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Original Research Article

COMPARISON OF POSTOPERATIVE CARDIAC ENZYME LEVELS IN ON-PUMP VERSUS OFF-PUMP CORONARY ARTERY BYPASS GRAFTING

NASRATULLAH*, RIAZ W, MIRZA BZ, NOOR M, IQBAL MB, ZEYAD H

Department of Cardiac Surgery, Punjab Institute of Cardiology, Lahore, Pakistan
**Corresponding author email address:* drnasratullahshafee786@gmail.com

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ABSTRACT

Background: *Coronary artery bypass grafting (CABG) remains a fundamental procedure for myocardial revascularization in patients with coronary artery disease. The two principal surgical approaches, on-pump CABG (ONCAB), which utilizes cardiopulmonary bypass, and off-pump CABG (OPCAB), performed on a beating heart, differ markedly in their physiological effects on myocardial tissue. Postoperative cardiac biomarkers, including CK-MB, Troponin I, and Troponin T, serve as sensitive indicators of perioperative myocardial injury.* ***Objective:*** *To compare postoperative cardiac enzyme levels between ONCAB and OPCAB procedures and determine the relative extent of myocardial injury associated with each technique.* ***Study Design:*** *Non-randomized controlled trial.* ***Settings:*** *Department of Cardiothoracic Surgery, Punjab Institute of Cardiology, Lahore, Pakistan.* ***Duration of Study:*** *11 April to 11 July 2025.* ***Methods:*** *Sixty-eight patients undergoing elective CABG were enrolled using non-probability, consecutive sampling, and allocated equally to the ONCAB and OPCAB groups. Baseline demographic characteristics, comorbidities, and body mass index were documented. Serum CK-MB, Troponin I, and Troponin T levels were measured preoperatively and at 1, 4, and 8 hours postoperatively. Data were analyzed using SPSS version 27. Independent t-tests and chi-square tests were applied, with $p \leq 0.05$ considered statistically significant.* ***Results:*** *The mean age of participants was 58.4 ± 6.8 years, and 79.4% were male. Common comorbidities included hypertension (61.8%), diabetes mellitus (55.9%), and hyperlipidemia (45.6%). Baseline enzyme values were statistically comparable between groups ($p > 0.05$). Postoperatively, mean CK-MB, Troponin I, and Troponin T levels at 1, 4, and 8 hours were significantly higher in the ONCAB group than in the OPCAB group ($p < 0.001$ for all). Stratified analysis revealed no significant influence of age, gender, BMI, or comorbidities on enzyme elevation, indicating procedure-related differences.* ***Conclusion:*** *On-pump CABG was associated with significantly greater postoperative elevation of cardiac enzymes compared with off-pump surgery, reflecting higher myocardial injury linked to cardiopulmonary bypass. The off-pump approach may thus offer superior myocardial protection and should be considered where technically feasible, particularly in high-risk populations with prevalent cardiovascular comorbidities in Pakistan.*

Keywords: Coronary Artery Bypass Grafting; On-Pump CABG; Off-Pump CABG; Cardiac Enzymes; Troponin; CK-MB; Myocardial Injury

INTRODUCTION

Coronary artery bypass grafting (CABG) is a widely performed surgical intervention aimed at improving myocardial perfusion in patients with significant coronary artery disease (CAD). Two primary techniques dominate this surgical landscape: on-pump CABG (ONCAB), which uses cardiopulmonary bypass (CPB), and off-pump CABG (OPCAB), which is performed without CPB. The choice of surgical approach has been a matter of considerable debate within the cardiothoracic surgical community, particularly regarding its implications for postoperative outcomes. Critical to these discussions are cardiac enzyme levels, specifically troponins and creatine kinase (CK), which serve as biomarkers for myocardial injury during the perioperative period.

High serum levels of cardiac enzymes postoperatively have been linked to worse clinical outcomes, including increased morbidity and mortality (1-3). ONCAB is associated with significant fluctuations in systemic and myocardial perfusion, exacerbated by ischemia during aortic cross-clamping, leading to elevated levels of these biomarkers compared with OPCAB patients, who avoid this stress (4, 5).

Recent studies have clarified this relationship. For instance, Eriş et al. demonstrated that a less invasive approach, such as OPCAB, significantly reduces enzyme release compared to ONCAB, not only because of reduced myocardial injury but also because of a diminished inflammatory response post-surgery (6-8). This finding is echoed by Bayram et al., who reported lower postoperative AST and ALT values in the off-pump cohort, reflecting better hepatic perfusion and a reduced systemic inflammatory response (9). Conversely, the ONCAB group often experiences heightened inflammatory responses due to CPB-related complications, which can further compromise patient recovery (4, 8).

Moreover, meta-analyses have synthesized data from multiple trials, revealing that while OPCAB can lead to favorable outcomes for enzymatic markers, these benefits may vary depending on patient demographics and comorbidities (1, 3), a pertinent consideration in diverse populations, such as those in Pakistan. For instance, tissue responses to ischemic conditions, driven by underlying conditions prevalent in certain demographics, could influence postoperative enzyme fluctuations observed during these surgeries, suggesting a need for tailored surgical approaches (10, 11).

Comparing postoperative morbidity across populations highlights these nuances. In studies focused on Pakistani patients, deviations in cardiac enzyme responses post-surgery reveal implications for evaluating interventions to optimize outcomes (11). Given Karachi's diverse urban population, variations due to socioeconomic status and access to pre-surgical management further necessitate localized guidelines that reflect these demographic factors (11).

The ongoing debates around the postoperative cardiac enzyme profiles in the context of ONCAB and OPCAB encapsulate a critical aspect of cardiac surgery a field committed to addressing the complexities of patient care in an individualized manner. As cities grow, it becomes crucial to investigate how regional health determinants affect surgical

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outcomes to establish guidelines that reduce global health disparities (12).

In summary, the nuanced interaction between surgical technique and postoperative cardiac enzyme levels reflects the complex pathophysiology of myocardial injury post-CABG. Further investigations, particularly within specific populations such as the Pakistani cohort, hold promise for identifying strategies to enhance surgical outcomes in a contextually relevant manner.

METHODOLOGY

This non-randomized controlled trial was conducted in the Department of Cardiac Surgery at the Punjab Institute of Cardiology, Lahore, Pakistan, over a period of three months, from 11 April to 11 July, following ethical approval from the institutional review board and the College of Physicians and Surgeons Pakistan (CPSP). The study aimed to compare postoperative cardiac enzyme levels, creatine kinase-MB (CK-MB), troponin I, and troponin T, among patients undergoing on-pump coronary artery bypass grafting (ONCAB) and off-pump coronary artery bypass grafting (OPCAB). A total of 68 patients scheduled for elective CABG were included in the study using a nonprobability, consecutive sampling technique, with 34 patients assigned to each group. Assignment to the on-pump or off-pump procedure was based on the clinical judgment and preference of the operating cardiac surgeon. All procedures were performed by the same surgical team under the supervision of two consultant cardiac surgeons, each with over five years of experience, ensuring procedural consistency and minimizing operator bias.

Patients of both genders aged between forty and eighty years were considered eligible for inclusion. Individuals undergoing re-operative CABG or presenting with contraindicating comorbidities such as advanced chronic kidney disease (stage IV or higher), severe chronic obstructive pulmonary disease, or a recent perioperative myocardial infarction were excluded from the study. Following informed written consent, baseline demographic and clinical information, including age, gender, height, weight, and comorbid conditions such as diabetes mellitus, hypertension, and hyperlipidemia, was recorded. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m²), and categorized according to standard World Health Organization criteria. The primary outcome measures included postoperative levels of CK-MB, troponin I, and troponin T, which were used as indicators of myocardial injury.

Blood samples were collected at four time points: preoperatively (baseline) and at 1, 4, and 8 hours postoperatively. Each sample comprised 10 mL of aseptically drawn venous blood, which was analyzed in the hospital laboratory for CK-MB, troponin I, and troponin T concentrations. Standardized biochemical assays were used for enzyme quantification to maintain analytical precision and reproducibility. For patients undergoing ONCAB, cardiopulmonary bypass was established through a standard aorto-atrial cannulation technique, with mild systemic hypothermia and cold blood cardioplegia for myocardial protection. In contrast, OPCAB procedures were performed on a beating heart using mechanical stabilizers and intracoronary shunts, without cardiopulmonary bypass. Both surgical techniques adhered to the institution's standardized protocols for anesthesia, perioperative monitoring, and postoperative management.

Data were compiled using a structured proforma specifically designed for this study. Continuous variables, including age, BMI, and enzyme levels, were summarized as mean ± standard deviation, whereas categorical variables, such as gender and comorbidities, were presented as frequencies and percentages. Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 27.0. Independent sample t-tests were applied to compare mean values of CK-MB, troponin I, and troponin T between the ONCAB and OPCAB groups at each time point. The chi-square test was used to analyze categorical variables. Stratified analyses were performed to assess potential confounding factors, including age, gender, BMI, diabetes mellitus, hypertension, and hyperlipidemia. For stratified comparisons, post-stratified independent t-tests and one-way analysis of variance (ANOVA) were applied, as appropriate. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

A total of 68 patients undergoing coronary artery bypass grafting (CABG) were included in the study, with 34 in each on-pump (ONCAB) and off-pump (OPCAB) group. The mean age of the study population was 58.4 ± 6.8 years, ranging from 44 to 75 years. The majority of the patients were male (n = 54, 79.4%), while 14 (20.6%) were female. The mean body mass index (BMI) was 27.3 ± 3.9 kg/m², with most patients falling into the overweight category. Comorbidities were common: hypertension in 61.8%, diabetes mellitus in 55.9%, and hyperlipidemia in 45.6% of patients. No statistically significant difference was found between the two groups for demographic variables ($p > 0.05$). (Table 1).

Postoperative enzyme levels were assessed at 1, 4, and 8 hours after surgery. Mean preoperative cardiac enzyme values were comparable between both groups ($p > 0.05$). However, at 1, 4, and 8 hours postoperatively, mean levels of CK-MB, Troponin I, and Troponin T were significantly higher in the ONCAB group than in the OPCAB group ($p < 0.001$ for all comparisons). (Table 2,3,4)

When stratified by age, gender, and BMI, enzyme levels followed a consistent pattern: ONCAB patients demonstrated higher postoperative enzyme release across all subgroups. No significant difference in enzyme levels was observed across subgroups of diabetes, hypertension, or hyperlipidemia ($p > 0.05$), suggesting that the observed elevation was predominantly procedure-related rather than comorbidity-driven. (Table 5).

Table 1: Demographic Characteristics of Study Participants (n = 68)

Variable	ONCAB (n = 34)	OPCAB (n = 34)	Total (n = 68)	p-value
Age (years, mean ± SD)	59.1 ± 7.2	57.6 ± 6.3	58.4 ± 6.8	0.38
Gender				
Male	27 (79.4%)	27 (79.4%)	54 (79.4%)	1.00
Female	7 (20.6%)	7 (20.6%)	14 (20.6%)	
BMI (kg/m², mean ± SD)	27.6 ± 4.0	27.0 ± 3.8	27.3 ± 3.9	0.57
Hypertension	22 (64.7%)	20 (58.8%)	42 (61.8%)	0.62
Diabetes Mellitus	20 (58.8%)	18 (52.9%)	38 (55.9%)	0.63
Hyperlipidemia	17 (50.0%)	14 (41.2%)	31 (45.6%)	0.48
Independent sample t-test and Chi-square test applied.				

Table 2: Comparison of Mean CK-MB Levels Between Groups

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Time Point	ONCAB (Mean ± SD) IU/L	OPCAB (Mean ± SD) IU/L	p-value
Pre-surgery	16.4 ± 5.2	15.8 ± 4.7	0.62
1 Hour Post-surgery	42.3 ± 15.6	25.5 ± 10.2	<0.001
4 Hours Post-surgery	58.7 ± 20.4	32.1 ± 12.7	<0.001
8 Hours Post-surgery	61.5 ± 21.8	34.6 ± 13.1	<0.001

Table 3: Comparison of Mean Troponin I Levels Between Groups

Time Point	ONCAB (Mean ± SD) ng/mL	OPCAB (Mean ± SD) ng/mL	p-value
Pre-surgery	0.018 ± 0.010	0.017 ± 0.008	0.67
1 Hour Post-surgery	0.68 ± 0.30	0.34 ± 0.18	<0.001
4 Hours Post-surgery	1.14 ± 0.50	0.49 ± 0.22	<0.001
8 Hours Post-surgery	1.32 ± 0.58	0.61 ± 0.28	<0.001

Table 4: Comparison of Mean Troponin T Levels Between Groups

Time Point	ONCAB (Mean ± SD) ng/mL	OPCAB (Mean ± SD) ng/mL	p-value
Pre-surgery	0.014 ± 0.006	0.013 ± 0.005	0.59
1 Hour Post-surgery	0.45 ± 0.21	0.23 ± 0.11	<0.001
4 Hours Post-surgery	0.72 ± 0.30	0.36 ± 0.16	<0.001
8 Hours Post-surgery	0.83 ± 0.33	0.41 ± 0.19	<0.001

Table 5: Stratified Comparison of 8-Hour CK-MB Levels by Age and Gender

Variable	Subgroup	ONCAB (Mean ± SD) IU/L	OPCAB (Mean ± SD) IU/L	p-value
Age Group	40–59 years	59.3 ± 20.1	33.8 ± 12.4	<0.001
	≥60 years	63.8 ± 22.6	35.4 ± 13.7	<0.001
Gender	Male	60.9 ± 21.7	34.2 ± 12.9	<0.001
	Female	62.8 ± 22.1	35.0 ± 13.8	<0.001

DISCUSSION

The present study aims to elucidate postoperative cardiac enzyme levels in patients undergoing on-pump coronary artery bypass grafting (ONCAB) versus off-pump coronary artery bypass grafting (OPCAB). Our study's findings indicate that patients in the ONCAB group exhibited significantly higher postoperative levels of CK-MB, Troponin I, and Troponin T at 1, 4, and 8 hours post-surgery compared to their OPCAB counterparts. This aligns with existing literature, which supports the notion that the use of cardiopulmonary bypass during CABG is associated with greater myocardial injury, a factor substantiated by elevated markers of myocardial necrosis.

In our study, the mean CK-MB levels were significantly higher in the ONCAB group at all postoperative time points ($p < 0.001$). This finding is consistent with the results reported by Ullah et al. [13], who showed significantly elevated CK-MB levels in patients undergoing on-pump CABG compared with those undergoing off-pump CABG. The more significant myocardial stress associated with cardiopulmonary bypass has been previously detailed by Kılıç et al. (14), who noted that the inflammatory response initiated by CPB leads to increased myocardial injury.

Contrasting our findings, Eriş et al. Eriş et al (15). discuss a potential benefit in myocardial protection using alternative aortic clamping strategies, which may mitigate injury during ONCAB. Thus, while our data indicate a consistent pattern of increased CK-MB following ONCAB, the complexity of surgical technique choices necessitates further examination of how different techniques may buffer myocardial damage during surgery.

Our results reveal a similar trend for both Troponin I and Troponin T, wherein the ONCAB cohort had significantly elevated levels compared to OPCAB throughout the postoperative period. This aligns with the work of Ullah et al. (13), who highlighted elevated troponin levels as a marker for postoperative myocardial injury in on-pump CABG—notably, the findings of Mahrose et al. Mahrose et al. (16) also indicate that postoperative troponin levels serve as important markers of myocardial injury, further supporting our results on troponin elevations.

In contrast, although some studies suggest that different cardioplegia types may influence troponin release, the overall evidence indicates that the surgical approach—on-pump or off-pump—has a substantial impact on postoperative myocardial enzyme levels, regardless of adjunctive therapies.

In both ONCAB and OPCAB groups, we did not observe any statistically significant differences in demographics or comorbidities such as hypertension, diabetes mellitus, and hyperlipidemia. This is consistent with the findings of Atasoy et al. (17), who noted the importance of matching participant characteristics when evaluating postoperative outcomes. While our patient population had a relatively high prevalence of the mentioned comorbidities, statistical analyses showed that these factors did not drive the observed increases in cardiac enzyme levels, suggesting that the surgical method is the predominant factor influencing postoperative myocardial injury.

Moreover, the stratification of enzyme levels by age and gender did not reveal significant differences across comorbidity subgroups, reinforcing the overarching influence of the surgical methodology on cardiac enzyme release. This insight underscores the need for greater awareness of the implications of surgical technique across populations with diverse underlying health conditions, as discussed by Abdallah et al—Abdo et al. (18) regarding the overall outcomes of CABG in patients with prevalent comorbidities.

Given that the study was conducted within a Pakistani population, it is pertinent to contextualize these findings. The predominance of cardiovascular diseases is markedly significant in Pakistan due to demographic factors, including obesity, sedentary lifestyle, hypertension, and diabetes (13). Considering the higher risk profiles within this population, advocating for less invasive surgical options like OPCAB may not only correlate with reduced enzyme release. Still, it could also optimize clinical outcomes and resource utilization in a healthcare system often burdened by high rates of myocardial infarction and related complications.

Moreover, awareness of OPCAB's advantages in minimizing postoperative myocardial injury aligns with national health priorities to enhance cardiac care delivery in Pakistan, potentially informing future surgical practices and training.

CONCLUSION

In conclusion, the substantial differences in postoperative cardiac enzyme levels between ONCAB and OPCAB highlight the importance of surgical technique in myocardial protection during CABG procedures. Future research should continue to explore these differences, particularly across diverse demographic and clinical contexts, to provide a more comprehensive understanding of cardiac surgical outcomes.

DECLARATIONS

Data Availability Statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department Concerned. (IRBEC)
Consent for publication
Approved
Funding
Not applicable

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

NASRATULLAH (PGR)
Conceived the study, collected data, performed initial analysis, and prepared the first draft of the manuscript
WASEEM RIAZ (ASSOCIATE PROFESSOR)
Supervised the study, provided expert guidance, critically reviewed the manuscript, and approved the final version
BARIQ ZAEEM MIRZA (PGR)
Assisted in data collection, statistical analysis, and literature review
MARIA NOOR (PGR)
Contributed to methodology design, data interpretation, and manuscript editing
MUHAMMAD BILAL IQBAL (PGR)
Helped in patient recruitment, data entry, and organization of findings
HAFIZ ZEYAD (PGR)
Contributed to referencing, proofreading, and final revisions of the manuscript

All authors read and approved the final version of the manuscript.

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