

## Research Article

# Outcome of Postcardiac Surgery Acute Myocardial Infarction and Role of Emergency Percutaneous Coronary Interventions

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**Background.** Cardiac surgery carries a well-known risk of perioperative myocardial infarction (MI), which is associated with high morbidity and both in-hospital and late mortality. The rapid haemodynamics deterioration and presence of myocardial ischemia early after cardiac surgical operations is a complex life-threatening condition where rapid diagnosis and management is of fundamental importance. **Objective.** To analyse the factors associated with mortality of patients with postcardiotomy MI and to study the role of emergency coronary angiography in management and outcome. **Methods.** We retrospectively enrolled adult patients diagnosed to have postcardiotomy MI and underwent emergency coronary angiography at our tertiary care hospital between January 2016 and August 2019. **Results.** Sixty-one patients from consecutive 1869 adult patients who underwent cardiac surgeries were enrolled in our study. The studied patients had a mean age of  $49 \pm 16.2$  years with a mean BMI of  $29.5 \pm 6.6$  and 65.6% of them were males. As compared to the survivors group, the nonsurvivors of perioperative MI had significant preoperative CKD, postoperative AKI, longer CPB time, frequent histories of previous PCI, previous cardiectomies, pre and postoperative ECMO use, higher median troponin I levels, higher peak and 24 hours median lactate levels. Regression analysis revealed that reoperation for revascularization (OR: 23; 95% CI: 8.27–217.06;  $P = 0.034$ ) and hyperlactataemia (OR: 3.21; 95% CI: 1.14–9.04;  $P = 0.027$ ) were independent factors associated with hospital mortality after perioperative MI. Hospital mortality occurred in 25.7% vs 86.7% ( $P < 0.001$ ), AKI occurred in 37.1% vs 93.3% ( $P < 0.001$ ), haemodialysis was used in 28.6% vs 80% ( $P = 0.002$ ), and mediastinal exploration for bleeding was performed in 31.4% vs 80% ( $P = 0.006$ ) in the PCI and reoperation groups, respectively, while there were no significant differences regarding gastrointestinal bleeding, cerebral strokes, or intracerebral bleeding. The median peak troponin level was 795 (IQR 630–1200) vs 4190 (IQR 3700–6300) ( $P < 0.001$ ) in the PCI and reoperation groups, respectively. Absence of significant angiographic findings occurred in 18% of patients. **Conclusions.** Perioperative MI is associated with significant morbidities and hospital mortality. Reoperation for revascularization and progressive hyperlactataemia are independent predictors of hospital mortality. Emergency coronary angiography is helpful in diagnosis and management of perioperative MI.

## 1. Background

Cardiac surgery carries a well-known risk of perioperative myocardial infarction (MI), which is associated with high morbidity and both in-hospital and late mortality [1, 2]. Perioperative MI is also associated with an increased use of healthcare resources, and it correlates with an increased risk of progressive heart failure in the years after cardiac surgery [3–5].

The aetiology of perioperative MI can be classified as graft-related and nongraft-related causes [6]. The commonest graft-related causes are anastomotic stenosis, graft spasm, acute graft thrombosis, and graft kinking or overstretching [7]. The nongraft-related causes include inadequate intraoperative cardioprotection, direct myocardial trauma by sutures, microvascular embolisms related to reperfusion, myocardial damage by the release of oxygen free radicals, and distal coronary microembolization [8–11].

Different studies about postcardiotomy MI have been performed with a wide range of reported incidence, 1%–26%, depending on the definition used and the type of surgical operation [12–15]. Criteria for diagnosing perioperative MI after cardiac surgeries other than CABG are still controversial and have not been collected in the Fourth Universal Definition of MI [16, 17]. The purpose of this study was to analyse the factors associated with mortality of patients with postcardiotomy MI and to study the role of emergency coronary angiography in management and outcome.

## 2. Methods

**2.1. Study Design.** This retrospective study was conducted at our tertiary care hospital where approximately 500 adult cardiac surgeries had been performed annually, and a cardiac surgical intensive care unit with 10 beds exclusively dedicated to the postoperative care of adult patients who had undergone cardiac surgeries.

Data were collected from a consecutive cohort of 1869 adult patients who underwent cardiac surgeries at our tertiary care hospital between January 2016 and August 2019. Cardiac operations were performed using standard techniques via cardiopulmonary bypass (CPB) with mostly central cannulation and mild systemic hypothermia ( $>32^{\circ}\text{C}$ ). Once the patients were transferred to the intensive care unit, 12-lead electrocardiogram (ECG) and high sensitivity troponin I serum levels were assessed every 8 hours until 48 hours. Transesophageal echocardiography (TEE) assessments were performed at the end of surgery (mandatory) and then at ICU (when needed) to investigate biventricular contractility, regional wall motion abnormalities, valves function, or any signs of pericardial tamponade.

All the patients who underwent emergent coronary angiography during the postoperative ICU stay were enrolled in our study. According to our hospital protocol, emergency coronary angiography was performed after detection of 1 or more of the following postoperative events: fatal ventricular arrhythmias (VT/VF), new onset of persistent ST segment changes on ECG, cardiac arrest or unexplained hemodynamic deterioration, new regional wall motion abnormality on transthoracic or transesophageal echocardiogram.

Patients with persistent haemodynamic deterioration despite maximal inotropic support were subjected to emergency implantation of venoarterial extracorporeal membrane oxygenation (VA-ECMO), and then, coronary angiograms were performed. We conducted this study using the hospital's Integrated Compliance Information System (ICIS) after getting approval from our Institute Ethics Committee.

**2.2. The Studied Variables.** Demographic and baseline characteristics of patients, clinical, laboratory, ECG, echocardiographic, and angiographic data were collected. The peak troponin I level after cardiac surgery was recorded with a normal reference of 15–52 ng/L. The peak arterial lactate

levels and the levels after 24 hours of ICU admission were collected. The sequential organ failure assessment (SOFA) score was calculated for all patients upon ICU admission and after 48 hours for organ failure assessment. The worst values for each variable in the SOFA score in the 24 hour-period were used during calculation. The patients were divided according to hospital mortality into the survivors and nonsurvivors groups. According to revascularization modality, we divided the patients into the PCI and reoperation groups.

**2.3. Statistical Analysis.** Data were summarized using mean with standard deviation or median with interquartile range (IQR) for quantitative variables and frequency with percentage for qualitative variables. Normality of data was checked using the Kolmogorov–Smirnov normality test. Comparisons between numerical data were done using Student's *t*-test or Mann–Whitney accordingly. Ordinal variables were compared using the chi square test. *P* values less than 0.05 were considered statistically significant. Graphs were used to illustrate some information. Regression analysis was performed to get the mortality predictors. Statistical tests were performed using the Statistical Package of Social Science Software program, version 23 (SPSS).

## 3. Results

**3.1. Demographic and Clinical Characteristics.** A total of 61 patients with diagnosed postcardiotomy myocardial infarction and subjected to emergency coronary angiography were enrolled in this study. The mean age was  $49 \pm 16.2$  years with a mean BMI of  $29.5 \pm 6.6$ , and 65.6% of them were males with no statistically significant differences between survivors and nonsurvivors. As compared to the survivors group, the nonsurvivors group had significantly more frequent CKD, preoperative ECMO support, emergency cardiectomies, histories of PCI, and cardiac surgeries. The nonsurvivors group had significantly higher aPTT and lesser GFR, while there were no significant differences regarding MI history, LVEF, type of surgeries, and other laboratory data as compared to the survivors group (Table 1).

**3.2. Operative and ICU Characteristics.** The cardiopulmonary bypass time was  $200.4 \pm 68.4$  vs  $168.2 \pm 84.3$  ( $P = 0.04$ ) in the nonsurvivors and survivors groups, respectively. Postoperative VA-ECMO use was significantly more frequent in the nonsurvivors group but without a significant difference in ECMO support days. The nonsurvivors group had significantly higher mean SOFA scores upon ICU admission and after 48 hours assessment. The median peak lactate level and lactate after 24 hours of ICU admission were significantly higher at the nonsurvivors group. The median peak troponin level was 3850 (IQR 2700–6300) vs 680 (IQR 580–893) ( $P < 0.001$ ) in the nonsurvivors and survivors groups, respectively. PCI was performed in 39.1% vs 68.4% ( $P = 0.02$ ) in the nonsurvivors and survivors groups, respectively, while reoperation (CABG) was performed in 56.5% vs 5.3% ( $P < 0.001$ ) in the nonsurvivors and survivors

TABLE 1: baseline characteristics.

Studied characteristics	All patients (n = 61)	Nonsurvivors (n = 23, 37.7%)	Survivors (n = 38, 62.3%)	P value	
Age (years)	49 ± 16.2	45.5 ± 16	51.2 ± 16.1	0.31	
Males	40 (65.6)	14 (60.9)	26 (68.4)	0.547	
BMI	29.5 ± 6.6	29.1 ± 7.3	29.7 ± 6.3	0.608	
DM	31 (50.8)	11 (47.8)	20 (52.6)	0.716	
Hypertension	31 (50.8)	9 (39.1)	22 (57.9)	0.155	
CKD	15 (24.6)	9 (39.1)	6 (15.8)	0.040	
Previous MI	13 (21.3)	8 (34.8)	5 (13.2)	0.059	
Previous PCI	5 (8.2)	5 (21.7)	0 (0)	0.006	
Previous cardiotomy	21 (34.4)	12 (52.2)	9 (23.7)	0.023	
Preoperative LVEF	46.2 ± 11.7	47.3 ± 9.4	45.5 ± 13	0.762	
Preoperative ECMO	4 (6.6)	4 (17.4)	0 (0)	0.017	
Surgery	Elective	53 (86.9)	17 (73.9)	36 (94.7)	0.044
	Emergency	8 (13.1)	6 (26.1)	2 (5.3)	
	CABG	14 (23)	6 (26.1)	8 (21.1)	
Surgery	Bentall operation	20 (32.8)	6 (26.1)	14 (36.8)	0.435
	Valve surgery	22 (36.1)	9 (39.1)	13 (34.2)	
	Valve + CABG	4 (6.5)	2 (8.7)	2 (5.26)	
Heart transplantation	1 (1.6)	0 (0)	1 (2.6)		
Hb (g/L)	126.3 ± 23.3	118.5 ± 24	131 ± 21.8	0.054	
Platelet count (10 <sup>9</sup> /L)	253.2 ± 84.4	237.4 ± 94.3	262.7 ± 77.6	0.333	
APTT (seconds)	38.6 ± 6.4	41.5 ± 6.9	36.8 ± 5.5	0.006	
INR	1.2 ± 0.2	1.3 ± 0.3	1.2 ± 0.2	0.085	
Fibrinogen (g/L)	3.4 ± 0.7	3.2 ± 0.7	3.5 ± 0.7	0.123	
GFR <60 (mL/min/1.73 m <sup>2</sup> )	12 (19.7)	9 (39.1)	3 (7.9)	0.006	

Data are presented as mean ± SD or N (%).

groups, respectively, without significant differences in the median time to angiography after cardiac surgery. Presence of insignificant coronary lesions that did not require intervention occurred (4.3% vs 26.3%,  $P = 0.04$ ) in the nonsurvivors and survivors groups, respectively. There were significantly frequent mediastinal explorations for bleeding, AKI, and use of haemodialysis in the nonsurvivors group. There were no significant differences between both groups regarding ischemic cerebral strokes, gastrointestinal bleeding, or ICU days (Table 2).

**3.3. Criteria of Acute Myocardial Ischemia.** The development of new bundle branch block occurred in 21.7% vs 2.6% ( $P = 0.02$ ), VT/VF in 87% vs 55.3% ( $P = 0.01$ ), and reduction of LVEF in  $23.8 \pm 9.2$  vs  $38.7 \pm 7.8$  ( $P < 0.001$ ) in the nonsurvivors and survivors groups, respectively. There were no statistically significant differences between both groups regarding new echocardiographic RWMA, angiographic findings, ST segment elevation or depression. There were no statistically significant differences between the survivors and nonsurvivors regarding the angiographic data (Table 3).

The development of RWMA had 96.2% sensitivity and 37.5% specificity with 91.1% positive predictive value, 60% negative predictive value, and 88.5% accuracy for predicting significant coronary lesions. The presence of ST segment elevation had 67.9% sensitivity and 98% specificity with 98% positive predictive value, 32% negative predictive value, and 72.1% accuracy for predicting significant coronary lesions. The presence of ST segment depression had 49.1% sensitivity and 0% specificity with 76.5% positive predictive value, 0% negative predictive value, and 42.6% accuracy for predicting significant coronary lesions.

**3.4. Hospital Outcome according to Revascularization Methods.** After emergency coronary angiography, 18% of cases showed insignificant coronary lesions. There were no complications related to coronary catheterizations. According to revascularization methods, there were 2 groups (PCI and reoperation for CABG). There were no statistically significant differences between both groups regarding demographic data or CPB and aortic cross-clamping times. The use of IABP and ECMO was significantly frequent in the reoperation group. The median time of angiography after surgery was 7 hours (IQR 4–10) vs 3 hours (IQR 2–6) ( $P = 0.01$ ) in the PCI and reoperation groups, respectively. The LM lesions were diagnosed in 20% vs 46.7% ( $P < 0.001$ ) in the PCI and reoperation groups, respectively, while CX lesions were diagnosed in (42.9% vs 6.7%,  $P < 0.001$ ) in the PCI and reoperation groups, respectively (Table 4, Figures 1–3).

Hospital mortality occurred in 25.7% vs 86.7% ( $P < 0.001$ ), AKI occurred in 37.1% vs 93.3% ( $P < 0.001$ ), haemodialysis used in 28.6% vs 80% ( $P = 0.002$ ), and mediastinal exploration for bleeding occurred in 31.4% vs 80% ( $P = 0.006$ ) in the PCI and reoperation groups, respectively, while there were no significant differences regarding gastrointestinal bleeding, cerebral strokes, or intracerebral bleeding (Table 5, Figure 4).

The reoperation group had significantly higher mean SOFA scores upon ICU admission and after 48 hours assessment as compared to the PCI group. The median peak lactate level and median lactate level after 24 hours of ICU admission were significantly higher at the reoperation group. The median peak troponin I level was 795 (IQR 630–1200) vs 4190 (IQR 3700–6300) ( $P < 0.001$ ) in the PCI and reoperation groups, respectively (Table 5).

TABLE 2: Operative and ICU parameters.

Studied parameters	All patients	Nonsurvivors	Survivors	P value
CPB time (minutes)	181 ± 79.4	200.4 ± 68.4	168.2 ± 84.3	0.041
Aortic clamping (minutes)	123.7 ± 54.9	134.7 ± 54.1	116.4 ± 55	0.286
Postoperative IABP	30 (49.2)	14 (60.9)	16 (42.1)	0.155
IABP days	6 (4–8)	8 (4–9)	6 (5–7)	0.544
Postoperative ECMO	32 (52.5)	18 (78.3)	14 (36.8)	0.002
ECMO days	8 (4–12.5)	8 (4–14)	8 (5–11)	0.82
Initial SOFA	12.4 ± 3.5	16.1 ± 1.5	10.3 ± 2.4	<0.001
SOFA at 48 hours	11.8 ± 6.4	19.4 ± 3.1	7.3 ± 2.4	<0.001
Peak lactate (mmol/L)	11.8 (8.4–15.8)	18.6 (14.8–20)	9.1 (5.6–11.8)	<0.001
Lactate at 24 hours	2.1 (1.2–4.3)	5 (3.8–6.4)	1.5 (1.2–2.1)	<0.001
Peak troponin (ng/L) (normal range: 15–52 ng/L)	890 (630–3800)	3850 (2700–6300)	680 (580–893)	<0.001
Time to angiography (hours)	6 (2–10)	7 (3–9)	6 (2–10)	0.94
PCI	35 (57.4)	9 (39.1)	26 (68.4)	0.025
Reoperation (CABG)	15 (24.6)	13 (56.5)	2 (5.3)	<0.001
No coronary intervention	11 (18)	1 (4.3)	10 (26.3)	0.040
Gastrointestinal bleeding	2 (3.3)	2 (8.7)	0 (0)	0.12
Mediastinal bleeding >1000 ml	19 (31.1)	8 (34.8)	11 (28.9)	0.14
Mediastinal exploration for bleeding	27 (44.3)	16 (69.6)	11 (28.9)	0.002
AKI	30 (49.2)	21 (91.3)	9 (23.7)	<0.001
Haemodialysis	25 (41)	17 (73.9)	8 (21.1)	<0.001
Ventilator days	6 (3–14)	12 (7–42)	3.5 (2–13)	0.01
ICU days	11 (5–21)	12 (7–52)	9.5 (5–17)	0.09
Ischemic stroke	10 (16.4)	6 (26.1)	4 (10.5)	0.157
ICH	4 (6.6)	4 (17.4)	0 (0)	0.017

Data are presented as mean ± SD, median (IQR), or N (%).

TABLE 3: ECG, echocardiographic, and angiographic characteristics of studied patients.

Studied parameters	All patients	Nonsurvivors	Survivors	P value
ST elevation	36 (59)	11 (47.8)	25 (65.8)	0.167
ST depression	34 (55.7)	10 (43.5)	24 (63.2)	0.134
New BBB	6 (9.8)	5 (21.7)	1 (2.6)	0.025
VT/VF	41 (67.2)	20 (87)	21 (55.3)	0.011
Postoperative LVEF	33.1 ± 11	23.8 ± 9.2	38.7 ± 7.8	<0.001
RWMAs	56 (91.8)	23 (100)	33 (86.8)	0.147
Angiographic findings	53 (86.9)	22 (95.7)	31 (81.6)	0.239
	Thrombosis	6 (27.3)	11 (35.5)	
	New stenosis	6 (27.3)	10 (32.3)	
	Spasm	2 (9.1)	1 (3.2)	
Angiographic results	Graft occlusion	4 (18.2)	6 (19.4)	0.75
	External compression	4 (18.2)	3 (9.7)	
	No lesions	1 (4.3)	7 (18.4)	
	LM	8 (34.8)	6 (15.8)	
	LAD	0	0	
Vessels affected	CX	7 (30.4)	9 (23.7)	0.25
	RCA	3 (13)	10 (26.3)	
	Graft	4 (17.4)	7 (18.4)	
	0-I	20 (87)	25 (65.8)	
TIMI flow	II	2 (8.7)	6 (15.8)	0.17
	III	1 (4.3)	7 (18.4)	
Dual antiplatelet therapy	39 (63.9)	9 (39.1)	30 (78.9)	0.007
Heparin infusion	42 (68.9)	15 (65.2)	27 (71.1)	0.633

Data are presented as mean ± SD or N (%).

3.5. *Predictors of Hospital Mortality.* Logistic regression analysis was performed to determine the predictors of hospital mortality after postcardiotomy myocardial infarction.

Hospital mortality was associated with reoperation (CABG) (OR: 23; 95% CI: 8.27–217.06;  $P = 0.034$ ) and hyperlactatemia (OR: 3.21; 95% CI: 1.14–9.04;  $P = 0.027$ ) (Table 6).

TABLE 4: Baseline characteristics of the PCI and reoperation groups.

Studied parameters	PCI group (n = 35, 57.4%)	Reoperation (n = 15, 24.6%)	P value
Age (years)	49.5 ± 16.5	43.7 ± 12.8	0.21
Males	24 (68.6)	8 (53.3)	0.50
BMI	30.2 ± 6.6	29.5 ± 7.4	0.27
DM	21 (60)	3 (20)	0.02
Hypertension	19 (54.3)	8 (53.3)	0.57
CKD	7 (20)	4 (26.7)	0.53
Previous MI	10 (28.6)	2 (13.3)	0.26
Previous PCI	3 (8.6)	2 (13.3)	0.46
Previous cardiotomy	15 (42.9)	4 (26.7)	0.16
Preoperative LVEF	44.4 ± 13	46 ± 6.9	0.09
Preoperative ECMO	4 (11.4)	0	0.21
CPB time (minutes)	173.2 ± 76.1	205.7 ± 83	0.44
Aortic clamping (minutes)	120.5 ± 54.5	138.1 ± 54.5	0.31
Postoperative IABP	18 (51.4)	10 (66.7)	0.04
Postoperative ECMO	16 (45.7)	12 (80)	0.03
Time to angiography (hours)	7 (4–10)	3 (2–6)	0.01
	LM	7 (46.7)	
	LAD	0	
Vessels treated	CX	1 (6.7)	<0.001
	RCA	3 (20)	
	Graft	4 (26.7)	

Data are presented as mean ± SD, median (IQR), or N (%).

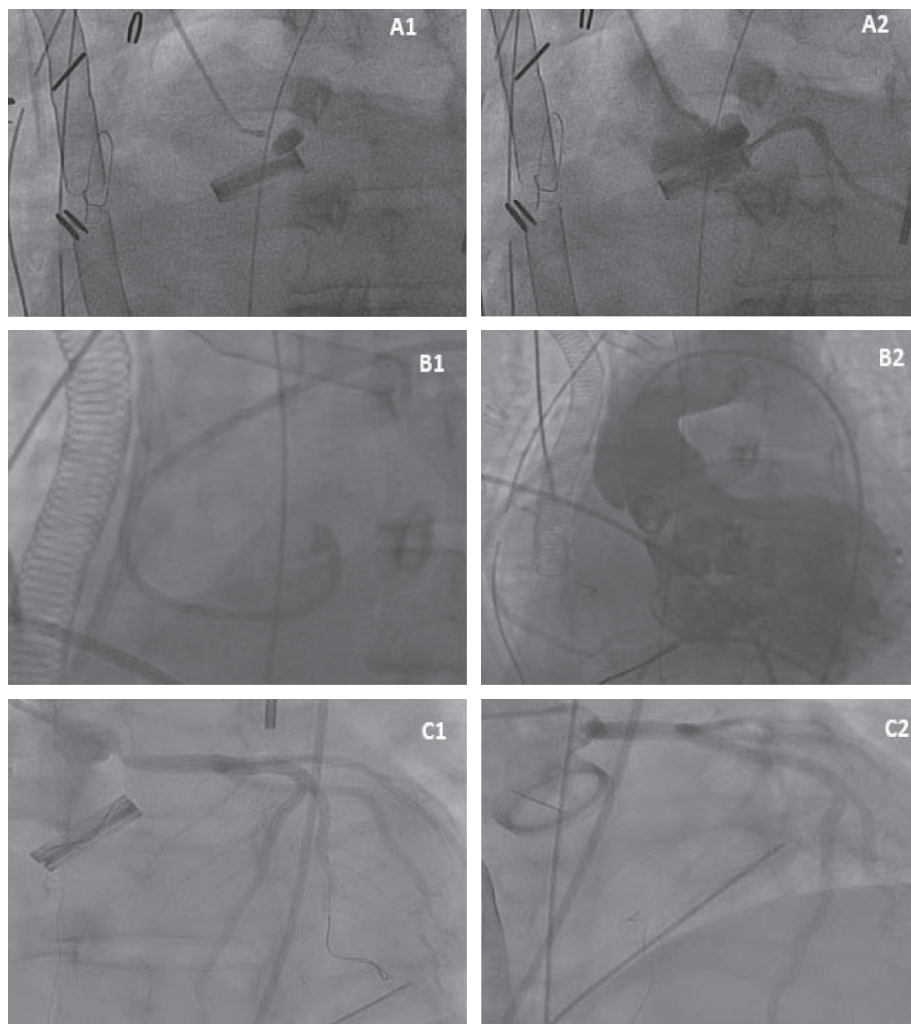


FIGURE 1: (a) Left main artery compression with mechanical valve and small dissection pouch at aortic root, and that case was referred to emergency CABG. (b) LM total occlusion after Bentall operation; aortogram showed the normal RCA and absent LM, emergency CABG. (c) LM critical stenosis after Bentall operation and successful LM stenting.

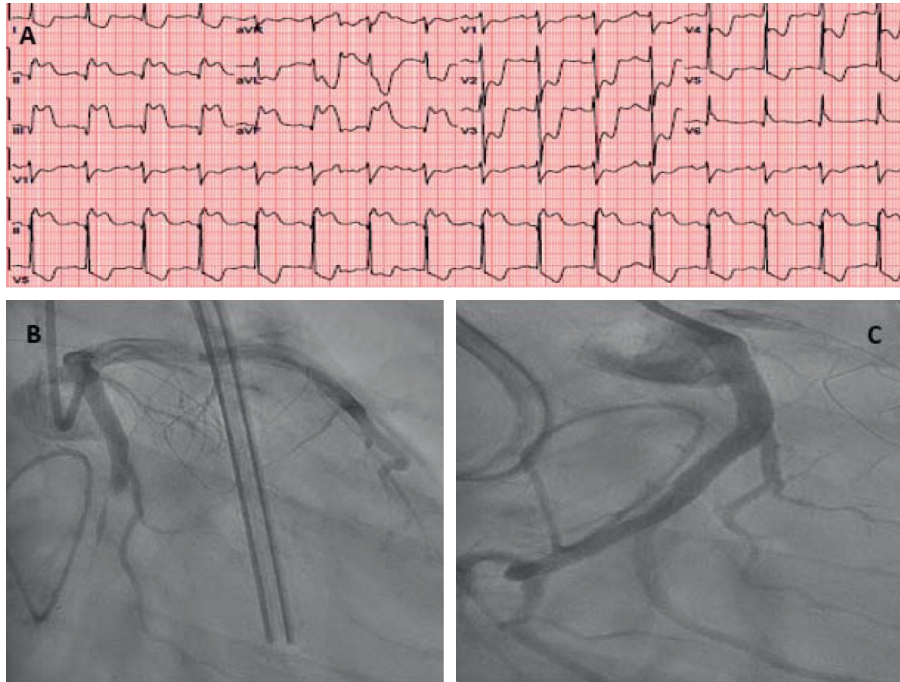


FIGURE 2: (a) ECG of a case with acute inferoposterior STEMI after mitral valve repair. (b) Left coronary angiogram showing CX midsegment total occlusion. (c) PCI and stenting with TIMI III.

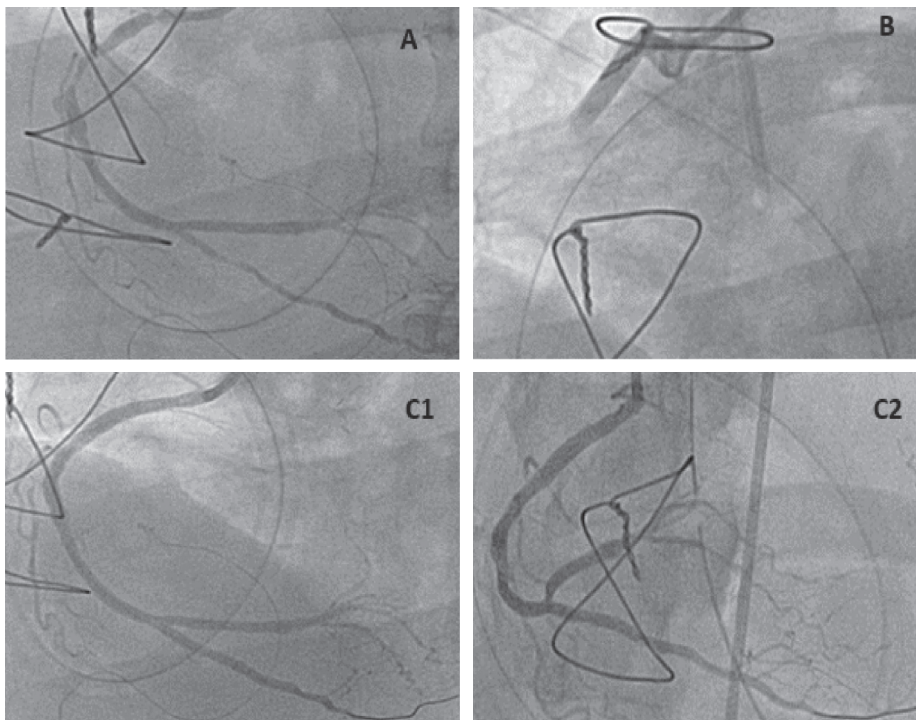


FIGURE 3: (a) Preoperative coronary angiogram showing RCA proximal significant stenosis and diseased proximal part of PDA. (b) The graft to RCA showed total occlusion (acute graft occlusion). (c) RCA and PDA after PCI and stenting.

TABLE 5: Hospital outcome according to revascularization modality.

Studied parameters	PCI group	Reoperation	P value
Initial SOFA	12.2 ± 3.5	14.7 ± 1.9	0.004
SOFA at 48 hours	10.4 ± 6	17.6 ± 4.6	0.001
Peak lactate (mmol/L)	11.2 (6.3–13.8)	16.9 (13.2–20)	<0.001
Lactate at 24 hours	1.5 (1.2–3.8)	5.2 (3.7–6.1)	<0.001
Peak troponin (ng/L)	795 (630–1200)	4190 (3700–6300)	<0.001
Mediastinal bleeding >1000 ml	10 (28.6)	6 (40)	0.13
Mediastinal exploration	11 (31.4)	12 (80)	0.006
Gastrointestinal bleeding	0 (0)	2 (13.3)	0.12
AKI	13 (37.1)	14 (93.3)	<0.001
Haemodialysis	10 (28.6)	12 (80)	0.002
Ventilator days	4 (2–14)	14 (8–52)	0.002
ICU days	12 (3–21)	18 (8–63)	0.05
Ischemic stroke	8 (22.9)	1 (6.7)	0.24
ICH	2 (5.7)	2 (13.3)	0.38
Hospital mortality	9 (25.7)	13 (86.7)	<0.001

Data are presented as mean ± SD, median (IQR), or N (%).

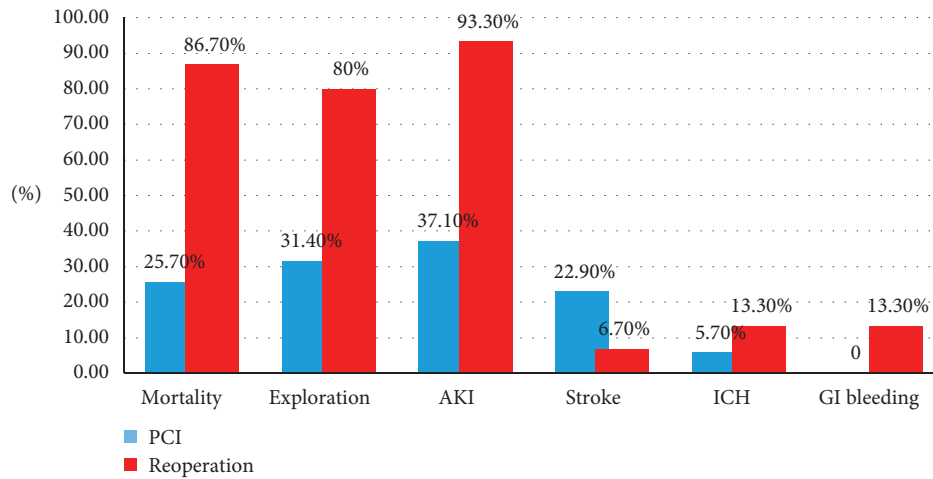


FIGURE 4: Hospital outcomes of the PCI and reoperation groups.

#### 4. Discussion

The rapid deterioration of haemodynamics or presence of signs of myocardial ischemia early after cardiac surgical operations is a complex life-threatening condition where rapid and precise diagnosis and management are of fundamental importance. Criteria for diagnosing perioperative MI after cardiac surgeries other than CABG are still controversial and have not been collected in the Fourth Universal Definition of MI [16, 17]. The diagnosis of perioperative MI is challenging, especially during the early postoperative period. In fact, ECG, cardiac biomarkers, and cardiac imaging can be misleading in the early postoperative hours [18]. However, it is generally accepted that the presence of new and persistent ECG alterations, new regional wall motion abnormalities on echocardiography, significant elevations in cardiac enzyme levels and hemodynamic instability despite high doses of inotropic and vasopressor drugs, or frequent ventricular arrhythmias are sufficient criteria to suspect perioperative MI [19].

TABLE 6: Predictors of hospital mortality.

Significant variables	P value	OR	95% CI
Postoperative ECMO	0.136	0.039	0.001–2.775
Troponin	0.661	1.000	0.998–1.001
Lactate peak	0.027	3.212	1.141–9.042
Reoperation	0.034	23.005	8.27–217.06

Few studies described the benefits of emergency coronary angiography and interventions after CABG operations for acute graft failure. [6, 20–22] Gaudino et al. [23] described the effectiveness of emergency coronary angiography in diagnosis and management for myocardial ischemia after different cardiac surgeries. We found in our study that emergency coronary angiography had a role in early diagnosis of the aetiology of haemodynamics deterioration and myocardial ischemia. About 18% of patients with perioperative MI showed insignificant coronary lesions. Also, coronary angiography helped in management of 57.4% of cases by coronary interventions and stenting with fewer

postoperative complications compared to the patients transferred to operation room for revascularization.

We found that the presence of echocardiographic new RWMA had higher sensitivity but lower specificity than the presence of new ST segment elevation for predicting angiographic coronary lesions in perioperative MI, while ST segment depression had lowest sensitivity and specificity for prediction of angiographic lesions. The benefits of echocardiography during and after cardiac surgeries include its ability to evaluate the cardiac contractility, valves function, detection of cardiac tamponade, and detection of regional wall motion abnormalities. [24–26].

We used the peak cardiac troponin I as a biomarker to detect the degree of myocardial damage as this study was retrospective with unknown baseline troponin and absence of standardized postoperative measurements patterns. In our cardiac surgical critical care unit, we do not depend on the value or pattern of troponin in patients with life-threatening conditions after cardiomy. Interestingly, the median troponin I was significantly higher in the nonsurvivors compared to the survivors and in the reoperation group compared to the PCI group. This may explain more extensive myocardial damage and worse clinical outcome in these groups. However, troponin was not significant in our multivariable regression analysis for mortality. Troponin was linked to mortality and worse outcomes after cardiac surgeries in several studies [27–29].

We evaluated our critically ill patients with the SOFA score and blood lactate levels, which reflect the haemodynamic profile and organs perfusion and functions. We used the SOFA score in assessment due to its simplicity and validity to predict mortality [30, 31]. The mortality group had a significantly higher mean SOFA score upon ICU admission with an increased trend after 48 hours reflecting the multiorgan functions deterioration. The PCI group had a significantly lower mean SOFA score with a decreasing trend after 48 hours as compared to the reoperation group. We used the peak lactate level and the level after 24 hours of ICU admission to get data about organ perfusion. Hyperlactatemia has been linked to increased mortality among critically ill patients including those postcardiotomy [32]. The nonsurvivors had a higher median lactate peak level with delayed clearance after 24 hours compared to the survivors group. Also, the PCI group had a lower median peak lactate level with a lower median lactate level after 24 hours compared to the reoperation group. The hyperlactatemia with delayed clearance could reflect the impaired different organ perfusion and development of organ dysfunction and increased mortality after postcardiotomy MI especially in the reoperation group. Moreover, our regression analysis revealed that reoperation and progressive hyperlactataemia were the independent predictors of hospital mortality after perioperative MI.

In our study, the nonsurvivors group of perioperative MI had significantly preoperative CKD with GFR less than 60 (mL/min/1.73 m<sup>2</sup>) and postoperative AKI and haemodialysis as compared to the survivors group. Our results were similar to other studies that confirmed the greater postcardiotomy morbidity and mortality with decreased renal

functions [33, 34]. Interestingly, we found that the frequency of AKI and use of haemodialysis were significantly greater in the reoperation group than in the PCI group despite the risk of contrast-induced nephropathy in those unstable patients. Sef et al. [22] reported the safety of PCI for perioperative MI after CABG without increased risk of acute renal failure.

Despite dual antiplatelet therapy, the PCI group did not have significantly different bleeding complications than the reoperation group, and we could not provide an explanation for this finding. Our nonsurvivors group had a significantly longer CPB time compared to the survivors group. The CPB time is well known as an independent risk factor of postcardiotomy morbidity and mortality [35]. Cubero-Gallego et al. [34] found that the CPB time was longer in patients with perioperative MI after valve surgery than those without perioperative MI.

To date, there are few retrospective studies of perioperative MI without randomization of different revascularization options, but they showed significant mortality benefits of PCI over reoperation [12, 19–23].

Finally, rapid and precise diagnosis of postcardiotomy MI and possible revascularization should be done to avoid the bad consequences. According to our results, emergency coronary angiography was helpful in rapid diagnosis of coronary lesions and allowed interventions, which were associated with lesser myocardial damage, better haemodynamics, and organ functions compared to emergency reoperation for revascularization.

## 5. Conclusions

Perioperative MI is associated with significant morbidities and hospital mortality. Reoperation for revascularization and progressive hyperlactataemia are independent predictors of hospital mortality. Emergency coronary angiography is helpful in diagnosis and management of perioperative MI.

## Abbreviations

AKI:	Acute kidney injury
aPTT:	Activated partial thromboplastin time
BBB:	Bundle branch block
BMI:	Body mass index
CABG:	Coronary artery bypass graft
CKD:	Chronic kidney disease
CI:	Confidence interval
CPB time:	Cardiopulmonary bypass time
CX:	Circumflex artery
DM:	Diabetes mellitus
IABP:	Intra-aortic balloon pump
ICH:	Intracerebral haemorrhage
LAD:	Left anterior descending artery
LM:	Left main artery
LVEF:	Left ventricle ejection fraction
MI:	Myocardial infarction
OR:	Odds ratio
PCI:	Percutaneous coronary intervention
RCA:	Right coronary artery
RWMA:	Regional wall motion abnormalities



SOFA:	Sequential organ failure assessment
STEMI:	ST segment elevation myocardial infarction
TEE:	Transesophageal echocardiography
VA-	Venoarterial extracorporeal membrane
ECMO:	oxygenation
VT/VF:	Ventricular tachycardia/fibrillation.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Additional Points

Our work was a retrospective study with possible selection bias without randomization because the choice of modality of revascularization (PCI versus reoperation) was individualized according to the clinical condition and circumstances. Even though the PCI and reoperation groups had apparently similar baseline characteristics and the PCI group had better outcomes and lesser mortality, we cannot conclude that PCI is better than reoperation as a recommendation. We just concluded that PCI was helpful in management.

## Conflicts of Interest

The authors declare that there are no conflicts of interest.

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