RESEARCH PAPER

Comparative Evaluation of Intra- and Postoperative Cardiac Biomarkers in On-Pump Cardiac Surgery with and Without Esmolol Infusion

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ABSTRACT

Background

Cardiac surgery performed with cardiopulmonary bypass (CPB) is consistently associated with myocardial injury and a systemic stress response, which are manifested by perioperative increases in cardiac biomarkers such as cardiac troponins and creatine kinase-MB (CK-MB). The purpose of this study is to assess the effect of esmolol, a short-acting β-blocker, on cardiac stress during on-pump heart surgery by measuring intra- and postoperative cardiac biomarkers, to evaluate myocardial protection and enhance surgical outcomes while reducing complications.

Methods

This was a comparative cross-sectional study conducted in the Department of Cardiac Surgery, BSMMU, over one year. This study enrolled 40 patients (Group A: n=20, received esmolol; Group B: n=20, no esmolol) using convenience sampling. Data were collected through a questionnaire and checklist, analyzed using Chi-squared and t-tests ($p \leq 0.05$) in SPSS v26, with informed consent, confidentiality, and IRB approval maintained.

Results

Among 40 patients, age (47.9±11.18 vs 49.05±11.26 years, p=0.375) and gender (60% vs 55% male, p=0.749) were comparable. Troponin I (T1: 2.90±1.77 vs 0.11±0.19; T5: 9.45±4.56 vs 5.32±3.31 ng/ml, p<0.001) and CK-MB (T2: 27.02±7.06 vs 23.07±7.07; T5: 41.21±29.76 vs 25.02±7.89 IU/L, p<0.001) were significantly higher in Group B than Group A.

Conclusion

Esmolol infusion during on-pump cardiac surgery was linked to reduced intraoperative and postoperative cardiac biomarker levels compared with no esmolol use, indicating a possible protective effect on the myocardium. Thus, esmolol may serve as an effective adjunct to limit perioperative myocardial injury during cardiopulmonary bypass.

Keywords: Esmolol infusion, cardiac biomarker, myocardium, Troponin I, CK-MB.

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Introduction

Cardiac surgery performed with cardiopulmonary bypass (CPB) is consistently associated with myocardial injury and a systemic stress response,

which are manifested by perioperative increases in cardiac biomarkers such as cardiac troponins and creatine kinase-MB (CK-MB). The perioperative behavior of these biomarkers provides an objective measure of procedural myocardial damage and has been shown to correlate with both short-term and long-term adverse clinical outcomes following on-pump coronary artery bypass grafting (CABG) and other cardiac surgical procedures [1-3].

Evidence from contemporary studies demonstrates that on-pump cardiac surgery results in marked postoperative elevations of cardiac biomarkers, frequently exceeding those observed with off-pump techniques. This difference suggests a greater degree of myocardial injury related to ischemia–reperfusion mechanisms and the effects of global cardiac arrest inherent to CPB [4,5].

Among the currently available biomarkers, cardiac troponins—specifically cardiac troponin I (cTnI) and cardiac troponin T (cTnT)—are regarded as the most sensitive and specific markers of myocardial injury in the postoperative cardiac surgery setting. Postoperative troponin elevation has been consistently linked to increased morbidity, mortality, and longer intensive care unit stays [6,7].

Esmolol is a selective β_1-adrenoceptor antagonist with an ultra-short duration of action and rapid titratability, making it an attractive adjunct to conventional cardioprotective strategies. Available clinical evidence indicates that perioperative administration of esmolol may attenuate the surgical stress response, improve hemodynamic control, and limit perioperative myocardial injury, as reflected by reductions in postoperative cardiac biomarker levels [8,9].

Concurrently, various intraoperative pharmacologic approaches aimed at myocardial protection have been investigated. Esmolol, an ultra-short-acting and easily titratable β_1-adrenoceptor antagonist, has gained attention as a potential adjunct to conventional cardioprotective strategies [10,11]. Clinical studies suggest that esmolol administered during or immediately before CPB can reduce postoperative troponin release, thereby limiting myocardial ischemic injury and potentially improving early postoperative cardiac function.

Furthermore, multiple studies have demonstrated that the use of esmolol during cardiac surgery is associated with a decreased incidence of perioperative myocardial ischemia and cardiac arrhythmias, providing additional support for its potential cardioprotective effects in patients undergoing cardiopulmonary bypass-assisted procedures [12,13].

However, despite these encouraging observations, the existing clinical data remain inconsistent, with considerable heterogeneity in study designs, dosing protocols, and measured outcomes. As a result, the cardioprotective efficacy of esmolol in the context of on-pump cardiac surgery has not yet been conclusively determined. This uncertainty highlights the need for further comparative assessment of intraoperative and postoperative cardiac biomarker profiles in patients undergoing on-pump cardiac surgery with and without esmolol infusion [14]. These observations highlight the need for well-designed comparative studies evaluating intraoperative and postoperative cardiac biomarker profiles in patients undergoing on-pump cardiac surgery with and without esmolol infusion.

Such investigations are essential to more clearly define the true myocardial protective effects of esmolol, not only in terms of clinical outcomes but also through detailed biomarker assessment reflecting the extent of myocardial injury. Ongoing research in this field may ultimately guide the optimization of pharmacologic adjuncts and perioperative monitoring strategies in patients undergoing CPB-assisted cardiac surgery.

Objective

- To compare the level of the cardiac biomarkers between patients who received Esmolol infusion and those who did not.

Methodology & Materials

This comparative cross-sectional study was conducted at the Department of Cardiac Surgery, Bangabandhu Sheikh Mujib Medical University (BSMMU), Shahbag, Dhaka, Bangladesh, from July 2023 to June 2024. A total of 40 adult patients undergoing on-pump cardiac surgery with cardiopulmonary bypass were included based on predefined inclusion and exclusion criteria. Patients were allocated into two groups—those who received peri-operative esmolol infusion and those who did not—in order to comparatively evaluate intra- and postoperative cardiac biomarkers, specifically serum Troponin I and CK-MB.

Inclusion Criteria:

- Adult patients undergoing On-pump Cardiac Surgery due to any cardiac disease.

Exclusion Criteria:

- Diagnosis of acute myocardial infarction within last 4 weeks before scheduled surgery.
- Pronged Cardiopulmonary bypass time (CPB time >180 minutes).
- An activated phase of Rheumatic disease.
- Left ventricular ejection fraction of 40%.
- Preoperatively confirmed intra-cardiac shunt.
- Hematocrit <30%.

- Severe systemic diseases including pulmonary diseases, renal, musculoskeletal diseases or immune system illness.

Data were collected using a pre-tested semi-structured questionnaire and a comprehensive checklist, developed in English according to the study objectives, to record socio-demographic, pre-operative, peri-operative, and post-operative variables through review of medical records, direct interviews, and observation. Eligible patients were enrolled after obtaining informed written consent, and detailed history, clinical examination, and relevant investigations were documented. Standard anesthetic techniques were used for all patients, followed by median sternotomy and establishment of cardiopulmonary bypass using appropriately sized arterial and venous cannulae. In the esmolol group, intravenous esmolol infusion was administered from skin incision until initiation of cardiopulmonary bypass and continued with cardioplegia thereafter, while the control group did not receive esmolol. Serum Troponin I and CK-MB levels were measured at predefined time points from baseline through the first postoperative day using blood samples collected in heparin-coated tubes, and peri-operative variables including cardiopulmonary bypass time, and aortic cross-clamp time were recorded. All patients were monitored postoperatively in the intensive care unit. Biomarker analyses were performed in the Department of Biochemistry, BSMMU, using an automated cardiac laboratory analyzer (Dimension ExL with LM, Germany) with manual cross-verification. Data were cleaned, coded, and analyzed using SPSS version 26; continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages, with comparisons made using the unpaired t-test, Chi-square test, or Fisher's exact test as appropriate, and a p-value ≤0.05 considered statistically significant. Ethical approval was obtained from the Institutional Review Board of BSMMU, confidentiality was maintained, and participants retained the right to withdraw at any stage without affecting their medical care.

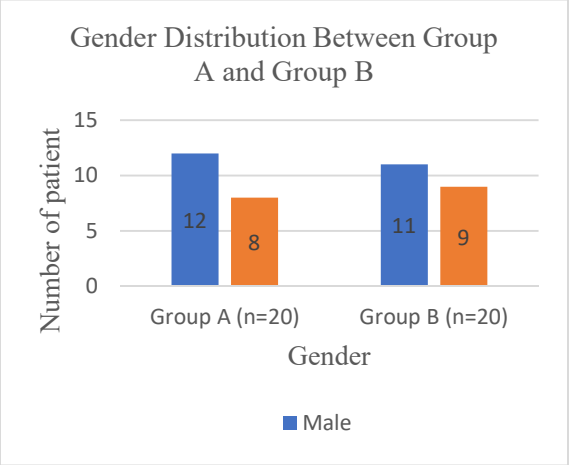
Results

Table I: Comparison of age between two groups

Age in years	Group A (n=20)	Group B (n=20)	p value
18-29	2 (10%)	3 (15%)	0.499
30-49	12 (60%)	10 (50%)	
50-65	6 (30%)	7 (35%)	
Total	20 (100%)	20 (100%)	
Mean±SD	47.9±11.18	49.05±11.26	0.375

Table shows mean age of the patients of group A was 47.9±11.18 years and for group B was 49.05±11.26 years. Most of the patients were between 30-49 years range, which was 60% in group A and 50% in group B. The difference in mean age (p=0.375) and distribution of patients according to age range (p=0.499) was not statistically significant between the two groups.

Figure I: Gender Distribution Between Group A and Group B



The chart shows that male patients were predominant in both groups. In Group A, 12 (60%) were male and 8 (40%) were female, while in Group B, 11 (55%) were male and 9 (45%) were female. The gender distribution between the two groups was comparable (p = 0.749, not significant).

Table II: Comparison of perioperative Troponin I

Troponin I (ng/ml)	Group A (n=20) Mean ± SD	Group B (n=20) Mean ± SD	p value
Baseline (T0)	0.067 ± 0.11	0.072 ± 0.14	0.452

Before aortic cannulation (T1)	0.11 ± 0.19	2.90 ± 1.77	<0.001
Before aortic cross clamp (T2)	1.07 ± 0.69	4.26 ± 1.81	<0.001
After release of aortic cross clamp (T3)	4.40 ± 1.83	6.41 ± 1.93	<0.001
At the end of surgery (T4)	6.51 ± 1.81	11.46 ± 5.14	<0.001
First postoperative day (T5)	5.32 ± 3.31	9.45±4.56	<0.001

Table shows Troponin I levels in Groups A and B at various perioperative time points. Baseline levels (T0) were comparable (0.067±0.11 vs 0.072±0.14 ng/ml, p=0.452). From before aortic cannulation (T1: 2.90±1.77 vs 0.11±0.19, p<0.001) to the end of surgery (T4: 11.46±5.14 vs 6.51±1.81, p<0.001) and on the first postoperative day (T5: 9.45±4.56 vs 5.32±3.31, p<0.001), Group B had significantly higher levels than Group A.

Table III: Comparison of perioperative CK-MB

CK-MB (IU/L)	**Group A (n=20) Mean ± SD**	**Group B (n=20) Mean ± SD**	**p value**
Baseline (T0)	18.44 ± 8.01	17.97 ± 5.64	0.417
Before aortic cannulation (T1)	19.49 ± 7.83	19.17 ± 5.35	0.440 ns
Before aortic cross clamp (T2)	23.07 ± 7.07	27.02 ± 7.06	0.039 s
After release of aortic cross clamp (T3)	26.28 ± 7.48	34.37 ± 10.09	0.002 s
At the end of surgery (T4)	36.36 ± 12.83	57.35 ± 42.52	<0.001 s
First postoperative day (T5)	25.02 ± 7.89	41.21 ± 29.76	<0.001 s

The table shows CK-MB levels in Groups A and B at different perioperative time points. At baseline (T0: 18.44±8.01 vs 17.97±5.64 IU/L, p=0.417) and before aortic cannulation (T1: 19.49±7.83 vs 19.17±5.35 IU/L, p=0.440), levels were similar. Significant differences appeared from before aortic cross clamp (T2: 23.07±7.07 vs 27.02±7.06 IU/L, p=0.039) through the end of surgery (T4: 36.36±12.83 vs 57.35±42.52 IU/L, p<0.001) and on the first postoperative day (T5: 25.02±7.89 vs 41.21±29.76 IU/L, p<0.001), with Group B consistently higher. CK-MB levels then decreased slightly on the first postoperative day, similar to troponin I.

Discussion

In this study, the baseline demographic analysis showed that the mean age of patients was 47.9 ± 11.18 years in Group A and 49.05 ± 11.26 years in Group B, with no statistically significant difference (p = 0.375). Most patients were aged 30–49 years (60% in Group A and 50% in Group B), representing a relatively young cohort undergoing elective on-pump cardiac surgery. The similarity in age distribution between groups reduces the likelihood of age-related confounding when interpreting changes in perioperative biomarkers. These findings align with previous CABG studies in which baseline characteristics, including age, were comparable between groups, suggesting that demographic factors were unlikely to influence perioperative outcomes [15]. The gender distribution was also similar, with males comprising 60% of Group A and 55% of Group B (p = 0.749). This male predominance is commonly reported in cardiac surgery populations, reflecting the higher incidence of advanced coronary artery disease in men [16]. The comparable gender ratio between groups further ensures that sex did not bias the observed biomarker trends.

Baseline cardiac troponin I (cTnI) levels (T0) were similar in both groups (0.067 ± 0.11 vs 0.072 ± 0.14 ng/ml, p = 0.452). From before aortic cannulation (T1) through the first postoperative day (T5), Group B consistently had significantly higher troponin I levels than Group A (all p < 0.001). This progressive rise follows the known release kinetics of cardiac troponins during cardiac surgery, where troponin levels increase shortly after myocardial ischemia and peak early postoperatively due to surgical stress, ischemia–reperfusion injury, and cardioplegic arrest [17]. Elevated troponin in the immediate and early postoperative period is well documented and reflects the degree of myocardial injury induced by CPB and surgical manipulation. The higher troponin levels in Group B suggest that this group experienced greater perioperative myocardial injury, consistent with patterns observed during more extensive surgical stress.

Previous studies have shown that troponin I and troponin T rise significantly after on-pump surgery, even without clinical myocardial infarction, typically peaking within 18–24 hours postoperatively. [18] Serial sampling further indicates that peak values often occur between 6 and 24 hours, reflecting the expected time course of myocardial biomarker release following CPB [19]. In this context, the troponin elevation in Group B closely mirrors these established patterns, confirming the reliability of perioperative troponin as an indicator of myocardial injury.

The trend of CK-MB in this study also supports the interpretation of perioperative myocardial injury. Baseline CK-MB levels were similar (18.44 ± 8.01 vs 17.97 ± 5.64 IU/L, p = 0.417), and no difference was observed before aortic cannulation (T1, p = 0.440). However, from before cross-clamping (T2) onward, Group B showed significantly higher CK-MB levels through the end of surgery and the first postoperative day (p = 0.039 to <0.001). This pattern indicates that myocardial stress and injury continued throughout the operation and into the early postoperative period. Previous reports describe CK-MB peaking within the first 24 hours after cardiac surgery, reflecting procedural myocardial impact [18,20,21].

While CK-MB and troponin exhibit similar perioperative patterns, troponin is considered more specific and prognostically valuable. Troponin I correlate more strongly with postoperative cardiac events than CK-MB and is a better predictor of adverse outcomes such as mortality, hospital stay duration, and perioperative complications [22]. In this study, both biomarkers were elevated in Group B compared with Group A, but the sustained elevation of troponin I emphasizes its sensitivity as a marker of myocardial injury.

The observed differences in biomarker levels from T1 to T5 may reflect intraoperative factors such as CPB duration, aortic cross-clamp time, and myocardial protection strategies. Prolonged CPB and extended cross-clamp times have been linked to higher postoperative troponin and CK-MB levels, highlighting the influence of these procedural variables on myocardial injury [18,23]. Although comorbidities and preexisting myocardial disease may also affect biomarker release, the consistently higher levels in Group B suggest greater overall myocardial insult during surgery.

Prior prospective and retrospective studies have highlighted the clinical relevance of perioperative biomarker elevations after on-pump surgery. Elevated troponin I levels, even without clinical myocardial infarction, have been associated with worse short- and long-term outcomes, including increased mortality and major adverse cardiac events [20,24,25]. CK-MB is also predictive of outcomes but is less specific, limiting its prognostic value relative to troponin [22]. These observations reinforce that perioperative elevations in both biomarkers reflect meaningful myocardial injury and may be useful for risk stratification and clinical management.

The biomarker profiles observed here are consistent with the pathophysiology of perioperative myocardial injury. Cardiac biomarkers rise in response to intraoperative stressors such as aortic cross-clamping, reperfusion injury, myocardial stretch, and CPB-induced inflammation [17,19,21]. Early elevations before cross-clamp manipulation suggest contributions from surgical incision, cannulation, and initial ischemic insult, while sustained postoperative increases indicate ongoing myocardial stress. Importantly, these elevations reflect a spectrum of injury, including subclinical necrosis and reversible cellular damage, and do not necessarily signify overt myocardial infarction [18].

Despite clear patterns in biomarker elevations, several limitations exist. Imaging or clinical endpoints, such as postoperative myocardial infarction, echocardiographic ventricular assessment, or long-term outcomes, were not included, which limits the clinical interpretation of biomarker changes. The sample size of 20 patients per group may also restrict generalizability, particularly for subgroup analyses. Finally, although the biomarkers are well-validated indicators of myocardial injury, laboratory variability and perioperative factors could influence absolute levels.

In conclusion, this study demonstrates significant perioperative elevations in troponin I and CK-MB in patients undergoing on-pump cardiac surgery, with Group B showing consistently higher levels throughout the operative and early postoperative periods. These findings are consistent with previously reported perioperative biomarker kinetics, where troponin and CK-MB rise after CPB and reflect the extent of myocardial injury [18,20,22]. The higher biomarker levels in one group indicate greater myocardial stress, which may have implications for risk assessment and postoperative care. Future studies with larger cohorts, imaging, and long-term follow-up are recommended to better define the prognostic value of perioperative biomarkers in cardiac surgery.

Limitations of the study

- The study did not investigate whether different doses of esmolol might have varying effects on outcomes.
- The study focused on a limited set of clinical outcomes
- Relatively small number of participants.
- The study is single centered.
- The study was done with different teams of surgeons.
- The study needs longer follow-up periods to assess the long-term impact of esmolol on cardiac function and overall patient recovery.

Conclusion

In this study, perioperative assessment of cardiac biomarkers in patients undergoing on-pump cardiac surgery revealed significant differences between the two groups. Group B consistently showed higher levels of Troponin I and CK-MB from before aortic

cannulation to the first postoperative day, reflecting greater perioperative myocardial injury compared with Group A. The groups were similar in baseline demographics, including age and gender, indicating that these factors did not influence the observed biomarker differences. These results underscore the value of Troponin I and CK-MB as reliable indicators of myocardial injury in on-pump cardiac surgery and suggest that measures to reduce perioperative myocardial stress may be reflected in biomarker levels.

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