Texas Heart Institute Journal

Clinical Investigation

Relationship Between Preprocedural Lipid Levels and Periprocedural Myocardial Injury in Patients Undergoing Elective Percutaneous Coronary Intervention

Mohsen Maadani, MD; Nima Sari Sarraf, MD; Sanam Alilou, MD; Kamran Aeinfar, MD; Parham Sadeghipour, MD; Ali Zahedmehr, MD; Mahmood Sheikh Fathollahi, PhD; Seyyed Isa Hashemi Ghadi, MD; Abbas Zavarehee, PhD; Maryam Zolfaghari, MD; Reza Zolfaghari, MD

Cardiovascular Intervention Research Center, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, Iran

Background: *Periprocedural myocardial injury is a predictor of cardiovascular morbidity and mortality after percutaneous coronary intervention.*

Methods: *The authors examined the effects of preprocedural lipid levels (low-density lipoprotein, high-density lipoprotein, and triglycerides) in 977 patients with coronary artery disease who underwent elective percutaneous coronary intervention.*

Results: *Elevated cardiac troponin I level (≥5× the upper limit of normal) was used to indicate periprocedural myocardial injury. Serum lipid samples were collected 12 hours preprocedurally. Cardiac troponin I was collected 1, 6, and 12 hours postprocedurally. Correlations between preprocedural lipid levels and postprocedural cardiac troponin I were studied. Low-density lipoprotein levels were less than 70 mg/dL in 70% of patients and greater than 100 mg/dL in only 7.4% of patients; 13% had triglyceride levels greater than or equal to 150 mg/dL, and 96% had high-density lipoprotein levels less than 40 mg/dL. Patients with elevated cardiac troponin I had significantly lower left ventricular ejection fraction than did those with cardiac troponin I levels less than 5× the upper limit of normal (*P = .01*). Double- and triple-vessel disease were more common in patients with elevated cardiac troponin I (*P < .002*). Multivariable logistic and linear regression analyses revealed no statistically significant associations between lipid levels and postprocedural cardiac troponin I elevation, possibly because such large proportions of included patients had low levels of low-density lipoprotein (70%) and a history of statin intake (86%).*

Conclusion: *The authors found no association between lipid profile and periprocedural myocardial injury.* ***(Tex Heart Inst J. 2022;49(6):e207384)***

Citation:
Maadani M, Sarraf NS, Alilou S, Aeinfar K, Sadeghipour P, Zahedmehr A, Fathollahi MS, Ghadi SIH, Zavarehee A, Zolfaghari M, Zolfaghari R. Relationship between preprocedural lipid profile levels and periprocedural myocardial injury in patients undergoing elective percutaneous coronary intervention. *Tex Heart Inst J.* 2022;49(6):e207384. doi:10.14503/THIJ-20-7384

Keywords:
Percutaneous coronary intervention; lipids; troponin I; myocardial reperfusion injury

Corresponding author:
Reza Zolfaghari, MD, Vali-Asr Ave, Niyayesh Boulevard, Cardiovascular Intervention Research Center, Rajaie Cardiovascular Medical and Research Center, Iran University of Medical Sciences, Tehran, 1996114151, Iran

E-mail:
rzolf@yahoo.com

Coronary artery disease (CAD) is a substantial global health problem and is considered the leading cause of death worldwide.[1] Percutaneous coronary intervention (PCI) is the most common invasive cardiology treatment performed to treat CAD the world over.[2]

The incidence of periprocedural myocardial injury (infarction) has not fallen substantially despite technological advances and effective medical treatment.[3] Many clinical studies have shown that periprocedural myocardial injury is a predictor of adverse clinical outcomes after PCI. According to the Global Working Group on Myocardial Infarction (comprising members of the European Society of Cardiology and the American Heart Association), one of the criteria for defining periprocedural myocardial injury is an elevation in serum biomarkers (specifically, cardiac troponin).[4] Cardiac troponins are sensitive, specific markers of myocardial necrosis, and troponin elevation portends an increase in long-term all-cause mortality and related adverse events that underlie periprocedural myocardial injury.[5-7]

Dyslipidemia is an independent risk factor for CAD. Clinical trials have shown that elevated levels of serum low-density lipoprotein (LDL) cholesterol and low levels

of serum high-density lipoprotein (HDL) cholesterol are linearly associated with CAD and that aggressive therapy to lower LDL levels reduces the frequency of adverse outcomes in patients with CAD.[8-11] Previous debate about the role of elevated triglyceride (TG) levels in CAD has given way to new data showing that hypertriglyceridemia is indeed an independent risk factor for CAD.[12,13] What remains unclear is whether aggressive treatment aiming to improve the lipid profile before intervention can further diminish periprocedural myocardial injury and enhance outcomes and prognosis in patients with stable CAD who are undergoing elective PCI.

In this study, the authors evaluated preprocedural LDL, HDL, and TG levels to determine their effect, if any, on periprocedural myocardial injury in patients undergoing elective PCI.

Patients and Methods

This prospective, single-center study recruited consecutive patients with a primary diagnosis of stable CAD who underwent percutaneous revascularization between March 1, 2019, and February 29, 2020, at Rajaie Cardiovascular Medical and Research Center, Tehran, Iran. Patients were eligible for inclusion if they exhibited stable angina with normal cardiac troponin I (cTnI) levels before the procedure. Patients with recent myocardial infarction or incomplete lipid profile data were excluded.

Experienced interventional cardiologists performed all PCI procedures in accordance with the latest guidelines from the American College of Cardiology and the American Heart Association, which recommend aspirin, clopidogrel, and moderate- to high-intensity statin therapy.[14] Before the procedure, all patients received a loading dose of 300 mg of aspirin irrespective of whether they were already on daily aspirin therapy. The day before the procedure, patients on daily clopidogrel received a clopidogrel loading dose of 300 mg; patients not on daily clopidogrel received a 600-mg loading dose. At the beginning of angioplasty, a 100-U/kg bolus of intravenous unfractionated heparin was injected. Additional boluses of 2,000 to 3,000 U were given every hour if the procedure lasted for more than 1 hour, up to a maximum dose of 10,000 U. All participants underwent continuous electrocardiographic monitoring before, during, and after PCI to detect possible ischemic events.

Baseline samples for the serum lipid profile, including LDL, HDL, and TG, were collected before PCI after 12 to 14 hours of fasting. Lipid levels were measured using the electroluminescence method with a Hitachi 917 rack chemistry analyzer (Roche). Postprocedural samples for cTnI analysis were collected 1, 6, and 12 hours after PCI and were analyzed using the chemiluminescence immunoassay method with an Abbott ARCHITECT analyzer.

Diagnoses of procedure-related myocardial injury were based on either (1) the development of new pathological Q waves in at least 2 contiguous electrocardiogram leads or (2) cTnI elevation greater than or equal to 5× the upper limit of normal (ULN), according to the Fourth Universal Definition of Myocardial Infarction.[6]

The study was performed in accordance with the ethical standards of the Declaration of Helsinki and approved by the Review Board and the Human Ethics Committee of Rajaie Cardiovascular Medical and Research Center. Informed consent was obtained from all participants.

Statistical Analysis

Results are presented as mean (SD) for numerical variables and absolute frequencies and percentages for categorical variables. The numerical variables were compared by using the independent 2-sample *t* test or 1-way analysis of variance between the 2 groups. Categorical variables were compared by using the χ^2 test.

For analysis, patients were stratified into various comparator groups, both by preprocedural lipid type and level (LDL, <70, 70-99, or ≥100 mg/dL; HDL, <40 or ≥40 mg/dL; and TG, <150, 150-199, or ≥200 mg/dL) and by peak level of postprocedural cTnI (≥5× the ULN or <5× the ULN).

Multivariable logistic regression analyses were performed to determine the relationship between the baseline clinical parameters (LDL, HDL, and TG) and elevated postprocedural cTnI (≥5× the ULN). As a sensitivity analysis, the relationships between the clinical parameters and the postprocedural cTnI level (considered a continuous dependent variable rather than a dichotomized variable) were examined by using multivariable linear regression analyses.

In the multivariable regressions, adjustments were made according to clinical judgment and similar studies.[15,16] Covariates used in the adjustment included age; sex; the number of diseased vessels subjected to PCI; fasting blood sugar level; creatinine level; left ventricular ejection fraction (LVEF); coronary angiography results; presence of diabetes mellitus, hypertension, bifurcation, chronic total occlusion, or in-stent restenosis; and use of predilation or postdilation. These confounding variables were regarded as preprocedural covariates independently associated with postprocedural cTnI levels.

All *P* values were considered 2-tailed, with statistical significance set at $P < .05$. The statistical software SPSS version 22.0 for Windows (SPSS, Inc) was used for the statistical analyses.

Results

During the study period, 1,024 patients at Rajaie Cardiovascular Medical and Research Center had a primary diagnosis of stable CAD and underwent percutaneous revascularization. Of these, 20 patients were excluded because of an elevated baseline cTnI level (indicating previous myocardial infarction) and 27 were excluded because of incomplete lipid profile tests or missing laboratory data. The remaining 977 patients were enrolled, including 697 men (mean [SD] age, 59.8 [10.5] years) and 280 women (mean [SD] age, 62.4 [9.0] years).

Low-Density Lipoprotein

Table I depicts baseline patient characteristics and angiographic and lab data by LDL subgroup. In terms of distribution, LDL less than 70 mg/dL was reported in 681 patients (69.7%), LDL 70 to 99 mg/dL in 224 patients (22.9%), and LDL greater than or equal to 100 mg/dL in 72 patients (7.4%). A higher proportion of patients in all LDL categories were male, and patients in all 3 LDL categories tended to have hypertension (P = .048). Patients with LDL greater than or equal to 100 mg/dL were younger than those in the other groups (P = .01). Other clinical characteristics did not differ significantly by LDL group, nor were there any statistically significant differences in medical therapy by group.

Angiography characteristics did not differ by LDL category, except for chronic total occlusion (P = .04). Preprocedural platelet and hemoglobin levels differed significantly by LDL group (P = .03 and P = .02, respectively). Although patients with LDL greater than 100 mg/dL had a higher platelet level, the level was within the normal range and the difference was not clinically meaningful.

High-Density Lipoprotein

Baseline clinical and procedural characteristics by HDL subgroup are detailed in Table II. In terms of distribution, HDL less than 40 mg/dL was reported in 933 patients (95.5%) and HDL greater than or equal to 40 mg/dL in 44 (4.5%). Patients in either group tended to be nonsmokers (P = .04). Patients with HDL less than 40 mg/dL were more likely to be younger (P = .03) and to be male than were patients with HDL greater than or equal to 40 mg/dL (P = .001). No other statistically significant differences were noted. No correlation was found between HDL and periprocedural myocardial injury in patients with LDL less than 70 mg/dL (β = .018; 95 CI, –.037 to .059; P = .64; R^2 = –0.001).

Triglycerides

Demographic, clinical, and angiographic characteristics by TG subgroup are shown in Table III. In terms of distribution, TG less than 150 mg/dL was reported in 855 patients (87.5%), TG 150 to 199 mg/dL in 71 (7.3%), and TG greater than or equal to 200 mg/dL in 51 (5.2%). Patients with TG greater than or equal to 200 mg/dL were more often younger (P < .001), had a higher mean fasting blood sugar level (P = .005), and had a higher frequency of diabetes mellitus (P = .04) than the other groups. Patients in the group with TG less than 150 mg/dL were more likely to be taking aspirin (P = .045). There were no substantial differences in angiography data among these subgroups. Remarkably, we found a positive correlation between TG and LDL levels (β = .311; 95% CI, .056-.090; P < .001; R^2 = 0.095), despite the absence of an association between TG and cTnI elevation.

Postoperative Coronary Troponin I Elevation

Table IV compares the baseline clinical and procedural characteristics of the patients with and without elevated cTnI (≥5× the ULN) after the procedure. Most of the patients had a cTnI level less than 5× the ULN (n = 698 vs 279). The patients with elevated cTnI were less likely to have diabetes mellitus (P = .01) but more likely to have had a previous myocardial infarction (P = .002). The remaining clinical characteristics did not differ significantly between the 2 groups. Nevertheless, there were significant differences vis-à-vis coronary angiography results, the number of vessels subjected to PCI, and use of predilation. Patients with double- and triple-vessel disease were more likely to have elevated cTnI (P < .001). All but 1 patient underwent 1 intervention only. One patient exhibited acute symptoms and electrocardiogram changes 6 hours after PCI, at which time cTnI was 3× the ULN. The changes were attributed to acute stent thrombosis, and the patient underwent immediate angioplasty.

Preoperatively, in-stent restenosis was reported in 61 patients and bifurcation in 156. Bifurcation PCI techniques included provisional stenting in 120/977 patients (12.3%), double-kissing crush in 4/977 (0.4%), mini-crush in 9/977 (1%), T-stenting in 2/977 (0.2%), and culotte in 3/977 (0.3%). Patients with elevated cTnI were more likely to have had predilation (P = .009) or bifurcation (P = .003) and had significantly lower LVEF (P = .01) and higher hemoglobin levels (P = .02). Still, mean hemoglobin levels were within the normal range for physiologic blood concentrations. No statistically significant differences were detected in the LDL, HDL, and TG categories by cTnI group (P = .98, .62, and .20, respectively).

Logistic Regression Analyses

Table V shows the logistic regression analysis results for LDL, HDL, and TG according to elevated post-PCI cTnI (cTnI ≥5× the ULN). Neither the unadjusted nor adjusted logistic regression models found an association between elevated postprocedural cTnI and the various LDL, HDL, and TG categories.

TABLE I. Baseline Clinical and Procedural Characteristics by LDL Cholesterol

Variable	LDL <70 mg/dL (n = 681)	LDL 70-99 mg/dL (n = 224)	LDL ≥100 mg/dL (n = 72)	*P* value[a]
Age, mean (SD), y	61.0 (9.8)	60.2 (10.3)	57.3 (11.9)	.01
Sex, male/female, No. (%)	506/175 (74.3/25.7)	142/82 (63.4/36.6)	49/23 (68.1/31.9)	.006
Hypertension, No. (%)	445 (65.3)	137 (61.2)	37 (51.4)	.048
Diabetes mellitus, No. (%)	246 (36.1)	92 (41.1)	25 (34.7)	.34
Current smoking, No. (%)	242 (35.5)	73 (32.6)	25 (34.7)	.72
Coronary angiography,[b] No. (%)				.07
Single-vessel disease	214 (31.5)	74 (33.5)	26 (36.1)	
Double-vessel disease	276 (40.6)	77 (34.8)	31 (43.1)	
Triple-vessel disease	100 (14.7)	49 (22.2)	6 (8.3)	
CABG	65 (9.6)	17 (7.7)	8 (11.1)	
LMCA	25 (3.7)	4 (1.8)	1 (1.4)	
No. of vessels subjected to PCI, No. (%)				.41
1	496 (72.8)	158 (70.5)	49 (68.1)	
2	166 (24.4)	59 (26.3)	23 (31.9)	
3	18 (2.6)	7 (3.1)	0	
Predilation, No. (%)	398 (58.4)	141 (62.9)	38 (52.8)	.26
Postdilation, No. (%)	480 (70.5)	151 (67.4)	50 (69.4)	.66
Successful procedure, No. (%)	659 (96.8)	217 (96.9)	71 (98.6)	.69
Indication for PCI, No. (%)				
Bifurcation	113 (16.6)	43 (19.2)	9 (12.5)	.39
Chronic total occlusion	84 (12.3)	15 (6.7)	11 (15.3)	.04
In-stent restenosis	42 (6.2)	18 (8.0)	1 (1.4)	.13
Medical therapy, No. (%)				
Aspirin	616 (90.5)	200 (89.3)	57 (79.2)	.21
Clopidogrel	363 (53.3)	114 (50.9)	32 (44.4)	.72
Statin	586 (86.0)	188 (83.9)	51 (70.8)	.13
Nitrate	386 (56.7)	106 (47.3)	33 (45.8)	.16
β-Blocker	509 (74.7)	172 (76.8)	48 (66.7)	.55
ACEI/ARB	461 (67.7)	153 (68.3)	39 (54.2)	.38
LVEF, mean (SD), %	44.4 (9.9)	45.1 (10.6)	45.8 (8.9)	.39
Laboratory test results, mean (SD)				
Hemoglobin, mg/dL	13.4 (1.6)	13.7 (1.5)	13.7 (1.6)	.02
Creatinine, mg/dL	1.1 (0.4)	1.1 (0.5)	1.1 (0.5)	.61
ESR, mm/h	17.8 (15.8)	18.1 (15.4)	22.2 (22.0)	.11
Platelet count, $\times 10^9$/L	212.1 (55.5)	219.0 (53.2)	227.8 (46.6)	.03
FBS, mg/dL	130.1 (53.5)	136.7 (59.8)	139.4 (52.9)	.21

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass grafting; ESR, erythrocyte sedimentation rate; FBS, fasting blood sugar; LDL, low-density lipoprotein; LMCA, left main coronary artery; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention

[a] $P < .05$ was considered statistically significant.
[b] Coronary angiograms show coronary artery involvement with coronary artery disease; 4 patients did not have angiograms.

TABLE II. Baseline Clinical and Procedural Characteristics by HDL Cholesterol Group

Variable	LDL <40 mg/dL (n = 933)	LDL ≥40 mg/dL (n = 44)	*P* value[a]
Age, mean (SD), y	60.4 (10.1)	63.7 (11.4)	.03
Sex, male/female, No. (%)	675/258 (72.3/27.7)	22/22 (50/50)	.001
Hypertension, No. (%)	595 (63.8)	24 (54.5)	.21
Diabetes mellitus, No. (%)	344 (36.9)	19 (43.2)	.40
Current smoking, No. (%)	331 (35.5)	9 (20.5)	.04
Coronary angiography,[b] No. (%)			.79
Single-vessel disease	302 (32.5)	12 (27.3)	
Double-vessel disease	365 (39.3)	19 (43.2)	
Triple-vessel disease	149 (16.0)	6 (13.6)	
CABG	84 (9.0)	6 (13.6)	
LMCA	29 (3.1)	1 (2.3)	
No. of vessels subjected to PCI, No. (%)			.81
1	673 (72.2)	30 (68.2)	
2	235 (25.2)	13 (29.5)	
3	24 (2.6)	1 (2.3)	
Predilation, No. (%)	550 (58.9)	27 (61.4)	.75
Postdilation, No. (%)	646 (69.2)	35 (79.5)	.15
Successful procedure, No. (%)	904 (96.9)	43 (97.7)	>.99
Indication for PCI, No. (%)			
Bifurcation	155 (16.6)	10 (22.7)	.29
Chronic total occlusion	105 (11.3)	5 (11.4)	>.99
In-stent restenosis	59 (6.3)	2 (4.5)	>.99
Medical therapy, No. (%)			
Aspirin	839 (89.9)	37 (84.1)	.43
Clopidogrel	490 (52.5)	20 (47.4)	.65
Statin	792 (84.9)	37 (84.1)	>.99
Nitrate	513 (55.0)	12 (27.3)	.01
β-Blocker	696 (74.6)	37 (84.1)	.43
ACEI/ARB	627 (67.2)	28 (63.6)	.71
LVEF, mean (SD), %	44.7 (10.0)	43.9 (9.9)	.61
Laboratory test results, mean (SD)			
Hemoglobin, mg/dL	13.5 (1.6)	13.0 (1.5)	.05
Creatinine, mg/dL	1.1 (0.4)	1.1 (0.4)	.83
ESR, mm/h	18.1 (16.3)	20.2 (15.2)	.40
Platelets, $\times 10^9$/L	214.6 (54.6)	220.8 (53.3)	.50
FBS, mg/dL	131.7 (53.5)	144.4 (82.1)	.19

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass grafting; ESR, erythrocyte sedimentation rate; FBS, fasting blood sugar; HDL, high-density lipoprotein; LMCA, left main coronary artery; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention

[a] $P < .05$ was considered statistically significant.
[b] Coronary angiography shows coronary artery involvement with coronary artery disease; 4 patients did not have angiograms.

TABLE III. Baseline Clinical and Procedural Characteristics by TG Group

Variable	TG <150 mg/dL (n = 855)	TG 150-199 mg/dL (n = 71)	TG ≥200 mg/dL (n = 51)	*P* value[a]
Age, mean (SD), y	66.1 (10.0)	58.2 (10.1)	54.3 (9.9)	<.001
Sex, male/female, No. (%)	609/246 (71.2/28.8)	47/24(66.2/33.8)	41/10 (80.4/19.6)	.23
Hypertension, No. (%)	548 (64.1)	41 (57.7)	30 (58.8)	.45
Diabetes mellitus, No. (%)	305 (35.7)	33 (46.5)	25 (49.0)	.04
Current smoking, No. (%)	293 (34.3)	27 (38.0)	20 (39.2)	.65
Coronary angiography,[b] No. (%)				.22
Single-vessel disease	264 (31.0)	32 (45.1)	18 (35.3)	
Double-vessel disease	340 (40.0)	23 (32.4)	21 (41.2)	
Triple-vessel disease	134 (15.7)	12 (16.9)	9 (17.6)	
CABG	84 (9.9)	3 (4.2)	3 (5.9)	
LM	29 (3.4)	1 (1.4)	0	
No. of vessels subjected to PCI, No. (%)				.85
1	611 (71.5)	55 (77.5)	37 (72.5)	
2	221 (25.9)	14 (19.7)	13 (25.5)	
3	22 (2.6)	2 (2.8)	1 (2.0)	
Predilation, No. (%)	508 (59.4)	38 (53.5)	31 (60.8)	.60
Postdilation, No. (%)	598 (69.9)	51 (71.8)	32 (62.7)	.51
Successful procedure, No. (%)	828 (96.8)	69 (97.2)	50 (98.0)	.88
Indication for PCI, No. (%)				
Bifurcation	146 (17.1)	14 (19.7)	5 (9.8)	.33
Chronic total occlusion	99 (11.6)	4 (5.6)	7 (13.7)	.27
In-stent restenosis	53 (6.2)	4 (5.6)	4 (7.8)	.87
Medical therapy, No. (%)				
Aspirin	768 (89.8)	28 (39.4)	23 (45.1)	.045
Clopidogrel	215 25.1)	37 (52.1)	35 (68.6)	.24
Statin	724 (84.7)	57 (80.3)	48 (94.1)	.25
Nitrate	465 (54.4)	42 (59.2)	17 (33.3)	.14
β-Blocker	634 (74.2)	54 (76.1)	45 (88.2)	.37
ACEI/ARB	586 (68.5)	34 (47.9)	36 (70.6)	.05
LVEF, mean (SD), %	44.4 (10.1)	47.2 (8.5)	44.4 (9.6)	.09
Laboratory test results, mean (SD)				
Hemoglobin, mg/dL	13.5 (1.6)	13.7 (1.6)	13.7 (1.6)	.22
Creatinine, mg/dL	1.1 (0.4)	1.1 (0.3)	1.2 (0.6)	.13
ESR, mm/h	18.1 (15.8)	16.0 (13.8)	18.2 (16.3)	.06
Platelet count, $\times 10^9$/L	213.5 (54.9)	230.2 (48.3)	214.9 (54.5)	.046
FBS, mg/dL	130.0 (53.8)	142.1 (54.9)	154.6 (67.2)	.005

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass grafting; ESR, erythrocyte sedimentation rate; FBS, fasting blood sugar; LMCA, left main coronary artery; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; TG, triglycerides

[a] $P < .05$ was considered statistically significant.
[b] Coronary angiography shows coronary artery involvement with coronary artery disease; 4 patients did not have angiograms.

TABLE IV. Baseline Clinical and Procedural Characteristics by cTnI Elevation Group

Variable	cTnI <5× ULN (n = 698)	cTnI ≥5× ULN (n = 279)	*P* value[a]
Age, mean (SD), y	60.8 (10.6)	60.5 (10.0)	.61
Sex, male/female, No. (%)	493/205 (70.6/29.4)	204/75 (73.1/26.9)	.44
Hypertension, No. (%)	432 (61.9)	187 (67.0)	.13
Diabetes mellitus, No. (%)	277 (39.7)	86 (30.8)	.01
Current smoking, No. (%)	242 (34.7)	98 (35.1)	.89
Coronary angiography,[b] No. (%)			.002
Single-vessel disease	247 (35.5)	67 (24.1)	
Double-vessel disease	272 (39.1)	112 (40.3)	
Triple-vessel disease	97 (14.0)	58 (20.9)	
CABG	61 (8.8)	29 (10.4)	
LMCA	18 (2.6)	12 (4.3)	
No. of vessels subjected to PCI, No. (%)			<.001
1	532 (76.3)	171 (61.3)	
2	152 (21.8)	96 (34.4)	
3	13 (1.9)	12 (4.3)	
Predilation, No. (%)	394 (56.4)	183 (65.6)	.009
Postdilation, No. (%)	476 (68.2)	205 (73.5)	.11
Successful procedure, No. (%)	678 (97.1)	269 (96.4)	.56
Indication for PCI, No. (%)			
Bifurcation	102 (14.6)	63 (22.6)	.003
Chronic total occlusion	75 (10.7)	35 (12.5)	.42
In-stent restenosis	44 (6.3)	17 (6.1)	.90
Medical therapy, No. (%)			
Aspirin	627 (89.8)	248 (88.9)	.77
Clopidogrel	353 (50.6)	160 (57.3)	.19
Statin	594 (85.1)	234 (83.9)	.74
Nitrate	379 (54.3)	146 (52.3)	.73
β-Blocker	522 (74.8)	210 (75.3)	.89
ACEI/ARB	465 (66.6)	191 (68.5)	.69
LVEF, mean (SD), %	45.2 (9.7)	43.3 (10.5)	.01
Laboratory test results, mean (SD)			
Hemoglobin, mean (SD), mg/dL	13.5 (1.6)	13.5 (1.5)	.02
Creatinine level, mean (SD), mg/dL	1.1 (0.3)	1.1 (0.5)	.98
ESR, mean (SD), mm/h	19.2 (17.5)	17.8 (15.6)	.26
Platelet count, mean (SD), $\times 10^9$/L	215.6 (54.7)	213.0 (53.9)	.50
FBS, mean (SD), mg/dL	130.7 (55.0)	132.6 (55.1)	.66
LDL-C, No. (%), mg/dL			.98
<70	487 (69.8)	194 (69.5)	
70-99	159 (22.8)	65 (23.3)	
≥100	52 (7.4)	20 (7.2)	
HDL-C, mg/dL, No. (%)			.62
<40	668 (95.7)	265 (95.0)	
≥40	30 (4.3)	14 (5.0)	
TG, mg/dL, No. (%)			.20
<150	607 (87.0)	248 (88.9)	
150-199	49 (7.0)	22 (7.9)	
≥200	42 (6.0)	9 (3.2)	

ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; cTnI, cardiac troponin I; ESR, erythrocyte sedimentation rate; FBS, fasting blood glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; LMCA, left main coronary artery; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; TG, triglycerides; ULN, upper limit of normal

[a] $P < .05$ was considered statistically significant.
[b] Coronary angiography shows coronary artery involvement with coronary artery disease; 4 patients did not have angiograms.

TABLE V. Logistic Regression Analysis of the Impact of Clinical Parameters on Elevated Postprocedural cTnI (≥5× ULN)

Clinical parameter	Unadjusted OR (95% CI)	*P* value[b]	Adjusted[a] OR (95% CI)	*P* value[b]
LDL-C, mg/dL				
<70	Reference	-	Reference	-
70-99	1.02 (0.73-1.43)	.88	1.16 (0.76-1.79)	.48
≥100	0.96 (0.56-1.66)	.90	1.27 (0.63-2.55)	.50
HDL-C, mg/dL				
<40	Reference	-	Reference	-
≥40	1.17 (0.61-2.25)	.62	1.53 (0.72-3.30)	.27
TG, mg/dL				
<150	Reference	-	Reference	-
150-199	1.09 (0.65-1.85)	.72	1.27 (0.68-2.38)	.44
≥200	0.52 (0.25-1.09)	.09	0.68 (0.29-1.57)	.37

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; TG, triglycerides; ULN, upper limit of normal

[a] Adjusted for age; sex; the number of diseased vessels subjected to intervention; fasting blood sugar level; creatinine level; left ventricular ejection fraction; coronary angiography results; presence of diabetes mellitus, hypertension, bifurcation, chronic total occlusion, or in-stent restenosis; and use of predilation or postdilation.
[b] $P < .05$ was considered statistically significant.

TABLE VI. Multiple Linear Regression Analysis of the Impact of Lipid Profile on Elevated cTnI (≥5× ULN) at the 12th Postprocedural Hour[a]

Clinical parameter	All patients	Patients with myocardial Injury	Patients without myocardial injury
LDL cholesterol, mg/dL			
β coefficient	.005	.006	–.001
95% CI	–0.006 to 0.015	–0.008 to 0.210	–0.004 to 0.003
P value	.41	.39	.80
R^2	0.09	0.06	0.06
HDL cholesterol, mg/dL			
β coefficient	.011	–.003	–.03
95% CI	–0.030 to 0.052	–0.060 to 0.054	–0.018 to 0.013
P value	.61	.92	.73
R^2	0.09	0.06	0.06
TG, mg/dL			
β coefficient	–.002	.004	–.001
95% CI	–0.006 to 0.002	–0.002 to 0.100	–0.002 to 0.001
P value	.27	.23	.23
R^2	0.09	0.06	0.06

HDL, high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; ULN, upper limit of normal

[a] $P < .05$ was considered statistically significant. Values adjusted for age; sex; the number of diseased vessels subjected to intervention; fasting blood sugar level; creatinine level; left ventricular ejection fraction; coronary angiography results; presence of diabetes mellitus, hypertension, bifurcation, chronic total occlusion, or in-stent restenosis; and use of predilation or postdilation.

As a sensitivity analysis, the relationships between cTnI elevation in the 12 hours after PCI as a continuous variable (in contrast to a dichotomized variable) and the LDL, HDL, and TG categories were separately explored via multiple linear regression analyses (see Table VI). At 1 and 6 hours after PCI, similar results were obtained for the LDL, HDL, and TG categories, except for a difference in LDL and cTnI in patients without periprocedural myocardial injury at 1 hour post-PCI.

Discussion

Periprocedural myocardial injury is a frequent complication during PCI and is strongly associated with postprocedural cardiovascular morbidity and death.[17] Major risk factors for periprocedural myocardial injury after PCI can be categorized as patient related, lesion related, or procedure related, all of which contribute equally.[18]

Lipid profile was classified as a patient-related factor. Elevated serum LDL is a major cause of CAD and is a key component of coronary plaque development and rupture.[19,20] Nevertheless, the existing literature lacks data on the relationship between lipid levels and periprocedural myocardial injury, especially in the present era of statin use. In the present study, the value of the preprocedural lipid profile (LDL, HDL, and TG) in predicting the incidence of periprocedural myocardial injury (evidenced by elevated cTnI) was examined in patients with stable CAD who underwent PCI. This evaluation was performed in a population with a high prevalence of statin intake and better-controlled LDL. No meaningful association between periprocedural myocardial injury and preprocedural lipid levels were found.

Li et al[16] investigated the association between preprocedural LDL and periprocedural myocardial injury in 2,529 patients with CAD who underwent elective PCI and found a log-linear relationship between LDL and cTnI levels. These authors concluded that a 1-SD increment in preprocedural LDL increased the risk of postprocedural cTnI elevation by 12% to 20%. Similarly, Buturak et al[21] observed a direct connection between preprocedural LDL levels and periprocedural myocardial injury in 195 patients with stable angina pectoris who underwent elective PCI: In that study, elevated LDL or non-HDL levels were positively correlated with postprocedural cTnI levels. Another study found that non-HDL was more valuable than LDL in predicting periprocedural myocardial injury in patients with type 2 diabetes mellitus.[22] In the present study, after adjusting for confounding factors in both the logistic and linear regression analyses, the authors found no association between LDL and postprocedural cTnI elevation.

The researchers also found no relationship between HDL and cTnI elevation, even after adjusting for confounding factors. Silbernagel et al[23] concluded that HDL was inversely associated with cardiovascular mortality in individuals without CAD but not in patients with CAD. Li et al[15] assessed 2,529 patients undergoing elective PCI and found that HDL level was not predictive of periprocedural myocardial injury. However, among patients with LDL less than 70 mg/dL, a 1-mg/dL increase in HDL was associated with a 3% reduction in risk of postprocedural cTnI greater than 3× the ULN. Li et al[16] also reported that patients with LDL greater than or equal to 70 mg/dL had higher TG and C-reactive protein levels, which can lead to HDL dysfunction. Barter et al[24] evaluated 2,661 participants with LDL less than 70 mg/dL and concluded that higher HDL levels were associated with a lower risk of major cardiovascular events. Moreover, recent data which investigated the atheroprotective potential of HDL particles elucidated that the large HDL particles are linked to a lower number of circulating LDL particles.[25,26] The present analysis yielded no correlation between HDL and periprocedural myocardial injury in patients with LDL less than 70 mg/dL (β = .018; 95% CI, −.037 to .059; P = .64; R^2 = −0.001).

Jiao et al[27] found that plasma TG and HDL exerted a synergistic effect on the occurrence of CAD. When the plasma LDL concentration was less than 130 mg/dL, the risk of CAD was 10 times as high in a population with high TG levels (>263.93 mg/dL) and low HDL concentrations (<25.90 mg/dL) as it was in a population with low TG levels (<59.34 mg/dL) and high HDL concentrations (>64.19 mg/dL). Li et al[16] found that HDL levels rose in tandem with a substantial fall in TG. Two other studies on the relationship between preprocedural LDL and periprocedural myocardial injury reported substantially lower TG levels in a population with lower LDL.[16,28] Likewise, the researchers found a positive correlation between TG and LDL (β = .311; 95% CI, .056-.090; P < .001; R^2 = 0.095), despite the absence of an association between TG and cTnI elevation.

Evidence showing an association between lipid profile and periprocedural myocardial injury comes from studies on lipid-lowering therapy that compare the effects of different doses of statins on periprocedural myocardial injury. Of note, because many included patients adhered to their long-term statin therapy throughout the perioperative period, the authors studied the baseline lipid profile.

Takano et al[29] found that high-dose rosuvastatin reduced the incidence of periprocedural myocardial injury more than low-dose rosuvastatin in statin-naive patients but not in patients who were already taking statins. Herrmann et al[30] showed that the incidence of creatine kinase elevation greater than 3× the ULN was more than 90% lower in statin-treated patients (0.4% vs 6.0%) and that statin therapy was the only factor independently associated with a lower risk of creatine ki-

nase elevation greater than 3× the ULN; no substantial differences between statin-treated patients and controls were found in terms of TG, LDL, HDL, total cholesterol, and lipoprotein(a). What remains unclear, however, is whether HDL alterations during statin therapy contribute to considerable cardiovascular risks. In the JUPITER trial, HDL and vascular events were inversely associated in patients on rosuvastatin (20 mg/d), whereas patients receiving placebo exhibited no such association.[31] Moreover, in a meta-analysis of 8 statin trials, HDL increase during statin therapy was not associated with reduced risk of major cardiovascular events.[32]

In the current study, no substantial interaction between statin therapy and cTnI was found, even after adjustments were made for confounders (Table V). More than 85% of included patients had statins in their medication history. Therefore, this study's findings can be explained by intensive and optimal medical treatment before the procedure, which might have eliminated the effects of lipids on periprocedural myocardial injury.

As for other patient-related factors, results showed a substantial difference pertaining to LVEF between patients with and without post-PCI cTnI elevation. Patients with cTnI greater than or equal to 5× the ULN had a markedly lower mean LVEF (43.3% [10.5%] vs 45.2% [9.7%]; $P = .01$). Previous research has indicated that patients with increased cTnI have substantially lower LVEF, higher clinical grading of heart failure, and higher mortality rates.[33,34] Gili et al[35] sought to determine the predictors of periprocedural myocardial injury after PCI and concluded that LVEF was a univariate predictor of major adverse cardiovascular events and death. Mancini et al[36] found that despite optimal medical treatment and PCI, LVEF and disease burden at baseline were prognostic of residual risk of secondary ischemic events.

Among procedure-related risk factors, the researchers detected a significant association between cTnI elevation and PCI for bifurcation, one of the more complex PCI procedures. Bifurcation correlated with higher levels of postprocedural cTnI, whereas the authors found no significant association between in-stent restenosis and cTnI elevation. Zhang et al[37] found that a true bifurcation lesion was a predictor of occlusion in a small side branch and that patients with small branch occlusions had a substantially higher incidence of periprocedural myocardial injury. Ojeda et al[38] concluded that the presence of a bifurcation lesion in the context of chronic total occlusion was linked to a higher incidence of periprocedural myocardial injury. Multivessel PCI and predilation during the procedure also may prompt cTnI elevation and periprocedural myocardial injury: Qadir et al[39] showed that elevated cTnI was correlated with the greater severity and larger extent of myocardial ischemic territory during non–ST-segment elevation myocardial infarction.

Study Limitations

The study had several limitations. First, the observational nature of the study might have incorporated bias into the results. Second, the lack of an association between lipid profile and elevated cTnI might have derived from the fact that approximately 70% of the studied population had LDL levels less than 70 mg/dL and only 7% had LDL levels greater than 100 mg/dL. Moreover, 88% of patients had TG levels less than 150 mg/dL, whereas only 5% had TG levels greater than 200 mg/dL. These factors could have lessened the sensitivity of this study.

Conclusion

Lipid levels were not associated with an increased incidence of periprocedural myocardial injury in a sample of patients undergoing elective PCI, possibly because these patients received extensive, optimal medical therapy before the procedure. However, angiographic factors such as a lower LVEF, previous myocardial infarction, and the number of vessels subjected to PCI were associated with cTnI elevation and thus with periprocedural myocardial injury.

Although these findings suggest that, in the current era of intervention with fully optimized medical therapy, lipid profile exerts no influence on periprocedural myocardial injury, this does not agree with the findings of previous investigations. It may be that complex vessel anatomy, procedures, and low LVEF may have more influence on postprocedural outcomes based on cTnI elevation. It is essential to evaluate these data in future multicenter studies with a wider range of patients and a wider distribution of lipid values in both elective and nonelective procedures.

Acknowledgments

The authors would like to thank the Catheterization Laboratory staff of Rajaie Cardiovascular Medical and Research Center and Maria Elena Vilar Alvarez for their contributions to this research.

Published: 13 December 2022

Conflict of Interest Disclosures: None

Funding/Support: None

References

1. GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet.* 2015;385(9963):117-171. doi:10.1016/S0140-6736(14)61682-2
2. Chin CT, Wong ASL. The appropriate use of percutaneous coronary intervention in contemporary

clinical practice. *Pro Singapore Healthc.* 2015;24(1):29-34. doi:10.1177/201010581502400105
3. Zeng RX, Li JJ, Liao PD, Zhang MZ. Relationship of non-cardiac biomarkers with periprocedural myocardial injury in patients undergoing percutaneous coronary intervention. *Int J Cardiol.* 2016;221:726-733. doi:10.1016/j.ijcard.2016.07.131
4. Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction (2018). *J Am Coll Cardiol.* 2018;72(18):2231-2264. doi:10.1016/j.jacc.2018.08.1038
5. Eggers KM, Lindahl B. Application of cardiac troponin in cardiovascular diseases other than acute coronary syndrome. *Clin Chem.* 2017;63(1):223-235. doi:10.1373/clinchem.2016.261495
6. Feldman DN, Kim L, Rene AG, Minutello RM, Bergman G, Wong SC. Prognostic value of cardiac troponin-I or troponin-T elevation following nonemergent percutaneous coronary intervention: a meta-analysis. *Catheter Cardiovasc Interv.* 2011;77(7):1020-1030. doi:10.1002/ccd.22962
7. Garg P, Morris P, Fazlanie AL, et al. Cardiac biomarkers of acute coronary syndrome: from history to high-sensitivity cardiac troponin. *Intern Emerg Med.* 2017;12(2):147-155. doi:10.1007/s11739-017-1612-1
8. Arsenault BJ, Rana JS, Stroes ESG, et al. Beyond low-density lipoprotein cholesterol: respective contributions of non–high-density lipoprotein cholesterol levels, triglycerides, and the total cholesterol/high-density lipoprotein cholesterol ratio to coronary heart disease risk in apparently healthy men and women. *J Am Coll Cardiol.* 2009;55(1):35-41. doi:10.1016/j.jacc.2009.07.057
9. Hosseini SK, Tahvildari M, Ansari MJA, Nakhjavani M, Esteghamati A, Tokaldany ML. Clinical lipid control success rate before and after percutaneous coronary intervention in Iran; a single center study. *Iran Red Crescent Med J.* 2013;15(6):467-472. doi:10.5812/ircmj.3370
10. Bandeali S, Farmer J. High-density lipoprotein and atherosclerosis: the role of antioxidant activity. *Curr Atheroscler Rep.* 2012;14(2):101-107. doi:10.1007/s11883-012-0235-2
11. Chang TI, Streja E, Moradi H. Could high-density lipoprotein cholesterol predict increased cardiovascular risk? *Curr Opin Endocrinol Diabetes Obes.* 2017;24(2):140-147. doi:10.1097/MED.0000000000000318
12. Bhatt DL, Steg PG, Miller M, et al; REDUCE-IT Investigators. Cardiovascular risk reduction with icosapent ethyl for hypertriglyceridemia. *N Engl J Med.* 2019;380(1):11-22. doi:10.1056/NEJMoa1812792
13. Reiner Ž. Hypertriglyceridaemia and risk of coronary artery disease. *Nat Rev Cardiol.* 2017;14(7):401-411. doi:10.1038/nrcardio.2017.31
14. Lawton JS, Tamis-Holland JE, Bangalore S, et al. 2021 ACC/AHA/SCAI guideline for coronary artery vascularization: executive summary: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *J Am Coll Cardiol.* 2022;79(2):197-215. doi:10.1161/CIR.0000000000001039
15. Li XL, Guo YL, Zhu CG, et al. Relationship of high-density lipoprotein cholesterol with periprocedural myocardial injury following elective percutaneous coronary intervention in patients with low-density lipoprotein cholesterol below 70 mg/dL. *J Am Heart Assoc.* 2015;4(1):e001412. doi:10.1161/JAHA.114.001412
16. Li XL, Li JJ, Guo YL, et al. Association of preprocedural low-density lipoprotein cholesterol levels with myocardial injury after elective percutaneous coronary intervention. *J Clin Lipidol.* 2014;8(4):423-432. doi:10.1016/j.jacl.2014.04.002
17. Cutlip DE, Kuntz RE. Does creatinine kinase-MB elevation after percutaneous coronary intervention predict outcomes in 2005? Cardiac enzyme elevation after successful percutaneous coronary intervention is not an independent predictor of adverse outcomes. *Circulation.* 2005;112(6):916-922; discussion 922. doi:10.1161/CIRCULATIONAHA.104.478347
18. Huang Z, Shui X, Ling Y, et al. Serum lipoprotein (a) and risk of periprocedural myocardial injury in patients undergoing percutaneous coronary intervention. *Clin Cardiol.* 2021;44(2):176-185. doi:10.1002/clc.23520
19. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) final report. *Circulation.* 2002;106(25):3143-3421.
20. Burke AP, Farb A, Malcom GT, Liang YH, Smialek J, Virmani R. Coronary risk factors and plaque morphology in men with coronary disease who died suddenly. *N Engl J Med.* 1997;336(18):1276-1282. doi:10.1056/NEJM199705013361802
21. Buturak A, Degirmencioglu A, Erturk M, et al. Impact of increased admission lipid levels on periprocedural myocardial injury following an elective percutaneous coronary intervention. *Coron Artery Dis.* 2015;26(4):333-340. doi:10.1097/MCA.0000000000000235
22. Zeng RX, Li XL, Zhang MZ, et al. Non-HDL cholesterol is a better target for predicting periprocedural myocardial injury following percutaneous coronary intervention in type 2 diabetes. *Atherosclerosis.* 2014;237(2):536-543. doi:10.1016/j.atherosclerosis.2014.10.030
23. Silbernagel G, Schöttker B, Appelbaum S, et al. High-density lipoprotein cholesterol, coronary artery disease, and cardiovascular mortality. *Eur Heart J.* 2013;34(46):3563-3571. doi:10.1093/eurheartj/eht343
24. Barter P, Gotto AM, LaRosa JC, et al; Treating to New Targets Investigators. HDL cholesterol, very low levels of LDL cholesterol, and cardiovascular events. *N Engl J Med.* 2007;357(13):1301-1310. doi:10.1056/NEJMoa064278
25. Parish S, Offer A, Clarke R, et al; Heart Protection Study Collaborative Group. Lipids and lipoproteins and risk of different vascular events in the MRC/BHF Heart Protection Study. *Circulation*. 2012;125(40):2469-2478. doi:10.1161/CIRCULATIONAHA.111.073684
26. Kosmas CE, Christodoulidis G, Cheng JW, Vittorio TJ, Lerakis S. High-density lipoprotein functionality in coronary artery disease. *Am J Med Sci*. 2014;347(6):504-508. doi:10.1097/MAJ.0000000000000231
27. Jiao ZY, Li XT, Li YB, et al. Correlation of triglycerides with myocardial infarction and analysis of risk factors for myocardial infarction in patients with elevated triglyceride. *J Thorac Dis.* 2018;10(5):2551-2557. doi:10.21037/jtd.2018.04.132
28. Zhong Z, Liu J, Zhang Q, et al. Relationship between preoperative low-density lipoprotein cholesterol and periprocedural myocardial injury In patients following elective percutaneous coronary intervention in southern China. *Med Sci Monit.* 2018;24:4154-4161. doi:10.12659/MSM.907400
29. Takano H, Ohba T, Yamamoto E, et al; PRIMITIVE Study Investigators. Usefulness of rosuvastatin to prevent periprocedural myocardial injury in patients undergoing elective coronary intervention. *Am J Cardiol.* 2013;111(12):1688-1693. doi:10.1016/j.amjcard.2013.02.018
30. Herrmann J, Lerman A, Baumgart D, et al. Preprocedural statin medication reduces the extent of

periprocedural non–Q-wave myocardial infarction. *Circulation.* 2002;106(17):2180-2183. doi:10.1161/01.cir.0000037520.89770.5e
31. Ridker PM, Genest J, Boekholdt SM, et al; JUPITER Trial Study Group. HDL cholesterol and residual risk of first cardiovascular events after treatment with potent statin therapy: an analysis from the JUPITER trial. *Lancet.* 2010;376(9738):333-339. doi:10.1016/S0140-6736(10)60713-1
32. Boekholdt SM, Arsenault BJ, Hovingh GK, et al. Levels and changes of HDL cholesterol and apolipoprotein A-I in relation to risk of cardiovascular events among statin-treated patients: a meta-analysis. *Circulation.* 2013;128(14):1504-1512. doi:10.1161/CIRCULATIONAHA
33. La Vecchia L, Mezzena G, Zanolla L, et al. Cardiac troponin I as diagnostic and prognostic marker in severe heart failure. *J Heart Lung Transplant.* 2000;19(7):644-652. doi:10.1016/s1053-2498(00)00120-0
34. Korff S, Katus HA, Giannitsis E. Differential diagnosis of elevated troponins. *Heart.* 2006;92(7):987-993. doi:10.1136/hrt.2005.071282
35. Gili S, D'Ascenzo F, Moretti C, et al. Impact on prognosis of periprocedural myocardial infarction after percutaneous coronary intervention. *J Interv Cardiol.* 2014;27(5):482-490. doi:10.1111/joic.12143
36. Mancini GBJ, Hartigan PM, Bates ER, et al. Prognostic importance of coronary anatomy and left ventricular ejection fraction despite optimal therapy: assessment of residual risk in the Clinical Outcomes Utilizing Revascularization and Aggressive DruG Evaluation Trial. *Am Heart J.* 2013;166(3):481-487. doi:10.1016/j.ahj.2013.07.007
37. Zhang D, Xu B, Yin D, et al. Predictors and periprocedural myocardial injury rate of small side branches occlusion in coronary bifurcation intervention. *Medicine (Baltimore).* 2015;94(25):e992. doi:10.1097/MD.0000000000000992
38. Ojeda S, Pan M, Gutiérrez A, et al. Bifurcation lesions involved in the recanalization process of coronary chronic total occlusions: incidence, treatment and clinical implications. *Int J Cardiol.* 2017;230:432-438. doi:10.1016/j.ijcard.2016.12.088
39. Qadir F, Farooq S, Khan M, Hanif B, Lakhani MS. Correlation of cardiac troponin I levels (10 folds upper limit of normal) and extent of coronary artery disease in non-ST elevation myocardial infarction. *J Pak Med Assoc.* 2010;60(6):423-428.