

ORIGINAL ARTICLE

Biochemical response to aortic cross-clamp duration: CK-MB and Troponin-I dynamics during myocardial ischemia in CABG patients.

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ABSTRACT... Objective: To evaluate perioperative changes in creatine kinase–myocardial band (CK-MB) and cardiac troponin-I levels in patients undergoing coronary artery bypass grafting (CABG) in relation to aortic cross-clamp duration. **Study Design:** Cohort Study. **Setting:** Department of Cardiac Surgery, Punjab Institute of Cardiology, Lahore, Pakistan. **Period:** Six Months from November 2022 to April 2023. **Methods:** A total of 190 patients undergoing elective on-pump CABG were included using a non-probability consecutive sampling. Patients were categorized into two groups based on aortic cross-clamp duration: Group A (<75 minutes) and Group B (≥75 minutes). Blood samples were collected at baseline, after cross-clamp removal and during the early postoperative period. Serum CK-MB and troponin-I levels were measured. Data was analyzed by SPSS version 25. Quantitative variables were expressed as mean ± standard deviation and an independent sample t-test was used to compare biomarker levels between the groups. A p-value ≤0.05 was considered statistically significant. **Results:** Baseline CK-MB and troponin-I levels were similar between two groups. Both biomarkers showed a significant increase after cross-clamp removal, reflecting myocardial stress associated with surgical ischemia. CK-MB levels increased significantly after cross-clamp exposure (p=0.004) and remained elevated in the early postoperative period (p=0.030). Similarly, troponin-I levels showed a significant rise following cross-clamp removal (p=0.035) and remained elevated postoperatively (p=0.050). **Conclusion:** Perioperative monitoring of CK-MB and troponin-I provides useful insight into myocardial injury during CABG and may help improve assessment of myocardial protection during cardiac surgery.

Key words: Aortic Cross-clamp, Coronary Artery Bypass Grafting, CK-MB, Myocardial Injury, Troponin-I.

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INTRODUCTION

Coronary artery disease remains one of the most common causes of cardiac morbidity that needs surgical intervention. Coronary artery bypass grafting (CABG) has long been considered as an effective method of myocardial revascularization in patients with multivessel coronary artery disease.¹ During on-pump CABG surgery, the ascending aorta is temporarily occluded by using an aortic cross-clamp. This allows the construction of coronary grafts in a controlled operative environment. Although this maneuver is essential for safe surgical repair, but immediately after the removal of clamp, it produces a period of controlled myocardial ischemia followed by reperfusion.² Ischemia of vital organs can lead to serious complications such as cerebral and myocardial infarction, resulting in permanent tissue damage. To restore the blood flow and limit the ischemic damage, reperfusion therapy is used.

But in some cases, instead of healing it can further increase the tissue injury through a phenomenon known as ischemia reperfusion (I/R) injury. This process can affect multiple organs and can lead to other complications, disability or even death.³ Several pathological mechanisms contribute to I/R injury, including cellular damage, oxidative stress, inflammatory responses, disruption of tissue barriers, extracellular matrix remodeling, angiogenesis, cardiomyocyte hypertrophy and fibrosis.⁴ The cardiac muscle cells give biochemical response to this ischemia-reperfusion process by releasing the intracellular enzymes and structural proteins into the circulation. Since decades, biochemical markers have been used to detect myocardial damage. Measurement of these biomarkers therefore provides valuable information about the extent of myocardial injury during cardiac surgery.⁵

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Among the earliest markers used in clinical cardiology were enzymes such as aspartate aminotransferase (AST), lactate dehydrogenase (LDH) and creatine kinase (CK). However, these markers lacked specificity for cardiac tissue because they are present in multiple organs including skeletal muscle and liver.⁶ After the discovery of the creatine kinase MB isoenzyme (CK-MB), an important milestone in the biochemical diagnosis of myocardial injury was added. CK is a cytosolic enzyme that catalyzes the reversible transfer of a phosphate group between creatine and adenosine triphosphate (ATP), playing a central role in cellular energy metabolism.⁷ Structurally, creatine kinase exists as three isoenzymes: CK-MM found predominantly in skeletal muscle, CK-BB located mainly in brain tissue and CK-MB which is relatively more specific to cardiac muscle. Because of its greater myocardial specificity compared with other markers, CK-MB became widely used for the detection of myocardial infarction and perioperative myocardial injury in cardiac surgery patients. CK-MB is also present in a very amount in skeletal muscles, which limits its absolute specificity for cardiac tissue. This limitation led to the search for more sensitive and specific biomarkers.⁶

In late twentieth century cardiac troponins were discovered that significantly advanced the biochemical diagnosis of myocardial injury. Troponins are regulatory proteins located on the thin filament of the contractile apparatus in striated muscles. The troponin complex consists of three distinct subunits: troponin C (TnC), troponin T (TnT) and troponin I (TnI). Troponin C binds calcium ions and plays a role in initiating muscle contraction. Troponin T anchors the troponin complex to tropomyosin and stabilizing the contractile structure. While the Troponin I, functions as the inhibitory component of the complex and prevents actin-myosin interaction in the absence of calcium. Among these subunits, cardiac troponin I (cTnI) is highly specific to myocardial tissue because the structure of its amino acids are significantly different from the isoforms present in skeletal muscle.^{8,9} After the development of sensitive immunoassays for cardiac troponin I and troponin T, the biochemical evaluation of myocardial injury has been revolutionized. When cardiomyocyte membrane integrity is compromised, such as during

ischemia, necrosis or reperfusion injury, these proteins are released into the bloodstream. As compared to CK-MB, cardiac troponins provide greater sensitivity and specificity to detect the myocardial damage and remain elevated in the circulation for a longer time after injury. For this reason, troponin measurement has become the gold standard biomarker for diagnosing myocardial infarction and assessing perioperative myocardial injury.¹⁰

During CABG surgery, myocardial protection strategies such as cardioplegia are used to reduce metabolic demand during aortic cross-clamping. Different durations of cross-clamp applications can influence the degree of myocardial ischemia and biochemical response. Prolonged ischemia can increase the permeability of cellular membrane, disruption of contractile proteins and release of cardiac biomarkers including CK-MB and troponins into the circulation.¹¹ Therefore, monitoring these biomarkers before and after aortic cross-clamping provides important information about myocardial stress and the effectiveness of intraoperative myocardial protection. Their release patterns reflect different aspects of myocardial cell injury along with the physiological mechanisms associated with ischemia and reperfusion. Although many studies have evaluated clinical outcomes following CABG, relatively fewer have focused on the biochemical dynamics of myocardial injury markers in relation to surgical ischemic exposure. Therefore, the present study aimed to evaluate the biochemical response to different durations of aortic cross-clamping in patients undergoing on-pump coronary artery bypass grafting by analyzing perioperative levels of CK-MB and cardiac troponin-I.

METHODS

This analytical cohort study was performed in the Department of Cardiac Surgery at the Punjab Institute of Cardiology, Lahore, Pakistan, during a six-month period from November 2022 to April 2023 after obtaining approval from the Institutional Review Board (No: UHS/Education/126-22/5722). The study included patients undergoing elective on-pump coronary artery bypass grafting (CABG). Written informed consent was obtained from all participants prior to surgery.

Patients aged between 50 and 75 years undergoing isolated CABG were eligible for inclusion. Individuals with acute or recent myocardial infarction, emergency surgical procedures, age below 50 years or above 75 years, chronic renal disease, chronic obstructive pulmonary disease, poor left ventricular function, use of intra-aortic balloon pump support, or combined valve surgery with CABG were excluded from the study. A total of 190 patients fulfilling the eligibility criteria were enrolled by using a non-probability consecutive sampling technique.

To evaluate the biochemical response to myocardial ischemia during surgery, patients were categorized according to the duration of aortic cross-clamp application into two groups: Group A with cross-clamp duration less than 75 minutes and Group B with cross-clamp duration equal to or greater than 75 minutes, each group having 95 individuals. Perioperative blood samples were collected to measure myocardial injury biomarkers.

Serum creatine kinase-MB (CK-MB) and cardiac troponin-I levels were determined at three predefined time points: prior to application of the aortic cross-clamp, immediately after removal of the cross-clamp and during the early postoperative period. These biochemical markers were used to evaluate the extent of myocardial injury associated with different durations of myocardial ischemia during CABG.

Statistical Analysis

Statistical analysis was performed using SPSS

version 25. Continuous variables were presented as mean $\pm$ standard deviation. The independent sample t-test was used to compare CK-MB and troponin-I levels between the two cross-clamp duration groups at different perioperative time points. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

Serum cardiac biomarkers demonstrated measurable changes in response to myocardial ischemia during surgery. Baseline levels of CK-MB and troponin-I were comparable between the two cross-clamp duration groups. However, significant differences were observed in perioperative biomarker levels after cross-clamping. This shows the changes in biochemical response to myocardial injury. Detailed comparisons of CK-MB and troponin-I levels at different perioperative time points are presented in the following tables.

DISCUSSION

The present study evaluated the biochemical response of myocardial tissue to varying durations of aortic cross-clamping during on-pump coronary artery bypass grafting by analyzing perioperative changes in CK-MB and cardiac troponin-I levels. Cardiac biomarkers are released into the circulation when myocardial cells are damaged or they are under stress, making them an important indicator of myocardial injury during cardiac surgery. These biomarkers are widely used to assess perioperative myocardial damage and to evaluate the effectiveness of myocardial protection strategies during CABG.⁶

TABLE-I

Comparison of CK-MB Levels According to Aortic Cross-Clamp Duration(t-test)

CK-MB Level	Cross Clamp <75 min (n=95) Mean $\pm$ sd	Cross Clamp $\geq$ 75 min (n=95) Mean $\pm$ sd	t-value	P-Value
CK-MB before cross clamp	3.85 $\pm$ 1.18	3.82 $\pm$ 1.19	0.17	0.855
CK-MB after cross clamp	37.98 $\pm$ 25.06	28.48 $\pm$ 18.86	2.94	0.004
CK-MB post-operative	13.53 $\pm$ 5.52	17.25 $\pm$ 16.05	-2.10	0.03

TABLE-II

Comparison of Troponin-I Levels according to aortic cross-clamp duration (t-test)

Troponin-I Level	Cross clamp <75 min (n=95) mean $\pm$ sd	Cross clamp $\geq$ 75 min (n=95) mean $\pm$ sd	t-value	P-Value
Troponin-I before cross clamp	0.02 $\pm$ 0.02	0.02 $\pm$ 0.01	0.12	0.903
Troponin-I after cross clamp	0.80 $\pm$ 0.15	0.71 $\pm$ 2.91	2.11	0.035
Troponin-I post-operative	0.07 $\pm$ 0.12	0.28 $\pm$ 1.03	-1.96	0.050

In the current study, baseline CK-MB levels were comparable between the two cross-clamp groups, with mean values of 3.85 ± 1.18 U/L in the <75-minute group and 3.82 ± 1.19 U/L in the ≥ 75 -minute group ($p = 0.855$) as shown in Table-I. This similarity indicates that both groups had comparable baseline biochemical status prior to myocardial ischemia induced by cross-clamping. However, significant differences were observed after cross-clamping. After removal of cross-clamp, CK-MB levels were markedly increased in both groups, with a higher mean level observed in the shorter cross-clamp group (37.98 ± 25.06 U/L) compared with the prolonged cross-clamp group (28.48 ± 18.86 U/L), which was statistically significant (p value= 0.004, Table-I). During the early postoperative period, CK-MB levels were decreased but remained elevated as compared to baseline, measuring 13.53 ± 5.52 U/L in the <75-minute group and 17.25 ± 16.05 U/L in the ≥ 75 -minute group ($p = 0.030$, Table 1). Similar findings have been reported in several international studies evaluating perioperative myocardial injury markers during CABG surgery. The results of the study of Romeo et al. in 2024 have also reported significant elevations of CK-MB after cardiac surgery, indicating myocardial injury related to ischemia-reperfusion during cardiopulmonary bypass.¹² Likewise, Schneider and colleagues observed that postoperative CK-MB elevation correlates with surgical myocardial stress and reflects the degree of myocardial cell damage following coronary revascularization.¹³ Studies conducted in South Asian populations have also demonstrated comparable biochemical responses. A Pakistani study by Nasratullah et al. comparing on-pump and off-pump CABG reported significantly higher postoperative CK-MB levels in patients undergoing on-pump surgery, suggesting greater myocardial stress associated with cardiopulmonary bypass. According to author surgical technique and myocardial ischemia play a major role in postoperative enzyme release. Improved myocardial protection strategies or alternative clamping techniques may reduce the release of enzyme elevation despite of prolonged surgical exposure. These findings highlight that enzyme release after CABG is influenced not only by ischemic time but also by intraoperative myocardial protection methods.¹⁴

Troponin-I is considered a highly specific biomarker of myocardial injury because it is structurally unique to cardiac muscle.¹⁰ In the present study, baseline troponin-I levels were similar between groups (0.02 ± 0.02 ng/mL vs 0.02 ± 0.01 ng/mL; $p = 0.903$) as shown in Table-II, indicating comparable preoperative myocardial status. After cross-clamp removal, troponin-I levels increased to 0.80 ± 0.15 ng/mL in the <75-minute group and 0.71 ± 2.91 ng/mL in the ≥ 75 -minute group ($p = 0.035$). In the early postoperative phase, troponin-I levels remained elevated, particularly in patients with longer cross-clamp duration (0.28 ± 1.03 ng/mL) compared with the shorter cross-clamp group (0.07 ± 0.12 ng/mL) ($p = 0.050$, Table-II). These findings are consistent with a international research by Ebadi et al. demonstrating that cardiac troponins increase significantly following CABG due to myocardial ischemia and reperfusion injury. A large cohort study involving more than 3,000 CABG patients reported that elevated postoperative high-sensitivity troponin and CK-MB levels were significantly associated with adverse cardiovascular events during follow-up, highlighting their prognostic value in cardiac surgery. The study also demonstrated that increase in postoperative biomarkers commonly occur within the first 8–24 hours after surgery, reflecting the biochemical response to myocardial ischemia and reperfusion.¹⁵ However, some studies have shown that the relationship between biomarker elevation and clinical outcomes may vary depending on patient characteristics. For example, study of Garganeeva et al. has reported that factors such as advanced age, diabetes mellitus, peripheral vascular disease and reduced ejection fraction may increase the likelihood of adverse cardiovascular events following CABG.¹⁶

Studies comparing on-pump and off-pump CABG have demonstrated that patients undergoing on-pump procedures tend to exhibit higher CK-MB and troponin levels due to cardiopulmonary bypass related inflammatory responses and myocardial ischemia. In contrast, off-pump techniques performed on a beating heart may reduce myocardial injury and systemic inflammatory responses. These findings support the concept that surgical technique and perioperative myocardial protection strategies are important determinants of postoperative biochemical

responses.^{17,18} The biochemical pattern observed in our study can also be explained by the physiological mechanisms of ischemia-reperfusion injury. During aortic cross-clamping, myocardial oxygen supply is temporarily interrupted, resulting in metabolic stress and cellular injury. When circulation is restored after removal of the clamp, reperfusion triggers oxidative stress, inflammatory responses and disruption of cardiomyocyte membranes, leading to leakage of intracellular proteins such as CK-MB and troponin into the bloodstream.¹⁹ These biochemical changes reflect the extent of myocardial injury and provide important insight into myocardial protection during cardiac surgery. Overall, the results of our study demonstrate significant perioperative changes in CK-MB and troponin-I levels in patients undergoing CABG, highlighting the value of these biomarkers in assessing myocardial injury associated with surgical ischemia and reperfusion. By monitoring these biochemical markers at different perioperative intervals will help the clinicians to evaluate myocardial stress during surgery and optimize strategies for myocardial protection.

This study had a relatively limited sample size and was conducted over a short study period. In addition, the analysis mainly focused on early postoperative biochemical markers and did not evaluate long-term clinical outcomes. Future studies with larger sample sizes and longer follow-up are recommended to understand the relationship between cross-clamp duration, cardiac biomarkers and long-term outcomes after CABG.

CONCLUSION

The findings of this study has demonstrated that the levels of CK-MB and troponin-I showed noticeable changes during the perioperative period in patients undergoing coronary artery bypass grafting. The elevation of these biomarkers after cross clamping of aorta reflects the degree of myocardial stress associated with ischemia and reperfusion during surgery. Monitoring of these biochemical markers at different perioperative stages may provide valuable information regarding myocardial injury and the physiological response to surgical ischemic exposure. Understanding these biochemical patterns will help the clinicians to evaluate the myocardial protection strategies and improve perioperative

management in patients undergoing CABG surgery.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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