KLİNİK ÇALIŞMA / CLINICAL TRIAL
Ege Klin Tıp Derg 2026;64 (2):190-197

Investigation of the Relationship Between Preoperative Left Ventricular Hypertrophy and Postoperative Troponin Elevation in Coronary Artery Bypass Surgery

Koroner Arter Bypass Cerrahisinde Preoperatif Sol Ventrikül Hipertrofisinin Postoperatif Troponin Yüksekliği ile İlişkisinin İncelenmesi

Emin BARBARUS*0000-0001-8586-9810
Muhammet Hüseyin ERKAN*0000-0002- 8390-2493
Volkan YÜKSEL*0000-0001-9518-2588
Ahmet DOLAPOĞLU*0000-0001-9161-2632

* Balikesir University, Faculty of Medicine, Department of Cardiovascular Surgery, Balıkesir

Yazışma Adresi: Emin BARBARUS
Department of Cardiovascular Surgery, Balikesir University, Bigadic Yolu st., 10145 Balikesir
E-mail: eminbarbarus@gmail.com

Geliş Tarihi:20.05.2026
Kabul Tarihi: 30.05.2026

Abstract

Objective: This study aimed to investigate factors associated with postoperative 24-hour troponin levels in patients undergoing elective on-pump three-vessel CABG, with particular emphasis on preoperative left ventricular hypertrophy and myocardial mass-indexed cardioplegia parameters.

Methods: This retrospective single-center study included 42 patients who underwent elective on-pump three-vessel CABG between January 2023 and October 2025. Patients were categorized according to the presence of LVH based on preoperative echocardiographic left ventricular mass index. Cardioplegia dose was assessed as total volume and indexed to body weight, left ventricular mass (LVM), and left ventricular mass index (LVMI). The primary biochemical outcome was postoperative 24-hour troponin level. Correlation and regression analyses were performed to evaluate associations between cardioplegia indices and troponin levels.

Results: The study included 42 patients with a mean age of 63.29±8.61 years, of whom 30 (71.4%) were male. Patients with LVH had significantly lower cardioplegia/LVM and cardioplegia/LVMI ratios despite similar total cardioplegia volumes (both $p<0.001$). The cardioplegia/kg ratio was higher in the LVH group ($p=0.008$) but was not associated with postoperative troponin levels (rho=-0.155, $p=0.329$). In contrast, postoperative 24-hour troponin levels showed significant inverse correlations with cardioplegia/LVM (rho=-0.389, $p=0.011$) and cardioplegia/LVMI (rho=-0.350, $p=0.023$). In multivariable linear regression analysis, cardioplegia/LVM was independently and inversely associated with postoperative troponin level. This association remained significant after adjustment for cardiopulmonary bypass time (B=-0.389, $p=0.010$).

Conclusion: In elective on-pump three-vessel CABG, myocardial mass-indexed cardioplegia parameters, particularly cardioplegia/LVM, may be more closely associated with postoperative troponin release than body-weight-indexed cardioplegia. These findings suggest that myocardial mass should be considered when planning myocardial protection strategies.

Keywords: Coronary artery bypass grafting; Left ventricular hypertrophy; Troponin

Öz

Amaç: Bu çalışma, kardiyopulmoner bypass altında elektif üç damar koroner arter bypass greftleme yapılan hastalarda postoperatif 24. saat troponin düzeyleri ile ilişkili faktörleri araştırmayı; özellikle preoperatif sol ventrikül hipertrofisi ve miyokard kütlesine indeksli kardiyopleji parametrelerinin bu ilişkideki rolünü değerlendirmeyi amaçlamıştır.

Yöntemler: Bu retrospektif tek merkezli çalışmaya, Ocak 2023 ile Ekim 2025 tarihleri arasında kardiyopulmoner bypass altında elektif üç damar koroner arter bypass greftleme yapılan 42 hasta dahil edildi. Hastalar, ameliyat öncesi ekokardiyografik sol ventrikül kütle indeksine göre LVH varlığına göre kategorize edildi. Kardiyopleji dozu, toplam hacim olarak değerlendirildi ve vücut ağırlığına, sol ventrikül kütlesine (LVM) ve sol ventrikül kütle indeksine (LVMI) göre indekslendi. Birincil biyokimyasal sonuç, postoperatif 24. saat troponin düzeyiydi. Kardiyopleji indeksleri ile troponin düzeyleri arasındaki ilişkileri değerlendirmek için korelasyon ve regresyon analizleri yapıldı.

Sonuçlar: Çalışmaya dahil edilen 42 hastanın yaş ortalaması 63,29±8,61 yıl olup, 30'u (%71,4) erkekti. Sol ventrikül hipertrofisi olan hastalarda, benzer toplam kardiyopleji hacimlerine rağmen, kardiyopleji/LVM ve kardiyopleji/LVMI oranları anlamlı olarak daha düşüktü (her ikisi için p<0,001). Kardiyopleji/kg oranı LVH grubunda daha yüksekti (p=0,008), ancak postoperatif troponin düzeyleriyle ilişkili değildi (rho=-0,155, p=0,329). Buna karşılık, postoperatif 24. saat troponin düzeyleri kardiyopleji/LVM (rho=-0,389, p=0,011) ve kardiyopleji/LVMI (rho=-0,350, p=0,023) oranlarıyla anlamlı ters korelasyon gösterdi. Çok değişkenli doğrusal regresyon analizinde kardiyopleji/LVM oranı, postoperatif troponin düzeyi ile bağımsız ve ters ilişkili bulundu. Bu ilişki, kardiyopulmoner bypass süresine göre düzeltme yapıldıktan sonra da devam etti (B=-0,389, p=0,010).

Sonuç: Elektif, kardiyopulmoner bypass altında gerçekleştirilen üç damar koroner arter bypass greftlemesinde, miyokard kütlesine indeksli kardiyopleji parametreleri, özellikle kardiyopleji/sol ventrikül kütlesi oranı, vücut ağırlığına indeksli kardiyoplejiden daha çok postoperatif troponin salınımıyla ilişkili olabilir. Bu bulgular, miyokard koruma stratejileri planlanırken miyokard kütlesinin dikkate alınması gerektiğini göstermektedir.

Anahtar Kelimeler: Koroner arter baypas greftlemesi; Sol ventrikül hipertrofisi; Troponin

Introduction

Postoperative troponin elevation is common after CABG and is a biochemical marker of perioperative myocardial injury(1). It is associated with early- and mid-term morbidity and mortality and may inform clinical decision-making (2,3).

However, the interpretation of postoperative troponin elevation is not always straightforward, as it may reflect serious complications such as graft occlusion or perioperative myocardial infarction, but may also result from direct surgical trauma, reperfusion injury, defibrillation, and inadequate myocardial protection (3,4).

Inadequate cardioplegic protection is considered one of the key mechanisms contributing to postoperative troponin release. Nevertheless, the degree of myocardial injury may depend not only on the total volume of cardioplegia administered, but also on the structural and metabolic properties of the myocardium requiring protection. Increased left ventricular wall thickness and myocardial mass have been shown to affect myocardial oxygen consumption and the response to ischemia (5). Accordingly, patients with left ventricular hypertrophy may exhibit a different postoperative troponin response. Despite this biological plausibility, the relationship between increased myocardial mass and postoperative troponin levels remains incompletely understood.

The present study aimed to investigate factors associated with postoperative 24-hour troponin levels in patients undergoing elective on-pump three-vessel CABG, with a particular focus on preoperative left ventricular hypertrophy and cardioplegia parameters indexed to left ventricular mass and left ventricular mass index.

Methods

Study Design and Patient Selection

This retrospective, observational, single-center study included patients who underwent elective on-pump three-vessel coronary artery bypass grafting (CABG) at the Department of Cardiovascular Surgery, Faculty of Medicine, Balıkesir University, between January 2023 and October 2025. Ethical approval for the study was obtained from the Balıkesir University Faculty of Medicine Health Research Ethics Committee (Decision No: 2025/10-7, November 18, 2025).

Eligible patients underwent elective on-pump three-vessel CABG and had the preoperative echocardiographic measurements required for LVM calculation and postoperative 24-hour troponin data.

During the study period, 213 patients underwent isolated three-vessel CABG. We excluded patients who underwent emergency surgery, off-pump CABG, or previous cardiac surgery; those requiring additional cardiac intervention for postoperative myocardial infarction; and those with missing echocardiographic or troponin data. The final analysis included 42 patients.

Data Collection and Definitions

Demographic, clinical, echocardiographic, and intraoperative data were retrospectively obtained from hospital records and the electronic medical record system. Recorded demographic and clinical variables included age, sex, smoking status, and comorbid conditions. Preoperative echocardiographic parameters included left ventricular end-diastolic diameter, interventricular septal thickness, posterior wall thickness and left ventricular ejection fraction.

Left ventricular mass (LVM) was calculated from echocardiographic measurements using the Devereux formula: LVM(g) = 0.8 × {1.04 × [(IVSd + LVEDD + PWd)^3 – LVEDD^3]}+ 0.6 g. Left ventricular mass index (LVMI) was derived by dividing LVM by body surface area. Left ventricular hypertrophy was defined using sex-specific cut-off values as an LVMI >115 g/m^2 for men and >95 g/m^2 for women.

Patients were categorized into two groups according to the presence or absence of left ventricular hypertrophy based on preoperative echocardiographic findings. Intraoperative variables included aortic cross-clamp time, cardiopulmonary bypass time, and total cardioplegia volume administered.

Cardioplegia Indices and Outcome Measure

In all patients, myocardial protection was achieved using del Nido cardioplegia. The solution was administered after aortic cross-clamping via the antegrade route according to the institutional myocardial protection protocol. Additional doses were administered when required according to cross-clamp duration and intraoperative myocardial protection needs. The total cardioplegia volume delivered during the procedure was recorded for each patient and used for subsequent indexing analyses.

Cardioplegia dose was evaluated not only as total administered volume but also using indexed parameters intended to better reflect myocardial protection requirements. For this purpose, the cardioplegia to body weight ratio, cardioplegia to left ventricular mass ratio, and cardioplegia to left ventricular mass index ratio were calculated.

Postoperative troponin measurement was routinely performed in all patients undergoing CABG at our institution as part of the standard postoperative follow-up protocol and was not based on selective clinical indication. Troponin levels were measured at predefined postoperative time points, and the 24-hour postoperative troponin value was used as the primary biochemical endpoint in the present study.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics software. Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum), depending on distributional characteristics, whereas categorical variables were presented as counts and percentages.

Group comparisons were performed using the independent-samples t-test for normally distributed continuous variables and the Mann–Whitney U test for non-normally distributed continuous variables. Categorical variables were compared using the Pearson chi-square test or Fisher's exact test, as appropriate.

The relationship between postoperative 24-hour troponin levels and cardioplegia indices was examined using Spearman correlation analysis. Since troponin values showed a skewed distribution, logarithmic transformation was applied prior to regression analyses, and log-transformed postoperative 24-hour troponin level [ln(Troponin-24h)] was used as the dependent variable. Univariable linear regression analyses were performed for demographic, echocardiographic, intraoperative, and indexed cardioplegia variables. Variables found to be significant in univariable analyses were subsequently entered into the multivariable linear regression model. Accordingly, cardiopulmonary bypass time and the cardioplegia to left ventricular mass ratio were included in the final multivariable model to evaluate the independent association between myocardial mass-adjusted cardioplegia delivery and postoperative troponin levels. A two-sided p value <0.05 was considered statistically significant.

Results

A total of 42 patients were included in the study. The mean age was 63.29 ± 8.61 years, and 30 patients (71.4%) were male. Based on preoperative echocardiographic assessment, patients were divided into two groups: those without LVH (n=20) and those with LVH (n=22). There were no significant differences between the LVH and non-LVH groups in terms of age (p=0.194), body mass index (p=0.787), sex distribution (p=0.241), smoking status (p=0.476), hypertension (p=0.126), diabetes mellitus (p=0.516), or chronic obstructive pulmonary disease (p=1.000) (Table 1). In contrast, hyperlipidemia was significantly more frequent in the non-LVH group than in the LVH group (60.0% vs. 22.7%, p=0.027). The demographic, clinical, echocardiographic, and intraoperative characteristics of the study population are summarized in Table 1.

Table 1. Descriptive characteristics of the study population according to left ventricular hypertrophy

	Left ventricular hypertrophy		stat	p Value
	Absent (n=20)	Present (n=22)		
Age	61.45±9.58	64.95±7.59	1.320	0.194[t]
BMI	28.24±3.79	27.91±4.13	-0.271	0.787[t]
Sex				
Female	4 (20.0)	8 (36.4)	1.375	0.241[c]
Male	16 (80.0)	14 (63.6)		
Smoke				
Absent	9 (47.4)	8 (36.4)	0.509	0.476[c]
Present	10 (52.6)	14 (63.6)		
Chronic Diseases				
Hypertension	8 (40.0)	14 (63.6)	2.346	0.126[c]
Diabetes Mellitus	8 (40.0)	11 (50.0)	0.423	0.516[c]
Hyperlipidemia	12 (60.0)	5 (22.7)	-	0.027[f]
COPD	2 (10.0)	2 (9.1)	-	1.000[f]
LVEDD (mm)	45 (38-49)	50 (39-58)	126.500	**0.016[m]**
IVS thickness (mm)	11 (10-13)	12.5 (11-17)	76.000	**<0.001[m]**
PW thickness (mm)	10 (10-12)	12 (8-15)	74.000	**<0.001[m]**
EF (%)	50 (35-65)	50 (30-55)	202.500	0.649[m]
LVM (g)	174.82±30.06	247.81±38.82	6.762	**<0.001[t]**
LVMI (g/m²)	91.36±14.07	133.97±14.84	9.523	**<0.001[t]**
X-Clamp Time (min)	43.70±7.31	48.13±11.17	1.536	0.133[t]
CPB Time (min)	69 (54-98)	74 (50-128)	182.000	0.338[m]
Cardioplegia (ml)	700 (500-1100)	750 (600-1100)	181.000	0.318[m]
Troponin-24h	895 (222-6324)	1076 (420-7760)	172.000	0.227[m]
Cardioplegia/Body weight	9.27±1.16	10.25±1.12	2.792	0.008[t]
Cardioplegia/LVM	4.04 (2.88-5.29)	3.08 (2.45-3.64)	-5.110	**<0.001[t]**
Cardioplegia/LVMI	8.00±1.74	5.73±1.09	23.000	**<0.001[m]**

M: Mann Whitney U test, t: independent two-sample t-test, c:Pearson's chi-square test, mean±standard deviation, n (%).BMI, body mass index; COPD, chronic obstructive pulmonary disease; LVEDD, left ventricular end-diastolic diameter; IVS, interventricular septum; PW, posterior wall; EF, ejection fraction; LVM, left ventricular mass; LVMI, left ventricular mass index; CPB, cardiopulmonary bypass.

As expected, the echocardiographic structural parameters used to define LVH were higher in the LVH group; therefore, they are presented descriptively in Table 1 and were not interpreted as independent findings. Left ventricular ejection fraction did not differ between groups (p=0.649).

Regarding intraoperative variables, aortic cross-clamp time was longer in the LVH group; however, the difference did not reach statistical significance (48.13 ± 11.17 vs. 43.70 ± 7.31 minutes, p=0.133). Likewise, cardiopulmonary bypass time and total cardioplegia volume did not differ significantly between the groups (p=0.338 and p=0.318, respectively). Although postoperative 24-hour troponin levels were numerically higher in the LVH group, this difference was not statistically significant (p=0.227).

In contrast, analysis of indexed cardioplegia variables revealed significant differences between the groups. The cardioplegia to body weight ratio was significantly higher in the LVH group (10.25 ± 1.12 vs. 9.27 ± 1.16, p=0.008). However, both the cardioplegia to left ventricular mass ratio (p<0.001) and the cardioplegia to left ventricular mass index ratio (p<0.001) were significantly lower in the LVH group.

The relationship between postoperative 24-hour troponin levels and cardioplegia indices was assessed using Spearman correlation analysis. No significant association was observed between troponin level and the cardioplegia to body weight ratio (rho = -0.155, p = 0.329). In contrast, significant negative correlations were found between troponin level and both the cardioplegia to left ventricular mass ratio (rho = -0.389, p = 0.011; Figure 1) and the cardioplegia to left ventricular mass index ratio (rho = -0.350, p = 0.023). In addition, there was a strong positive correlation between the cardioplegia to left ventricular mass ratio and the cardioplegia to left ventricular mass index ratio (rho = 0.881, p < 0.001).

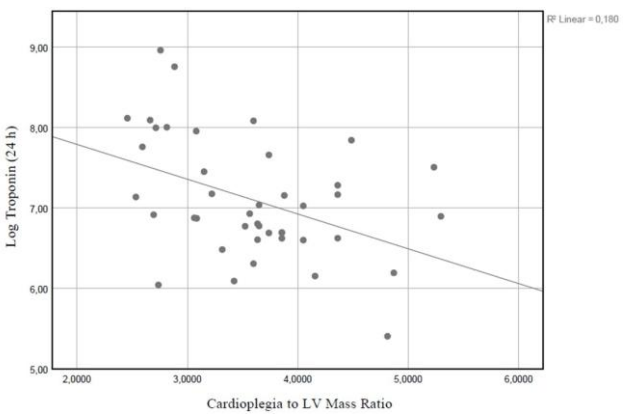

Figure 1. Scatter plot showing the relationship between Cardioplegia/LV Mass Ratio and Log Troponin (24 h).

In univariable linear regression analyses using log-transformed postoperative 24-hour troponin level as the dependent variable, age, sex, left ventricular hypertrophy status, left ventricular ejection fraction, aortic cross-clamp time, left ventricular mass, left ventricular mass index, and the cardioplegia to body weight ratio were not significantly associated with troponin level. In contrast, cardiopulmonary bypass time (B=0.015, β=0.336, 95% CI: 0.002 to 0.029, p=0.029; R^2=0.113), total cardioplegia volume (B=-0.002, β=-0.337, 95% CI: -0.004 to 0.000, p=0.029; R^2=0.114), the cardioplegia to left ventricular mass ratio (B=-0.432, β=-0.424, 95% CI: -0.727 to -0.137, p=0.005; R^2=0.180), and the cardioplegia to left ventricular mass index ratio (B=-0.150, β=-0.368, 95% CI: -0.272 to -0.029, p=0.017; R^2=0.135) were significantly associated with troponin level (Table 2).

Table 2. Univariable linear regression analyses for log-transformed postoperative 24-hour troponin levels

	B	Standard Error	Standardized β	95% CI	p value	R^2
Age	0.004	0.014	0.051	-0.023 to 0.032	0.749	0.003
Sex (Ref.:Female)	0.146	0.257	0.089	-0.374 to 0.665	0.574	0.008
Left ventricular hypertrophy (Ref.: Absent)	0.273	0.229	0.185	-0.191 to 0.737	0.241	0.034
Left ventricular ejection fraction	-0.019	0.016	-0.184	-0.051 to 0.013	0.242	0.034
X-clamp time	0.021	0.012	0.267	-0.003 to 0.044	0.087	0.072
CPB time	0.015	0.007	0.336	0.002 to 0.029	**0.029**	0.113
Cardioplegia volume	-0.002	0.001	-0.337	-0.004 to 0.000	**0.029**	0.114
Left ventricular mass	0.003	0.002	0.227	-0.001 to 0.008	0.149	0.051
Left ventricular mass index	0.007	0.004	0.231	-0.002 to 0.016	0.140	0.054
Cardioplegia/body weight	-0.124	0.094	-0.205	-0.314 to 0.065	0.193	0.042
Cardioplegia/LVM	-0.432	0.146	-0.424	-0.727 to -0.137	**0.005**	0.180
Cardioplegia/LVMI	-0.150	0.060	-0.368	-0.272 to -0.029	**0.017**	0.135

Dependent variable: log-transformed postoperative 24-hour troponin level. CI, confidence interval.

To further evaluate the independent effect of the cardioplegia to left ventricular mass ratio on postoperative troponin level, a multivariable linear regression model was constructed including cardiopulmonary bypass time as a covariate. The overall model was statistically significant (F=6.678, p=0.003) and explained 25.5% of the variance in log-transformed troponin levels (R^2=0.255; adjusted R^2=0.217). In this adjusted model, the cardioplegia to left ventricular mass ratio remained independently and inversely associated with postoperative troponin level (B=-0.389, β=-0.381, 95% CI: -0.677 to -0.100, p=0.010), whereas cardiopulmonary bypass time showed a borderline association (B=0.013, β=0.277, 95% CI: 0.000 to 0.026, p=0.054) (Table 3).

Table 3. Multivariable linear regression analysis for log-transformed postoperative 24-hour troponin levels

	B	Standard Error	Standardized β	95% CI	p value
CPB time	0.013	0.006	0.277	0.000 to 0.026	0.054
Cardioplegia/LVM	-0.389	0.143	-0.381	-0.677 to -0.100	**0.010**

Dependent variable: log-transformed postoperative 24-hour troponin levels. CI, confidence interval.

Discussion

In elective on-pump three-vessel CABG, postoperative 24-hour troponin levels were associated with cardioplegia indices normalized to myocardial mass rather than with LVH status itself. Although postoperative troponin levels were numerically higher in patients with LVH, this difference was not statistically significant. However, despite similar total cardioplegia volumes between the groups, cardioplegia/LVM and cardioplegia/LVMI ratios were significantly lower in patients with LVH. In addition, significant inverse relationships were observed between postoperative troponin levels and both cardioplegia/LVM and cardioplegia/LVMI, whereas no similar relationship was demonstrated for the cardioplegia/kg ratio. The persistence of the independent association between the cardioplegia/LVM ratio and postoperative troponin levels after adjustment for cardiopulmonary bypass time suggests that the actual myocardial mass requiring protection may need to be considered in the assessment of myocardial protection.

Troponin elevation after CABG is a well-recognized phenomenon and is considered one of the biochemical indicators of perioperative myocardial injury (6). The ESC joint position paper also emphasizes the central role of troponin as a biomarker in the definition of myocardial injury and infarction after CABG (7).

Omran et al. showed that postoperative high-sensitivity troponin I may inform decision-making after isolated CABG, particularly at 12–16 hours and at higher thresholds (3). Thus, troponin elevation is not merely a laboratory finding but a marker of myocardial injury requiring clinical interpretation.

Postoperative troponin release may result from surgical manipulation, ischemia–reperfusion injury, cardiopulmonary bypass, or cardioplegic arrest and should not be attributed to a single mechanism (6,7). Nevertheless, myocardial protection and cardioplegia administration may influence biomarker release. Cardioplegia dosing varies by solution, route, redosing interval, cross-clamp time, protocol, and patient characteristics. Some adult cold crystalloid protocols use 10 mL/kg initially and 5 mL/kg for redosing (8), whereas adult del Nido protocols often use 20 mL/kg with a maximum of 1000 mL (9). Therefore, body weight alone may not fully reflect cardioplegia adequacy in patients with increased myocardial mass..

The main contribution of our study is that it attempts to evaluate this conceptual distinction using clinical data. In our study, although the cardioplegia/kg ratio appeared to be higher in the LVH group, cardioplegia/LVM and cardioplegia/LVMI ratios were lower in the same group. In other words, when cardioplegia dose is assessed only according to body weight, it may appear to be “adequate” or even “higher”; however, when the myocardial mass requiring protection is taken into account, a relative dose inadequacy may become evident. The fact that cardioplegia/LVM and cardioplegia/LVMI, but not cardioplegia/kg, were significantly associated with troponin levels supports this interpretation. This finding suggests that a kilogram-based approach may not adequately represent the target tissue in the quantitative assessment of myocardial protection, especially in patients with increased left ventricular mass.

This approach is particularly important in the context of hypertrophied myocardium. Left ventricular hypertrophy has been reported to be associated with myocardial ischemia and may contribute to ischemia even in patients without obstructive coronary artery disease or severe coronary stenosis.

Eskerud et al. showed that, in patients with stable angina and non-obstructive coronary artery disease, LVH was independently associated with both the presence and extent of myocardial ischemia (5). On the other hand, protection of the hypertrophied myocardium during surgery represents a specific challenge. Recent reviews have shown that cardiopulmonary bypass and cardioplegic arrest in cardiac surgery may lead to global ischemia-reperfusion injury, while studies focusing on the hypertrophied heart suggest that this myocardium may respond differently to ischemia-reperfusion and cardioplegic arrest, and that myocardial protection strategies should be optimized in this patient group (10,11). This pathophysiological background supports the biological plausibility of our finding that cardioplegia may appear adequate when indexed to body weight, but relatively insufficient when indexed to LVM or LVMI.

It is also noteworthy that LVM and LVMI alone were not significantly associated with postoperative troponin levels, whereas cardioplegia/LVM and cardioplegia/LVMI ratios were significant. This suggests that the main determinant of postoperative troponin elevation may not be the presence of a “large” or “hypertrophied” ventricle alone, but rather the adequacy of the administered cardioplegia volume relative to the myocardial mass requiring protection. Indeed, the persistence of the independent association of the cardioplegia/LVM ratio after adjustment for cardiopulmonary bypass time suggests that postoperative troponin elevation may not be explained solely by surgical complexity or prolonged bypass time. This finding supports the hypothesis that relative cardioplegia inadequacy according to myocardial mass may contribute to postoperative myocardial injury. However, due to the observational nature of the study, this association should not be interpreted as causal, but rather as a relationship that requires confirmation in prospective studies.

From a clinical perspective, LVM and LVMI measurements, which can be readily calculated or reported from preoperative echocardiographic assessment, may potentially be used to individualize cardioplegia strategy. ASE/EACVI echocardiography guidelines state that left ventricular mass and indexed left ventricular mass can be reported as part of standard echocardiographic assessment in adults (12). Therefore, in patients with hypertension, long-standing pressure overload, or chronic ventricular remodeling, an approach that also takes myocardial mass into account may theoretically be more appropriate than cardioplegia planning based solely on body weight. However, the present study is not sufficient to propose a dosing algorithm. Our findings support the need to test the concept of “target myocardial mass-based cardioplegia dosing” in prospective, preferably multicenter studies, particularly in patients with hypertrophied or increased ventricular mass.

This study has several limitations. First, it has a retrospective and single-center design; therefore, causal interpretations are limited. Second, the sample size is small, which may particularly affect the stability of multivariable models. Third, not all determinants that may influence troponin elevation, such as surgical manipulation, reperfusion injury, need for defibrillation, and microvascular factors, could be analyzed at the same level of detail. Preoperative troponin values were not included in the analysis, which may limit the interpretation of postoperative 24-hour troponin levels as a marker of new perioperative myocardial injury. Fourth, LVM and LVMI were calculated from echocardiographic measurements; therefore, measurement variability may have influenced the cardioplegia/LVM and cardioplegia/LVMI ratios. In addition, the cardioplegia indexing analysis was a secondary evaluation based on available intraoperative and echocardiographic data and should therefore be interpreted as hypothesis-generating. Nevertheless, the inclusion of a cohort consisting of elective, on-pump, three-vessel CABG patients made the study population more homogeneous and strengthened the internal consistency of the findings.

Conclusion

In conclusion, this study suggests that, in patients undergoing elective on-pump three-vessel CABG, postoperative troponin levels may be more closely associated with cardioplegia ratios indexed to myocardial mass than with cardioplegia ratios calculated according to body weight. In particular, the independent inverse association between the cardioplegia/LVM ratio and postoperative troponin levels suggests that myocardial mass requiring protection, in addition to patient body weight, may need to be considered when planning myocardial protection. Larger prospective studies are needed to validate the clinical value of this approach.

References

1. Moon MH, Song H, Wang YP, Jo KH, Kim CK, Cho KD. Changes of cardiac troponin I and operative mortality of coronary artery bypass. Asian Cardiovasc Thorac Ann. 2014;22(1):40-45. doi:10.1177/0218492312468439.
2. Vikenes K, Andersen KS, Melberg T, Farstad M, Nordrehaug JE. Long-term prognostic value of cardiac troponin I and T versus creatine kinase-MB mass after cardiac surgery in low-risk patients with stable symptoms. Am J Cardiol. 2010;106(6):780-786. doi:10.1016/j.amjcard.2010.04.038.
3. Omran H, Deutsch MA, Groezinger E, et al. High-sensitivity cardiac troponin I after coronary artery bypass grafting for post-operative decision-making. Eur Heart J. 2022;43(25):2388-2403. doi:10.1093/eurheartj/ehab918.
4. White HD. Pathobiology of troponin elevations: do elevations occur with myocardial ischemia as well as necrosis? J Am Coll Cardiol. 2011;57(24):2406-2408. doi:10.1016/j.jacc.2011.01.029.
5. Eskerud I, Gerdts E, Larsen TH, Lønnebakken MT. Left ventricular hypertrophy contributes to myocardial ischemia in non-obstructive coronary artery disease (the MicroCAD study). Int J Cardiol. 2019;286:1-6. doi:10.1016/j.ijcard.2019.03.059.
6. Heuts S, Gollmann-Tepeköylü C, Denessen EJS, et al. Cardiac troponin release following coronary artery bypass grafting: mechanisms and clinical implications. Eur Heart J. 2023;44(2):100-112. doi:10.1093/eurheartj/ehac604.
7. Thielmann M, Sharma V, Al-Attar N, et al. ESC Joint Working Groups on Cardiovascular Surgery and the Cellular Biology of the Heart position paper: perioperative myocardial injury and infarction in patients undergoing coronary artery bypass graft surgery. Eur Heart J. 2017;38(31):2392-2407. doi:10.1093/eurheartj/ehx383.
8. Nardi P, Pellegrino A, Scafuri A, et al. Warm blood cardioplegia versus cold crystalloid cardioplegia for myocardial protection in coronary artery bypass grafting surgery. J Cardiothorac Surg. 2018;13:14. doi:10.1186/s13019-018-0709-8.
9. Kim K, Ball C, Grady P, Mick S. Use of del Nido cardioplegia for adult cardiac surgery at the Cleveland Clinic: perfusion implications. J Extra Corpor Technol. 2014;46(4):317-323.
10. Chiari P, Mewton N, Ovize M. Myocardial protection in cardiac surgery: a comprehensive review of current therapies and future cardioprotective strategies. Front Med (Lausanne). 2024;11:1386189. doi:10.3389/fmed.2024.1386189.
11. Suleiman MS, Hancock M, Shukla R, Rajakaruna C, Angelini GD. Cardioplegic strategies to protect the hypertrophic heart during cardiac surgery. Perfusion. 2011;26 Suppl 1:48-56. doi:10.1177/0267659111420607.
12. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging. 2015;16(3):233-270. doi:10.1093/ehjci/jev014.