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Corrected: Association Between Preoperative Fibrinogen Levels and Postoperative Morbidity and Mortality After On-Pump Cardiac Surgery: A Comparative Observational Study

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This article has been corrected.

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The conclusions section of the abstract has been corrected to show that Group B (preoperative fibrinogen ⩾3.3 g/L) had significantly higher intraoperative and postoperative blood loss, as well as greater whole-blood and fresh frozen plasma transfusion requirements compared with Group A.

Abstract

Background

Preoperative fibrinogen concentrations may be associated with bleeding, transfusion requirements, and postoperative outcomes following cardiac surgery. However, the relationship between fibrinogen levels and postoperative morbidity remains incompletely understood.

Objective

This study aims to evaluate the association between preoperative fibrinogen concentrations and postoperative morbidity and mortality in patients undergoing on-pump cardiac surgery.

Methods

This comparative observational study was conducted at the National Institute of Cardiovascular Diseases (NICVD), Dhaka, Bangladesh, from July 2023 to June 2024. A total of 100 adult patients undergoing on-pump cardiac surgery were included and classified into two groups according to their preoperative fibrinogen concentrations: Group A, fibrinogen < 3.3 g/L (n = 50), and Group B, fibrinogen ⩾ 3.3 g/L (n = 50). Continuous variables were compared using the independent-samples t-test, while categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. A two-sided p-value ⩽ 0.05 was considered statistically significant.

Results

The mean preoperative fibrinogen concentrations were 2.89 ± 0.25 g/L in Group A and 4.05 ± 0.44 g/L in Group B (p < 0.001). The groups had comparable demographic characteristics and operative durations. Mean intraoperative and postoperative blood loss was significantly higher in Group B than in Group A (645.16 ± 397.86 vs. 385.90 ± 281.77 mL, p = 0.001). Whole-blood transfusion requirements were significantly higher in Group B than in Group A (3.59 ± 0.48 vs. 2.85 ± 0.74 units, p = 0.001), whereas fresh frozen plasma (FFP) requirements were significantly higher in Group B than in Group A (2.10 ± 0.64 vs. 1.42 ± 0.67 units, p = 0.001). Prolonged inotropic support involving at least two inotropic agents for more than 24 hours was significantly more frequent in Group B than in Group A (58.0% vs. 30.0%, p = 0.005). Differences in re-exploration for bleeding (14.0% vs. 2.0%, p = 0.059), acute kidney injury (AKI; 24.0% vs. 8.0%, p = 0.054), and cardiac tamponade (8.0% vs. 0%, p = 0.118) were not statistically significant. Group B also had significantly longer mean intensive care unit stays (7.56 ± 2.18 vs. 4.16 ± 1.51 days) and postoperative hospital stays (12.34 ± 3.05 vs. 8.24 ± 1.52 days) (both p < 0.001). Operative mortality occurred in 2/50 (4.0%) patients in Group B and 1/50 (2.0%) patient in Group A, with no statistically significant difference (p = 1.000).

Conclusion

Preoperative fibrinogen concentrations ⩾ 3.3 g/L were associated with greater perioperative blood loss, higher whole-blood and FFP transfusion requirements, more frequent prolonged inotropic support, and longer intensive care unit and postoperative hospital stays. Differences in re-exploration for bleeding, AKI, cardiac tamponade, and operative mortality were not statistically significant. These findings represent unadjusted associations and do not establish causality or independent prognostic value.

Categories: Cardiac/Thoracic/Vascular Surgery
Keywords: cardiac surgery, cardiopulmonary bypass, fibrinogen, mortality, postoperative complications

Introduction

Cardiac surgery performed with cardiopulmonary bypass (CPB) is associated with substantial changes in hemostasis, inflammation, and organ perfusion. Contact between blood and the extracorporeal circuit, hemodilution, platelet dysfunction, and alterations in coagulation and fibrinolysis may contribute to postoperative bleeding and other complications. Identifying preoperative factors associated with adverse outcomes is therefore important for perioperative assessment and management [1,2].

Fibrinogen is a circulating glycoprotein that is converted by thrombin into fibrin during clot formation. It also contributes to platelet aggregation and clot strength. Both the concentration and functional activity of fibrinogen may influence perioperative hemostasis. Previous studies have investigated the relationship between preoperative fibrinogen levels and postoperative bleeding, transfusion requirements, and clinical outcomes after cardiac surgery, although the findings have varied according to patient populations, surgical techniques, and the timing and method of fibrinogen measurement [3,4].

The relationship between fibrinogen and postoperative outcomes may not be straightforward. Fibrinogen is also an acute-phase reactant, and an elevated concentration may reflect an inflammatory state rather than a direct impairment of hemostasis. Previous research has examined the association between inflammatory status and outcomes after cardiac surgery as well as the relationship between preoperative fibrinogen concentrations and hospital length of stay [5]. Consequently, fibrinogen concentration should be interpreted in the context of the patient's clinical condition and other perioperative risk factors.

Postoperative complications following cardiac surgery include bleeding requiring re-exploration, cardiac tamponade, low cardiac output syndrome, acute kidney injury (AKI), prolonged inotropic support, and death. Transfusion requirements and duration of ICU and hospital stays are also important indicators of postoperative resource utilization and recovery. Investigating the relationship between preoperative fibrinogen concentrations and these outcomes may help clarify whether fibrinogen measurement provides useful information during preoperative assessment [6,7].

Preoperative fibrinogen levels may provide important information about a patient's hemostatic and inflammatory status before cardiac surgery. Fibrinogen plays a central role in clot formation by serving as the precursor of fibrin, which forms the structural framework of a stable blood clot. Its circulating concentration may be influenced by several factors, including systemic inflammation, underlying cardiovascular conditions, hepatic function, and other physiological changes. Alterations in fibrinogen levels may affect clot stability, coagulation activity, and the balance between bleeding and thrombotic tendencies during the perioperative period. Furthermore, variations in baseline fibrinogen concentrations may reflect differences in patients' underlying clinical conditions and physiological responses to surgical stress. Therefore, the prognostic significance of preoperative fibrinogen may vary across patient populations and clinical settings, particularly in relation to perioperative blood loss, transfusion requirements, postoperative complications, and recovery following cardiac surgery [8-10].

This study aimed to compare postoperative morbidity, mortality, transfusion requirements, and lengths of ICU and hospital stays between patients with preoperative fibrinogen concentrations below 3.3 g/L and those with concentrations of 3.3 g/L or higher who underwent on-pump cardiac surgery at the National Institute of Cardiovascular Diseases (NICVD), Dhaka, Bangladesh.

Materials And Methods

Study design and setting

This comparative observational study was conducted in the Department of Cardiac Surgery at the NICVD, Dhaka, Bangladesh, from July 1, 2023, to June 30, 2024. The study evaluated the association between preoperative fibrinogen concentrations and postoperative outcomes among adult patients undergoing on-pump cardiac surgery using CPB.

Study population and sample size

The study population consisted of adult patients undergoing on-pump cardiac surgery at NICVD during the study period. The sample size was calculated using the formula for comparing two independent proportions:

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 [P_1(1 - P_1) + P_2(1 - P_2)]}{(P_1 - P_2)^2}$$

where n represents the required sample size in each group, $Z_{\alpha/2}$ is the standard normal deviate corresponding to a two-sided significance level of 5% (1.96), and Z_{β} is the standard normal deviate corresponding to 80% statistical power (0.84). P_1 represents the incidence of postoperative infection in patients with normal preoperative fibrinogen concentrations (5.6% or 0.056), and P_2 represents the incidence of postoperative complications in patients with elevated preoperative fibrinogen concentrations (18.9% or 0.189), based on the findings of D'Agostino et al. [11].

Substituting these values into the formula:

$$n = \frac{(1.96 + 0.84)^2 [0.056(1 - 0.056) + 0.189(1 - 0.189)]}{(0.056 - 0.189)^2}$$

$$n = \frac{7.84(0.05286 + 0.15328)}{0.017689}$$

$$n = \frac{1.6158}{0.017689}$$

$$n = 91.34 \approx 92$$

The calculated sample size was 92 patients in each group, giving a total of 184 patients. However, considering the available study period and recruitment constraints, 100 patients were enrolled, comprising 50 patients in each group, in accordance with the approved study protocol.

Sampling technique and grouping of patients

Eligible patients were recruited consecutively through convenience sampling during the study period, subject to the availability of preoperative fibrinogen measurements and fulfillment of the eligibility criteria. Patients were classified into two groups according to their preoperative serum fibrinogen concentrations. Group A consisted of 50 patients with preoperative fibrinogen concentrations below 3.3 g/L, whereas Group B consisted of 50 patients with preoperative fibrinogen concentrations of 3.3 g/L or higher. The equal group sizes reflected the final recruitment and selection process under the approved study protocol and did not result from random allocation.

The 3.3 g/L threshold was used as the predefined operational cutoff for group classification in this study according to institutional protocol. The institutional laboratory reference interval for fibrinogen was 2.0-4.0 g/L; therefore, the ⩾3.3 g/L category included some values within the laboratory reference interval. This cutoff should be interpreted as a study-defined grouping threshold rather than a validated diagnostic threshold for hyperfibrinogenemia.

Selection criteria

Inclusion Criteria

Adult patients aged 18-69 years with cardiac diseases who underwent on-pump cardiac surgery using CPB at NICVD during the study period were included.

Exclusion Criteria

Patients with severe left ventricular systolic dysfunction (left ventricular ejection fraction ⩽ 30%), those requiring left ventricular assist device implantation, and those with a previous history of cardiac surgery involving CPB were excluded. Patients with acute myocardial infarction, cerebrovascular accident, or percutaneous coronary intervention within 30 days before surgery were also excluded.

Patients with acute infection, autoimmune disease, malignancy, hematologic proliferative disease, systemic inflammatory disease, or preoperative hemoglobin concentration below 10 g/dL were excluded. Patients receiving steroid treatment or chemotherapy and those with chronic obstructive pulmonary disease or thyroid disorders, including hypothyroidism and hyperthyroidism, were also excluded.

Patients undergoing emergency cardiac surgery or coronary artery bypass grafting without CPB were

excluded. Reoperation for hemodynamic instability or bleeding and intra-aortic balloon pump requirement were also listed in the original exclusion criteria. These conditions were considered exclusions only when present before enrollment; postoperative events were retained as study outcomes.

Measurement of preoperative fibrinogen

Preoperative plasma fibrinogen concentration was measured one day before surgery using the Clauss method on an automated Sysmex coagulation analyzer. Dade® Thrombin Reagent (Siemens Healthineers, Erlangen, Germany) was used for the functional fibrinogen assay. The method is based on the principle that fibrinogen concentration is inversely proportional to clotting time following the addition of excess thrombin to diluted platelet-poor plasma at 37°C. Fibrinogen concentration was determined from a calibration curve established using Standard Human Plasma (SHP) calibrator. The assay was performed using the analyzer's automated Clauss fibrinogen application, incorporating plasma dilution and clot detection. Fibrinogen concentrations were expressed in g/L.

Perioperative variables and outcome assessment

Demographic and clinical characteristics, including age, sex, smoking status, diabetes mellitus, hypertension, and preoperative laboratory findings, were recorded. Intraoperative variables included operative duration, aortic cross-clamp time, and CPB time.

All patients were followed up throughout their postoperative hospital stay until discharge or death. The primary outcome was postoperative morbidity, defined as the occurrence of one or more postoperative complications during the in-hospital observation period. The assessed complications included re-exploration for bleeding, cardiac tamponade, low cardiac output syndrome, AKI, and prolonged inotropic support.

Blood-product transfusion was guided by the institutional cardiac surgery transfusion protocol and the clinical assessment of the treating surgical and anesthesia teams. Transfusion requirements were recorded separately for packed red blood cells, fresh frozen plasma, platelet concentrates, and whole blood, where applicable.

Postoperative cardiac tamponade was identified based on clinical evidence of hemodynamic compromise, supported by echocardiographic findings or surgical confirmation of pericardial blood or fluid accumulation causing cardiac compression. Low cardiac output syndrome was identified based on clinical evidence of inadequate systemic perfusion associated with reduced cardiac output, requiring pharmacological or mechanical circulatory support, according to the treating cardiac surgical team's assessment.

Prolonged inotropic support was defined as the requirement for at least two inotropic agents for more than 24 hours. Baseline serum creatinine was defined as the most recent preoperative serum creatinine measurement obtained before surgery. Postoperative serum creatinine measurements and hourly urine output were monitored during the postoperative hospital stay. The preoperative creatinine value was used as the reference for identifying changes in serum creatinine according to the KDIGO (Kidney Disease: Improving Global Outcomes) criteria [12]. Urine output was assessed in relation to body weight and duration of oliguria.

Secondary outcomes included operative mortality, blood-product transfusion requirements, duration of intensive care unit (ICU) stay, and postoperative hospital stay. Operative mortality was recorded during the in-hospital observation period.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics, version 27 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages (n (%)). Between-group comparisons of continuous variables were performed using the independent-samples t-test. Categorical variables were compared using the Pearson chi-square test or Fisher's exact test, as appropriate, based on expected cell frequencies.

A two-sided p-value $\leqslant 0.05$ was considered statistically significant. The analyses consisted of unadjusted comparisons between the two fibrinogen groups. No multivariable regression analysis was performed; therefore, the findings were interpreted as unadjusted associations rather than evidence of independent prognostic effects. No adjustment for multiple comparisons was performed, and the possibility of false-positive findings from multiple outcome comparisons was considered when interpreting the results.

Ethical considerations

Ethical approval was obtained from the Institutional Ethical Review Committee of the NICVD, Dhaka, Bangladesh (Memo No.: NICVD/Academic/Ethical/2023/52; approval date: June 5, 2023). The study was conducted in accordance with the ethical principles governing human research. Written informed consent

was obtained from participants in accordance with the approved research protocol. Patient confidentiality was maintained throughout data collection, analysis, and reporting.

Results

The study included 100 patients, with 50 patients in each fibrinogen group. The mean age was 43.52 ± 16.63 years in Group A and 44.32 ± 18.01 years in Group B. There were no statistically significant differences between the groups in age (p = 0.818), sex distribution (p = 0.410), smoking status (p = 0.529), diabetes mellitus (p = 0.548), or hypertension (p = 0.300), indicating comparable baseline demographic and clinical characteristics (Table *1*).

Characteristics	Group A (n = 50)	Group B (n = 50)	Test statistic (df)	p-value
Age, years, mean ± SD	43.52 ± 16.63	44.32 ± 18.01	t = −0.231 (98)	0.818
Male sex, n (%)	29 (58.0)	33 (66.0)	χ^2 = 0.679 (1)	0.410
Smoking, n (%)	16 (32.0)	19 (38.0)	χ^2 = 0.396 (1)	0.529
Diabetes mellitus, n (%)	25 (50.0)	28 (56.0)	χ^2 = 0.361 (1)	0.548
Hypertension, n (%)	29 (58.0)	34 (68.0)	χ^2 = 1.073 (1)	0.300

TABLE 1: Comparison of baseline demographic and clinical characteristics between the two study groups

Data are presented as mean ± standard deviation (SD) for continuous variables and as frequency and percentage, n (%), for categorical variables. Group differences were evaluated using an independent-samples t-test for continuous data and Pearson's chi-squared (χ^2) test for categorical data. p-value ≤ 0.05 was considered significant.

The mean preoperative fibrinogen concentration was significantly lower in Group A than in Group B (2.89 ± 0.25 vs. 4.05 ± 0.44 g/L, p < 0.001). Platelet counts (250.60 ± 26.99 vs. 256.64 ± 51.49) and hemoglobin concentrations (12.96 ± 2.07 vs. 12.80 ± 2.80 g/dL) did not differ significantly between the groups. Similarly, no statistically significant differences were observed in the duration of surgery (4.68 ± 0.73 vs. 4.74 ± 0.78 hours), aortic cross-clamp time (62.80 ± 25.63 vs. 64.14 ± 25.27 minutes), or CPB time (107.94 ± 26.73 vs. 108.58 ± 32.33 minutes) (Table *2*).

Variables	Group A (n = 50)	Group B (n = 50)	Test statistic (df)	p-value
Fibrinogen, g/L (Reference range: 2.0–4.0 g/L)	2.89 ± 0.25	4.05 ± 0.44	t = −16.27 (98)	< .001
Platelet count, $\times 10^3/mm^3$ (Reference range:150–400 $\times 10^3/mm^3$)	250.60 ± 26.99	256.64 ± 51.49	t = −0.73 (98)	.467
Hemoglobin, g/dL (Reference range: Male, 13.5–17.5g/dL; female, 12.0–15.5 gm/dL)	12.96 ± 2.07	12.80 ± 2.80	t = 0.32 (98)	.750
Duration of surgery, hours	4.68 ± 0.73	4.74 ± 0.78	t = −0.40 (98)	.690
Aortic cross-clamp time, minutes	62.80 ± 25.63	64.14 ± 25.27	t = −0.26 (98)	.795
CPB time, minutes	107.94 ± 26.73	108.58 ± 32.33	t = −0.11 (98)	.913

TABLE 2: Comparison of preoperative laboratory parameters and intraoperative characteristics between patients with low and high preoperative fibrinogen levels

All continuous variables are expressed as mean ± standard deviation (SD). Between-group comparisons were performed using the independent-samples t-test, with the corresponding t-statistics and degrees of freedom (df) reported. CPB time represents the total duration of CPB, while aortic cross-clamp time represents the duration of aortic occlusion during surgery. A two-sided p-value of less than 0.05 was considered statistically significant.

CPB: Cardiopulmonary bypass.

Intraoperative and postoperative blood loss was significantly higher in Group B than in Group A (645.16 ±

397.86 vs. 385.90 ± 281.77 mL, p = 0.001). Conversely, Group B had significantly higher mean whole-blood transfusion requirements (3.59 ± 0.48 vs. 2.85 ± 0.74 units, p = 0.001) and fresh frozen plasma (FFP) requirements (2.10 ± 0.64 vs. 1.42 ± 0.67 units, p = 0.001).

Prolonged inotropic support involving at least two inotropes for more than 24 hours was significantly more frequent in Group B than in Group A (29/50 (58.0%) vs. 15/50 (30.0%), p = 0.005). However, the differences in re-exploration for bleeding (7/50 (14.0%) vs. 1/50 (2.0%), p = 0.059), AKI (12/50 (24.0%) vs. 4/50 (8.0%), p = 0.054), and cardiac tamponade (4/50 (8.0%) vs. 0/50 (0.0%), p = 0.118) were not statistically significant. Low cardiac output syndrome was observed in 3/50 (6.0%) patients in Group B and 1/50 (2.0%) patient in Group A (p = 0.617). Operative mortality occurred in 2/50 (4.0%) patients in Group B and 1/50 (2.0%) patient in Group A, with no statistically significant difference (p = 1.000) (Table *3*).

Outcome variable	Group A (n = 50)	Group B (n = 50)	Test statistic (df)	p-value
Hematological and surgical metrics (mean ± SD)				
Intraoperative/postoperative blood loss, mL	385.90 ± 281.77	645.16 ± 397.86	t = 3.76 (98)	0.001
Whole-blood units	2.85 ± 0.74	3.59 ± 0.48	t = −5.94 (98)	0.001
Fresh frozen plasma units	1.42 ± 0.67	2.10 ± 0.64	t = −5.19 (98)	0.001
Clinical frequencies, n (%)				
Re-exploration for bleeding	1 (2.0%)	7 (14.0%)	Fisher's exact	0.059
Acute kidney injury	4 (8.0%)	12 (24.0%)	Fisher's exact	0.054
Cardiac tamponade	0 (0.0%)	4 (8.0%)	Fisher's exact	0.118
Low cardiac output syndrome	1 (2.0%)	3 (6.0%)	Fisher's exact	0.617
At least two inotropes for >24 hours	15 (30.0%)	29 (58.0%)	χ^2 = 7.95 (1)	0.005
Operative mortality	1 (2.0%)	2 (4.0%)	Fisher's exact	1.000

TABLE 3: Comparison of perioperative outcomes and postoperative complications of study population

Data are presented as mean ± standard deviation (SD) for continuous variables and as frequency and percentage, n (%), for categorical variables. Group comparisons were evaluated using an independent-samples t-test for continuous data and Pearson's chi-squared (χ^2) test or Fisher's exact test for categorical data. Statistical significance was defined as $p < 0.05$.

df: Degrees of freedom.

The mean ICU stay was 4.16 ± 1.51 days in Group A and 7.56 ± 2.18 days in Group B (p < 0.001). The mean postoperative hospital stay was 8.24 ± 1.52 days in Group A and 12.34 ± 3.05 days in Group B (p < 0.001). Thus, the group with preoperative fibrinogen concentrations ⩾3.3 g/L had longer reported ICU and postoperative hospital stays.

Discussion

The present study compared perioperative and postoperative outcomes among patients undergoing on-pump cardiac surgery with preoperative fibrinogen concentrations below 3.3 g/L and those with concentrations ⩾3.3 g/L. The principal findings were significantly greater intraoperative and postoperative blood loss, higher whole-blood and FFP requirements, prolonged inotropic support, and longer ICU and postoperative hospital stays in patients with fibrinogen concentrations ⩾3.3 g/L. Although re-exploration for bleeding, AKI, and cardiac tamponade were numerically more frequent in this group, these differences did not reach statistical significance. Operative mortality was uncommon and comparable between the groups. These findings suggest an association between higher preoperative fibrinogen concentrations, increased perioperative resource utilization, and selected postoperative outcomes, although the underlying mechanisms require further investigation.

The relationship between fibrinogen concentration and postoperative bleeding following cardiac surgery is complex. Fibrinogen plays an essential role in fibrin formation, platelet aggregation, and clot stability. Reduced fibrinogen availability or impaired fibrin polymerization may contribute to excessive bleeding. Previous studies have investigated the association between fibrinogen concentrations and postoperative

blood loss following coronary artery bypass grafting and other cardiac procedures [6,8,13]. A systematic review and meta-analysis also evaluated the relationship between preoperative and postoperative fibrinogen concentrations and blood loss after cardiac surgery [14]. These findings support the importance of assessing fibrinogen as part of perioperative hemostatic evaluation.

Nevertheless, the findings of the present study require cautious interpretation because Group B was defined by fibrinogen concentrations ⩾3.3 g/L rather than by reduced concentrations. Therefore, the higher frequency of certain complications in this group does not establish that elevated fibrinogen directly causes bleeding or organ dysfunction. Fibrinogen is an acute-phase reactant, and increased concentrations may reflect underlying inflammation or differences in patients' clinical conditions. Previous research has examined the influence of preoperative inflammatory status on outcomes following cardiac surgery [15]. As the present comparisons were unadjusted, the independent contribution of fibrinogen cannot be distinguished from potential confounding by other clinical and operative characteristics.

In the present study, patients with fibrinogen concentrations ⩾3.3 g/L had significantly greater intraoperative and postoperative blood loss than those with concentrations below this threshold (645.16 ± 397.86 vs. 385.90 ± 281.77 mL, p = 0.001). This difference was accompanied by significantly higher whole-blood and FFP requirements in Group B. The mean whole-blood requirement was 3.59 ± 0.48 units compared with 2.85 ± 0.74 units in Group A, while the corresponding FFP requirements were 2.10 ± 0.64 and 1.42 ± 0.67 units, respectively (both p = 0.001). These findings demonstrate greater transfusion requirements among patients with higher preoperative fibrinogen concentrations. Nevertheless, elevated fibrinogen should not be interpreted as a direct cause of increased bleeding. Therefore, the observed differences may reflect the combined influence of inflammatory, clinical, and perioperative factors rather than fibrinogen concentration alone.

Cardiac tamponade occurred in four patients (8.0%) in Group B, whereas no cases were recorded in Group A. Despite this numerical difference, the between-group comparison was not statistically significant (p = 0.118). The small number of events limits the precision of this comparison. Cardiac tamponade following cardiac surgery may result from postoperative bleeding, accumulation of pericardial fluid, or other surgical and hemodynamic complications. Therefore, the observed distribution should be interpreted as a descriptive finding rather than evidence of an established association with higher fibrinogen concentrations. Fisher's exact test was used to evaluate this outcome because of the small expected cell frequencies.

AKI was more frequent in Group B. Cardiac surgery-associated AKI is multifactorial and may result from hemodynamic instability, systemic inflammation, hemolysis, embolic events, and impaired renal perfusion [16]. The present findings demonstrate only an unadjusted association and do not establish fibrinogen as an independent predictor of renal dysfunction. The KDIGO criteria incorporate changes in serum creatinine and urine output. In this study, both parameters were monitored during postoperative hospitalization, and the diagnostic criteria applied to classify AKI should be clearly specified.

Prolonged inotropic support was also more frequent in Group B, potentially reflecting postoperative cardiovascular instability or differences in recovery. However, baseline cardiac function, procedural complexity, and perioperative hemodynamic factors may also have contributed. Although operative duration, aortic cross-clamp time, and CPB time did not differ significantly, residual confounding cannot be excluded.

The mean ICU stay was significantly longer in Group B than in Group A (7.56 ± 2.18 vs. 4.16 ± 1.51 days, p < 0.001). Similarly, postoperative hospital stay was longer among patients with fibrinogen concentrations ⩾3.3 g/L (12.34 ± 3.05 vs. 8.24 ± 1.52 days, p < 0.001). These differences may be related to the greater blood loss, increased transfusion requirements, and higher frequency of prolonged inotropic support observed in Group B. Previous research has also evaluated preoperative fibrinogen as a potential predictor of hospital length of stay following coronary artery bypass grafting [5]. However, ICU and hospital stays are influenced by multiple factors, including postoperative complications, underlying comorbidities, recovery of organ function, rehabilitation requirements, and institutional discharge practices. Consequently, the longer stays observed in Group B cannot be attributed exclusively to differences in fibrinogen concentrations.

Clinically, preoperative fibrinogen measurement may contribute to the overall assessment of patients undergoing cardiac surgery when interpreted alongside other clinical and laboratory parameters. However, these findings do not justify treatment changes based solely on the 3.3 g/L threshold or suggest that lowering fibrinogen would improve postoperative outcomes.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the relatively small sample size of 100 patients from a single center limits the precision of the estimates and the generalizability of the results. The achieved sample size was smaller than the originally calculated requirement of 184 patients, potentially reducing the statistical power to detect differences in clinical outcomes. Second, the convenience sampling technique and observational study design may have

introduced selection bias and residual confounding. The analyses were limited to unadjusted between-group comparisons; therefore, the potential influence of baseline characteristics, comorbidities, and operative factors could not be adequately accounted for, and the independent prognostic value of preoperative fibrinogen could not be established. Third, categorization according to a single predefined cutoff of 3.3 g/L may have obscured potential associations across the continuous range of fibrinogen concentrations. Moreover, the small number of events for uncommon postoperative complications, including cardiac tamponade, low cardiac output syndrome, and operative mortality, limits the reliability and precision of comparisons for these outcomes. Fourth, the sample-size calculation was based on previously reported postoperative infection rates, whereas the present study evaluated a broader range of perioperative outcomes. This difference between the sample-size assumptions and the outcomes assessed should be considered when interpreting the statistical findings. Finally, the study did not evaluate the effects of fibrinogen-guided perioperative interventions or establish whether modifying fibrinogen concentrations could improve clinical outcomes.

Future directions

Future research should involve adequately powered, multicenter prospective studies to further investigate the relationship between preoperative fibrinogen concentrations and postoperative outcomes following cardiac surgery. Fibrinogen should be evaluated as a continuous variable alongside predefined clinical thresholds to explore potential dose-response relationships. Future studies should also incorporate multivariable analyses to account for potential confounding factors, including baseline inflammatory status, comorbidities, cardiac function, and operative characteristics. Furthermore, investigations evaluating serial perioperative fibrinogen measurements and fibrinogen-guided management strategies may help clarify the clinical significance of altered fibrinogen concentrations and their potential role in improving postoperative outcomes.

Conclusions

In this comparative observational study of 100 patients undergoing on-pump cardiac surgery, preoperative fibrinogen concentrations ⩾3.3 g/L were associated with greater perioperative blood loss, higher whole-blood and FFP transfusion requirements, more frequent prolonged inotropic support, and longer ICU and postoperative hospital stays. Although re-exploration for bleeding, cardiac tamponade, and AKI were numerically more frequent in this group, these differences did not reach statistical significance. These findings suggest an association between higher preoperative fibrinogen concentrations and an increased perioperative resource and support burden; however, they do not establish causality or independent prognostic value. Given the observational design, limited sample size, and absence of adjusted analyses, the findings should be interpreted cautiously. Further adequately powered prospective studies are warranted to establish the prognostic significance of preoperative fibrinogen concentrations and determine their potential role in perioperative risk assessment in cardiac surgery.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Ethical Review Committee of National Institute of Cardiovascular Diseases issued approval (NICVD/Academic/Ethical/2023/52). **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **AI use statement:** The authors used ChatGPT (OpenAI, GPT-6) as follows: language polishing, structure or formatting in Introduction and Discussion. The authors used ChatGPT (OpenAI) to assist with language editing, improve clarity, and refine the manuscript. All AI-generated content was critically reviewed and verified by the authors. Clinical information, statistical results, and interpretations were cross-checked against the original study data and statistical analyses.

References were independently checked for accuracy and relevance. Necessary corrections were made, and the authors take full responsibility for the accuracy, integrity, and final content of the manuscript. The authors confirm that they have reviewed and verified all AI-assisted content and take full responsibility for the work. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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