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RESEARCH

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Predictors of perioperative myocardial infarction in patients undergoing off-pump coronary artery bypass grafting

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Abstract

Background: Perioperative myocardial infarction (PMI) increases morbidity and mortality after off-pump coronary artery bypass grafting (CABG). The objective of the current study was to characterize patients with PMI after off-pump CABG and identify its predictors.

Results: We included 1181 patients who had off-pump CABG from 2010 to 2020; 59 patients (5%) had PMI. We compared patients with PMI to those without PMI. Patients with PMI were older (57 (25th–75th percentiles: 51–63) vs. 54 (48–60) years; $P = 0.01$) and had higher NYHA class (28 (47.46%) vs. 326 (29.06%): $P = 0.01$). The distal anastomosis time was longer in patients with PMI (28 (23–35) vs. 24 (16–30) min; $P < 0.001$). Patients with PMI had higher post-operative low cardiac output (10 (18.18%) vs. 1 (0.1%): $P < 0.001$), prolonged ventilation (12 (8–39) vs. 8 (6–10) h, $P < 0.001$), ICU (71 (46–138) vs. 24 (23–42) h; $P < 0.001$), and hospital stay (9 (6–15) vs. 7 (6–8) days; $P < 0.001$). Mortality was significantly higher in patients with PMI (20 (33.9%) vs. 6 (0.53%); $P < 0.001$). Older age (OR: 1.05 (95% CI: 1.01–1.1); $P = 0.02$), increased number of distal anastomoses (OR: 1.74 (95% CI: 1.20–2.50); $P = 0.003$), preoperative congestive heart failure (OR: 10.27 (95% CI: 2.58–40.95); $P = 0.001$), and thrombolysis within 24 h of surgery (OR: 15.34 (1.93–121.9); $P = 0.01$) were associated with increased PMI, while PMI was lower in male patients (OR: 0.42 (95% CI: 0.19–0.93); $P = 0.03$) and with higher body surface area (BSA) (OR: 0.08 (95% CI: 0.07–0.86); $P = 0.04$).

Conclusions: Post-off-pump CABG PMI was associated with increased morbidity and mortality. Risk factors for PMI were older age, lower BSA, females, increased distal anastomoses, preoperative heart failure, and thrombolysis.

Keywords: Perioperative myocardial infarction, Off-pump coronary artery bypass grafting, Mortality

Background

Perioperative myocardial infarction (PMI) after coronary artery bypass grafting (CABG) is associated with high morbidity and mortality [1]. The incidence of PMI varies widely in the literature depending on the diagnostic criteria, and it ranges from 2 to 10% [2]. Several factors could contribute to the occurrence of PMI, including early graft occlusion, coronary thrombosis, poor myocardial protection, or incomplete revascularization [3].

Incomplete revascularization was reported during the early experience with off-pump CABG, and it could be a risk factor for increased PMI in those patients [4]. Recently, off-pump CABG became the standard of care in several centers with comparable complete revascularization to on-pump CABG [5]. Recent studies showed no difference between on and off-pump CABG in PMI occurrence [6]. Identifying predictors of PMI in patients undergoing off-pump CABG could improve surgical outcomes. Therefore, the objectives of the current study were to characterize patients with PMI after off-pump CABG and identify its predictors.

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Methods

Design and patients

This retrospective study was conducted from 2010 to 2020 in a single center. The study included 1181 patients who had off-pump CABG. We included off-pump CABG patients who had primary or redo, elective, or emergency surgery. Preoperatively unstable patients on high inotropic support or intra-aortic balloon pump and those who had minimally invasive off-pump CABG were excluded. All patients had surgery through a median sternotomy. The Local Ethical Committee approved the data collection for the study, and the need for patients' consent was waived because of the retrospective design.

Study data, outcomes, and definitions

Preoperative data collected for the study included the demographics, comorbidities, and laboratory results. Operative data included the operative urgency, redo surgery, and distal anastomoses' number and time. Postoperative outcomes included low cardiac output, pulmonary complications, renal impairment, stroke, and mortality. The primary outcome was PMI, and patients were classified according to the PMI into no-PMI and PMI groups. PMI was diagnosed by the presence of at least two of these: a new Q wave, CK-MB elevation, and new wall motion abnormality in echocardiography. Stroke was defined as neurological defects persisting more than 24 h with confirmatory computed tomography findings. Transient ischemic attacks are neurological defects that resolve within 24 h. Ejection fractions were classified as good ($>$ 50%), fair (30–49%), and poor ($<$ 30%). Hospital outcomes occurred within the same hospital admission or within 30 days of the operation. The need for postoperative mechanical support defined the low cardiac output syndrome. Pulmonary complications included re-intubation, pneumothorax, or pleural effusions that required interventions. Renal impairment was defined as elevated serum creatinine more than 1.5 times the preoperative level or the need for postoperative renal replacement therapy. Infective complications included sternal wound infection and mediastinitis.

Statistical analysis

We described continuous data as mean and standard deviation if normally distributed or median and (25th–75th percentiles) if not normally distributed. We used the student *t*-test to compare normal continuous data and the Mann-Whitney test for non-normal continuous variables. We described categorical variables as frequencies and percentages and compared them with the chi-square or Fisher exact test when appropriate. Univariable logistic regression analysis was performed. Variables with a *P*-value of 0.015 or lower in the univariable analysis were included in a multivariable model. Multivariable logistic regression analysis with backward elimination was used to identify risk factors for PMI. Variables with a *P*-value of less than 0.05 were included in the final model. Model calibration was tested using the Hosmer–Lemeshow test and discrimination using the area under the curve. All analyses were performed using Stata 16 (Stata Corp- College Station, TX, USA), and a *P*-value of less than 0.05 was considered statistically significant.

Results

Preoperative data

Fifty-nine patients (5%) had PMI. Patients with PMI were compared to those without PMI. Patients with PMI were significantly older ($P = 0.01$), had higher New York Heart Association (NYHA) ($P = 0.01$) and Canadian Cardiovascular Society (CCS) classes ($P = 0.049$), and history of heart failure ($P < 0.001$). Hypertension was more common in patients with PMI ($P = 0.04$). There were no significant differences in other comorbidities, laboratory results, and ejection fraction (Table 1).

Operative data

There were no differences regarding the operative urgency and redo surgery between PMI and non-PMI patients. However, the distal anastomosis time was longer in patients with PMI (28 (23–35) vs. 24 (16–30) min; $P < 0.001$), and they had smaller coronary artery sizes ($P = 0.01$). The distal anastomoses were higher in PMI patients ($P < 0.001$) (Table 2).

Postoperative outcomes

Patients with PMI had higher postoperative low cardiac output, blood transfusion, re-exploration for bleeding, pulmonary complications, infective complications, prolonged ventilation, ICU, and hospital stay. Mortality was significantly higher in patients with PMI ($P < 0.001$) (Table 3).

Factors associated with PMI

Multivariable logistic regression analysis revealed that older age (OR: 1.05 (95% CI: 1.01–1.1); $P = 0.02$), number of distal anastomoses (OR: 1.74 (95% CI: 1.20–2.50); $P = 0.003$), preoperative congestive heart failure (OR: 10.27 (95% CI: 2.58–40.95); $P = 0.001$), and thrombolysis within 24 h of surgery (OR: 15.34 (1.93–121.9); $P = 0.01$) were associated with increased PMI, while PMI was lower in male patients (OR: 0.42 (95% CI: 0.19–0.93); $P = 0.03$) and with higher body surface area (BSA) (OR: 0.08 (95% CI: 0.07–0.86); $P = 0.04$) (Table 4).

Table 1 Comparison of the preoperative data between patients with and without perioperative myocardial infarction

	Non-PMI patients ($n = 1122$)	PMI patients ($n = 59$)	*P*
Age (years)	54 (48–60)	57 (51–63)	0.01
Male	959 (85.47%)	45 (76.27%)	0.05
BMI (kg/m^2)	27.8 (24.8–30.9)	28.2 (24.2–33.2)	0.62
BSA (m^2)	1.9 (1.8–2)	1.9 (1.8–2)	0.22
NYHA III-IV	326 (29.06%)	28 (47.46%)	0.01
CCS III-IV	463 (41.27%)	32 (54.24%)	0.049
Congestive heart failure	17 (1.52%)	5 (8.47%)	$<$ 0.001
Previous myocardial infarction	334 (29.93%)	19 (32.79%)	0.65
Thrombolysis within 24 h	9 (0.81%)	2 (3.51%)	0.1
Previous PCI	112 (10.02%)	5 (8.77%)	0.76
Diabetes mellitus	461 (41.35%)	31 (52.54%)	0.09
Hypertension	606 (54.25%)	40 (67.80%)	0.04
Severe renal impairment/dialysis	26 (2.33%)	3 (5.08%)	0.18
COPD	24 (2.15%)	3 (5.08%)	0.15
Cerebrovascular disease	27 (2.42%)	1 (1.69%)	$>$0.99
Peripheral vascular disease	13 (1.17%)	2 (3.45%)	0.17
Atrial fibrillation	4 (0.37%)	0	$>$0.99
Hemoglobin (mg/dl)	13.5 (12.4–14.3)	13.2 (12.4–14.2)	0.75
Creatinine (mg/dl)	1 (0.9–1.2)	1 (0.9–1.3)	0.55
Bilirubin (mg/dl)	0.6 (0.5–0.8)	0.6 (0.4–0.8)	0.26
Ejection fraction			0.11
Good	846 (77.54%)	39 (67.24%)	
Fair	234 (21.45%)	18 (31.03%)	
Poor	11 (1.01%)	1 (1.72%)	

Continuous variables were presented as mean and standard deviation if normally distributed and median (25th–75th percentiles) if not normally distributed. Categorical data were presented as frequencies and percentages

BMI body mass index, *BSA* body surface area, *CCS* Canadian Cardiovascular Society, *COPD* chronic obstructive pulmonary disease, *NYHA* New York Heart Association, *PCI* percutaneous coronary interventions, *PMI* perioperative myocardial infarction

Table 2 Comparison of the operative data between patients with and without perioperative myocardial infarction

	Non-PMI patients ($n = 1122$)	PMI patients ($n = 59$)	*P*
Urgent surgery	6 (0.53%)	1 (1.69%)	0.30
Redo surgery	23 (2.05%)	1 (1.69%)	$>$0.99
Number of distal anastomoses			$<$ 0.001
1	484 (43.14%)	9 (15.25%)	
2	376 (33.51%)	21 (35.59%)	
3	205 (18.27%)	23 (38.98%)	
4	56 (4.99%)	5 (8.47%)	
5	1 (0.09%)	1 (1.69%)	
Coronary size (mm)	1.6 $\pm$ 0.74	1.5 $\pm$ 0.30	0.01
Total distal anastomosis time (min)	24 (16–30)	28 (23–35)	$<$ 0.001

Continuous variables were presented as mean and standard deviation if normally distributed and median (25th–75th percentiles) if not normally distributed. Categorical data were presented as frequencies and percentages

PMI perioperative myocardial infarction

Discussion

Perioperative myocardial infarction after coronary artery bypass grafting still presents a major cause of morbidity and mortality [7]. Our study found that PMI patients had higher postoperative complications, including low cardiac output, pulmonary and renal complications, prolonged

Table 3 Comparison of the postoperative outcomes between patients with and without perioperative myocardial infarction

	Non-PMI patients ($n = 1122$)	**PMI patients ($n = 59$)**	***P***
Low cardiac output	1 (0.10%)	10 (18.18%)	$<$ 0.001
Blood transfusion	632 (61.54%)	47 (88.68%)	$<$ 0.001
Re-exploration	30 (2.92%)	11 (20.75%)	$<$ 0.001
Duration of mechanical vent (h)	8 (6–10)	12 (8–39)	$<$ 0.001
Pulmonary complications	16 (1.56%)	12 (24%)	$<$ 0.001
Stroke	2 (0.20%)	2 (4%)	0.01
Infective complications	11 (1.07%)	5 (9.80%)	0.001
New onset renal impairment	22 (2.15%)	9 (18%)	$<$ 0.001
Hemoglobin on discharge (mg/dl)	11.7 (11–12.5)	11.1 (10.1–11.9)	0.04
Creatinine on discharge (mg/dl)	1 (0.9–1.2)	1 (0.9–1.3)	0.41
Bilirubin on discharge (mg/dl)	0.7 (0.5–1)	0.6 (0.4–1)	0.27
ICU stay (h)	24 (23–42)	73 (46–138)	$<$ 0.001
Hospital stay (days)	7 (6–8)	9 (6–15)	$<$ 0.001
Mortality	6 (0.53%)	20 (33.90%)	$<$ 0.001

Continuous variables were presented as mean and standard deviation if normally distributed and median (25th–75th percentiles) if not normally distributed. Categorical data were presented as frequencies and percentages

ICU intensive care unit, *PMI* perioperative myocardial infarction

Table 4 Risk factors for perioperative myocardial infarction

	Odds ratio (95% confidence interval)	***P***
Males	0.42 (0.19–0.93)	0.03
Age	1.05 (1.01–1.1)	0.02
Body surface area	0.08 (0.07–0.86)	0.04
Number of distal anastomoses	1.74 (1.20–2.50)	0.003
Congestive heart failure	10.27 (2.58–40.95)	0.001
Thrombolysis within 24 h	15.34 (1.93–121.9)	0.01

Area under the curve = 0.76; goodness of fit $P = 0.75$

mechanical ventilation, ICU, and hospital stay. Additionally, PMI was associated with higher mortality. We identified risk factors for PMI in our cohort and included older age, female gender, low BSA, congestive heart failure, thrombolysis, and a higher number of distal anastomoses.

The incidence of PMI varies widely in the literature. A major cause for this variability is the different diagnostic criteria and techniques used [8]. According to several reports, no optimal single diagnostic criteria for PMI are available, and combined diagnostic approaches are recommended [9]. The debate between on-pump and off-pump CABG continues, and the practice varies in different centers. In a meta-analysis of studies comparing on-pump and off-pump CABG, no difference in myocardial injury was reported between groups [10].

Hospital and long-term sequelae risk could be improved if the risk factors are identified and properly managed. Several risk factors associated with PMI after off-pump CABG were reported. The presence of collaterals could protect the patients against PMI [11]. We found that the risk of PMI was associated with increasing the number of distal anastomoses. This finding is similar to what was reported by Nathoe and colleagues [12]. This observation could be attributed to the longer distal occlusion time, leading to PMI in patients with poor collaterals. Therefore, several strategies could be used to reduce distal ischemia or improve the collateral circulation, such as the use of intra-coronary shunts [13], coronary staplers [14], or ischemic preconditioning [15]. Alkhouli and colleagues found that females, heart failure, dialysis, cirrhosis, emergency CABG, and mechanical circulatory support predicted early PMI after CABG [16]. In our series, congestive heart failure and recent thrombolysis increased the risk of PMI. These factors indicated patients' instability with severe coronary artery disease. CABG in patients with cardiogenic shock or those who failed non-surgical revascularization was associated with high morbidity and mortality [17]. In other series, the female gender was a risk factor for PMI, which was related to the smaller coronary arteries and poor collaterals [18]. We confirmed this finding in our patients, and we found that females had a higher risk of PMI. Similarly, lower BSA was associated with PMI, which could be related to the coronary artery sizes.

PMI was associated with increased complications and mortality in our series. Patients with PMI had prolonged ventilation, ICU, and hospital stay. Another study reported a negative impact of PMI on hospital outcomes, while there was no difference in long-term outcomes [19]. However, other studies showed that PMI negatively affected the incidence of long-term cardiovascular outcomes after CABG [20].

Study limitations

The study is limited by the retrospective design; however, PMI is a rare event, and this is the optimal study design to evaluate risk factors for PMI. Additionally, the study is a single-center experience, and several factors could be related to the operating surgeons and their expertise. Several unmeasured variables could have affected the outcomes and were not included in the analysis. Finally, we did not include invasive measures to diagnose PMI.

Conclusions

Post-off-pump CABG PMI was associated with high morbidity and mortality. Older age, lower BSA, females, increased distal anastomoses, preoperative heart failure, and thrombolysis were related to increased PMI. Targeting these factors could improve the outcomes of surgery.

Abbreviations

BSA: Body surface area; CABG: Coronary artery bypass grafting; CCS: Canadian Cardiovascular Society classes; COPD: Chronic obstructive pulmonary disease; ICU: Intensive care unit; NYHA: New York Heart Association; OPCAB: Off-pump coronary artery bypass grafting; PMI: Perioperative myocardial infarction.

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Authors' contributions

Mohamed amr: conceived and designed the analysis, collected the data, data analysis and took part in writing the paper. Elsayed Fayad: data collection and took part in writing the paper. The authors read and approved the final manuscript.

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Availability of data and materials

The authors declare that the data supporting the findings of this study are available upon request.

Declarations

Ethics approval and consent to participate

Consent to participate was waived by the Ethical Committee.

Consent for publication

Not applicable

Competing interests

The authors declare that there is no conflict of interest. Additionally, the authors have no financial interest or ties in or with the product or product distributor.

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