities may facilitate timely correction of hemostatic disturbances and contribute to reducing postoperative bleeding, transfusion requirements, and associated complications. Routine assessment of PT, INR, and APTT remains an important component of perioperative monitoring, particularly in patients at increased risk of coagulopathy. Individualized anticoagulation management, combined with careful interpretation of laboratory findings, may improve perioperative decision-making and optimize patient outcomes.

The present study has several strengths. It evaluated multiple coagulation and hematological parameters using paired pre-operative and post-operative measurements obtained from the same patients, thereby reducing inter-individual variability. Furthermore, the study provides valuable regional data from tertiary cardiac care centers in Pakistan, where published evidence regarding perioperative coagulation changes remains comparatively limited.

Several limitations should also be acknowledged. First, the study was conducted in two hospitals with a relatively modest sample size, which may limit the generalizability of the findings to broader populations. Second, laboratory assessment was restricted to conventional coagulation tests; more comprehensive evaluation using viscoelastic assays or platelet function testing was not available. Third, only immediate perioperative laboratory changes were evaluated, and long-term clinical outcomes such as postoperative bleeding volume, transfusion requirements, thromboembolic events, or mortality were not assessed. Finally, multivariable analyses to account for potential confounding factors were beyond the scope of the present investigation. Future multicenter studies with larger sample sizes, advanced hemostatic assessment, and longitudinal follow-up are recommended to further characterize CPB-induced coagulation disturbances and their clinical implications.

CONCLUSION

Cardiopulmonary bypass was associated with significant perioperative alterations in coagulation and selected hematological parameters among patients undergoing elective cardiac surgery. Significant postoperative prolongation of prothrombin time, international normalized ratio, and activated partial thromboplastin time indicates impairment of both the intrinsic and extrinsic coagulation pathways following CPB. In addition, significant changes in hemoglobin concentration, total leukocyte count, and lymphocyte count reflect the combined effects of haemodilution and systemic inflammatory activation associated with extracorporeal circulation. Platelet and neutrophil counts did not demonstrate statistically significant perioperative changes in this study. These findings support the importance of routine perioperative coagulation assessment and careful hemostatic monitoring to facilitate timely clinical decision-making and optimize the management of patients undergoing cardiac surgery with cardiopulmonary bypass.

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