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ANGIOGRAPHIC NO-REFLOW AFTER PRIMARY PERCUTANEOUS CORONARY INTERVENTION FOR ST-ELEVATION MYOCARDIAL INFARCTION: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT
Angiographic no-reflow is a clinically important complication of primary percutaneous coronary intervention (PCI) in patients with ST-segment elevation myocardial infarction (STEMI). In a prospective observational study this was established as its prevalence and frequently available clinical parameters associated with its occurrence in 400 consecutive adults undergoing primary PCI. Technically successful PCI without mechanical epicardial obstruction was defined as the final Thrombolysis in Myocardial Infarction flow grade 0-2 in the absence of no-reflow. No-reflow occurred in 80 patients (20.0%; 95% confidence interval [CI], 16.4%-24.2%). Compared with patients achieving normal flow, those with no-reflow were older (61.4 ± 10.2 vs. 56.6 ± 11.2 years; mean difference, 4.80 years; 95% CI, 2.09-7.51; P < 0.001), more frequently had diabetes mellitus (51.3% vs. 31.6%; odds ratio, 2.28; 95% CI, 1.39-3.75; P = 0.001), and had a longer total ischemic time (6.56 ± 2.86 vs. 4.38 ± 2.65 h; mean difference, 2.18 h; 95% CI, 1.52-2.84; P < 0.001). No-reflow was not significantly related to smoking or hypertension. One-fifth of the study population experienced angiographic no-reflow; older age, diabetes mellitus and longer ischemic time were associated with angiographic no-reflow, in unadjusted analysis.

KEYWORDS: Diabetes mellitus; Ischemic time; No-reflow phenomenon; Percutaneous coronary intervention; ST-segment elevation myocardial infarction; TIMI flow

INTRODUCTION

ST-segment elevation myocardial infarction (STEMI) still is a significant cause of cardiovascular morbidity and mortality. In the early period, reperfusion helps to reduce myocardial necrosis, maintain left ventricular function and enhance survival. Current European and North American guidelines have established primary PCI as the recommended reperfusion therapy if it can be performed immediately by a well-developed system of care (Ibanez et al., 2018; Byrne et al., 2023; Rao et al., 2025). Treatment delay shows a graded relationship with mortality, with each minute of ischemia being significant (De Luca et al., 2004; Nallamothu et al., 2007).

However, epicardial patency achieved by restoration is not always associated with restoration of myocardial tissue perfusion. No-reflow is the failure of microvascular reperfusion despite removal of the epicardial obstruction. It was first described experimentally following transient coronary occlusion and later shown in humans following coronary thrombolysis and reperfusion (Kloner et al., 1974; Schofer et al., 1985; Ambrosio et al., 1989). Ischemic time, reperfusion injury, and infarct size all have an impact on the degree of no-reflow (Reffelmann et al., 2002).

No-reflow can be evaluated in the clinic based on final TIMI flow grade, corrected TIMI frame count, myocardial blush grade, electrocardiographic ST-segment resolution, myocardial contrast echocardiography, or cardiac magnetic resonance imaging. These methods assess related, but not identical, elements of epicardial and microvascular reperfusion (TIMI Study Group, 1985; Gibson et al., 1996; van't Hof et al., 1998; Gibson et al., 1999; Hamada et al., 2001; Galiuto et al., 2003; Henriques et al., 2003; Ohara et al., 2005; Kampinga et al., 2010). Microvascular obstruction has been shown on CMR studies to be dynamic and has been shown to provide prognostic information beyond infarct size alone (Rochitte et al., 1998; Wu et al., 1998).

Distal atherothrombotic embolization, ischemic capillary damage, endothelial swelling, intramyocardial hemorrhage, inflammation and oxidative stress, vasoconstriction, edema, and reperfusion injury are all involved in the pathophysiology (Jaffe et al., 2008; Durante and Camici, 2015; Niccoli et al., 2016; Rezkalla et al., 2017; Kloner et

al., 2018; Konijnenberg et al., 2020). Larger infarct size, adverse left ventricular remodeling, heart failure, occurrence of ventricular arrhythmias, cardiogenic shock, and increased mortality have been associated with the occurrence of no-reflow (Ito et al., 1996; Ndrepepa et al., 2010; Harrison et al., 2013; Eitel et al., 2013).
The previous observations have identified other clinical or angiographic factors associated with no-reflow such as advanced age, prolonged ischemic time, diabetes mellitus, high thrombus burden, distal embolization, adverse lesion morphology, poor baseline coronary flow, etc. (Iwakura et al., 2001; Yip et al., 2002; Tanaka et al., 2002; Kirma et al., 2008; Fokkema et al., 2009; Wang et al., 2015; Ipek et al., 2016; Mazhar et al., 2016; Soeda et al., 2017; Tasar et al., 2019). Factors that can be identified before or during PCI, that can support preparation and monitoring after the PCI.
The purpose of the present study is to assess the incidence of angiographic no-reflow, and the frequence of routine clinical factors associated with no-reflow in patients with STEMI who underwent primary PCI.CI.

MATERIAL AND METHODS

Study design and setting

The study was a prospective, single-center, observational, analytical study in the Department of Cardiology of Lady Reading Hospital-Medical Teaching Institution (LRH-MTI), Peshawar, Pakistan that was performed for 12 months between February 2025 and February 2026. The total number of 400 consecutive adult patients with STEMI were enrolled by non-probability consecutive sampling.

Study population

Adults (age 18 years and older) with a definite diagnosis of STEMI and informed written consent were eligible. Patients who received fibrinolysis as treatment who were not placed on PCI and patients who had known previous coronary artery bypass grafting (CABG), coronary artery dissection, incomplete study data or refused participation were excluded. Diagnosis of STEMI was defined by the appropriate guideline criteria, which included the presence of compatible symptoms, ST-segment elevation on the electrocardiograms and biomarker confirmation. Primary PCI was carried out in accordance with the protocol in the institution's catheterization-laboratory.

Data collection and operational definitions

All demographic, clinical, angiographic and procedural data was collected on a structured proforma. Kind of age, sex, smoking, hypertension, diabetes mellitus, total ischemic time, Killip class, left ventricular ejection fraction, infarct-related artery, TIMI flow, thrombus burden, multivessel disease and procedural characteristics were included in the study record. For the present manuscript, age and smoking, hypertension, diabetes mellitus, total ischemic time and final TIMI flow were available. The total ischemic time was noted as hours on a study proforma. Operational definitions are only added when they are recorded in the approved protocol or original data-collection form.

Outcome definition

Angiographic no reflow (angiographic TIMI flow grade 0–2, without mechanical obstruction) was the primary outcome. Final TIMI grade 3 flow was considered normal coronary flow. This definition is based on angiographic epicardial flow, and is referred to in this report as angiographic no-reflow (TIMI Study Group, 1985).
The analysis was conducted using basic statistics and missing data.
IBM SPSS Statistics version 26.0 was used to analyse the data. The mean ± standard deviation was used to summarize continuous variables and frequencies and percentages were used to summarize categorical variables. The P-values provided in the study results were used for between-group comparisons. The magnitude of associations was described using unadjusted mean differences and odds ratio (ORs) with 95% confidence intervals (CIs) reported for groups. All tests were two-sided and $P < 0.05$ was deemed to be statistically significant. A multivariable regression analysis and formal model-validation analysis were not available, so all observations described are unadjusted associations and not independent predictors. The exclusion criteria stated were followed by excluding patients with incomplete data. No further statement about the amount or handling of missing data is made as the patient-level original data set was not available for checking.

Ethical considerations

The study was carried out following the Declaration of Helsinki. All participants gave written informed consent. This study received ethical approval **from** institutional review board**.**

RESULTS

The study included 400 patients who were admitted to hospital with STEMI who were undergoing primary PCI. Angiographic no reflow was observed in 80 patients (20.0%, 95% CI 16.4%-24.2%) while 320 (80.0%) had a normal coronary flow after PCI (Table 1).
The no-reflow group was older, and had diabetes mellitus and longer total ischemic time than the normal flow group. There were no significant differences in smoking or hypertension between groups (Table 2).Baseline clinical features

and unadjusted correlations with angiographic no reflow. Values are mean ± standard deviation or n (%). CI, confidence interval; MD, unadjusted mean difference (no-reflow - normal flow); OR, unadjusted odds ratio.
The highest relative association was found with diabetes mellitus: no-reflow occurred at 2.28 times the odds in patients with diabetes compared to those without diabetes (95% CI, 1.39-3.75). The total ischemic time was 2.18 h longer for patients with no-reflow compared with those with normal flow (95% CI, 1.52-2.84). There was a nonsignificant trend for hypertension but the confidence interval included the null value. As the available analysis was without patient level multivariable adjustment, none of these factors can be regarded as an independent predictor.

Table 1. Baseline Clinical Characteristics According to Angiographic No-Reflow Status

Variable	No-reflow (n=80)	Normal flow (n=320)	P-value
Age (years)	61.4 ± 10.2	56.6 ± 11.2	<0.001
Smoking	30 (37.5%)	136 (42.5%)	0.43
Hypertension	28 (35.0%)	81 (25.3%)	0.07
Diabetes mellitus	41 (51.3%)	101 (31.6%)	<0.001
Total ischemic time (hours)	6.56 ± 2.86	4.38 ± 2.65	<0.001

Table 2. Angiographic No-Reflow Frequency

Coronary flow status	Frequency (n)	Percentage (%)
No-reflow (TIMI 0-2)	80	20.0
Normal flow (TIMI 3)	320	80.0
Total	400	100.0

Table 3. Unadjusted Associations with Angiographic No-Reflow

Factor	Effect estimate	95% CI	P-value
Age	MD 4.80 years	2.09-7.51	<0.001
Diabetes mellitus	OR 2.28	1.39-3.75	<0.001
Total ischemic time	MD 2.18 hours	1.52-2.84	<0.001
Smoking	OR 0.81	0.49-1.34	0.43
Hypertension	OR 1.59	0.94-2.68	0.07

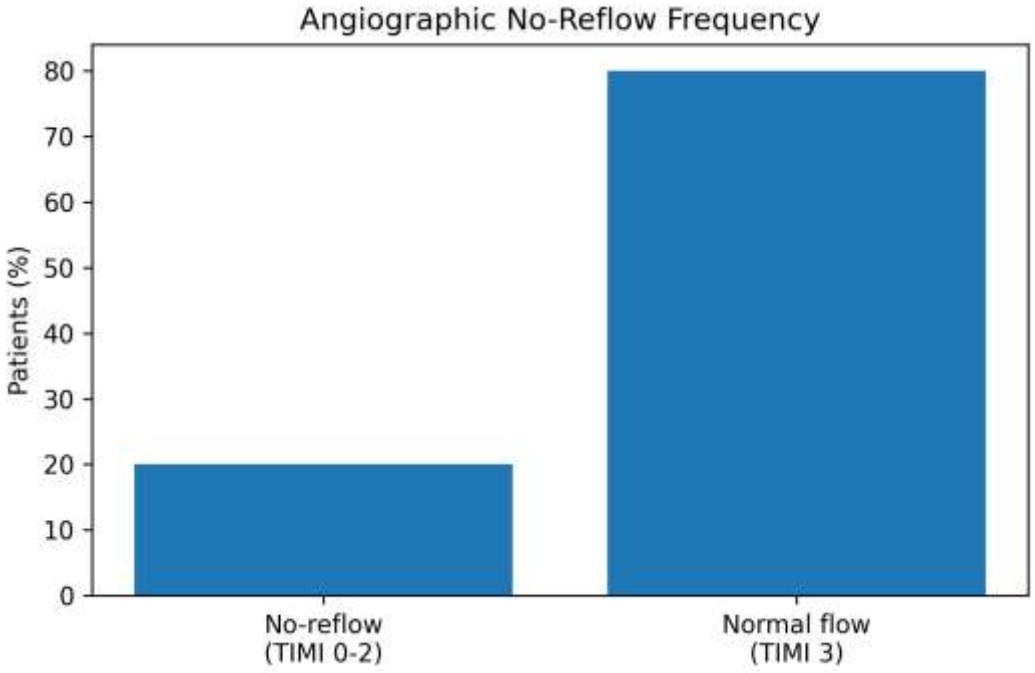

Figure 1. Distribution of angiographic no-reflow and normal coronary flow.

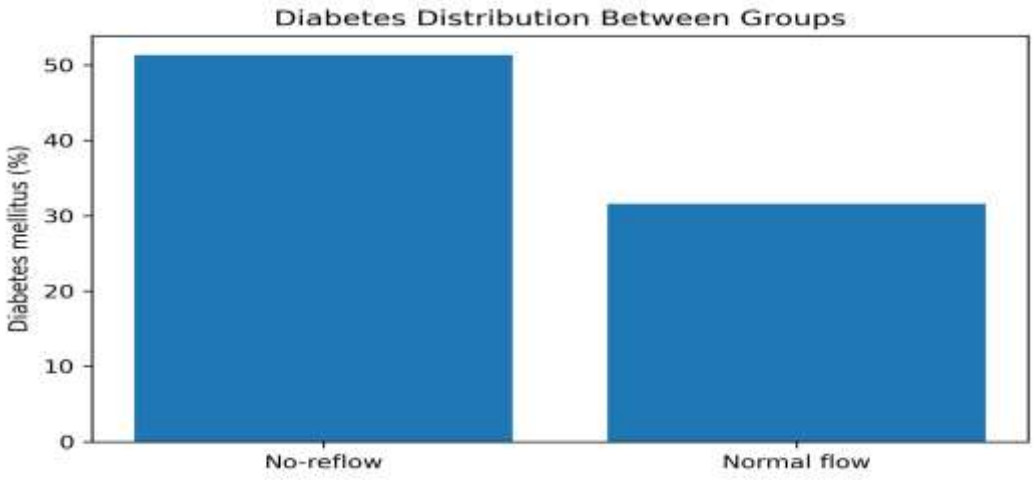

Figure 2. Comparison of diabetes mellitus prevalence between groups.

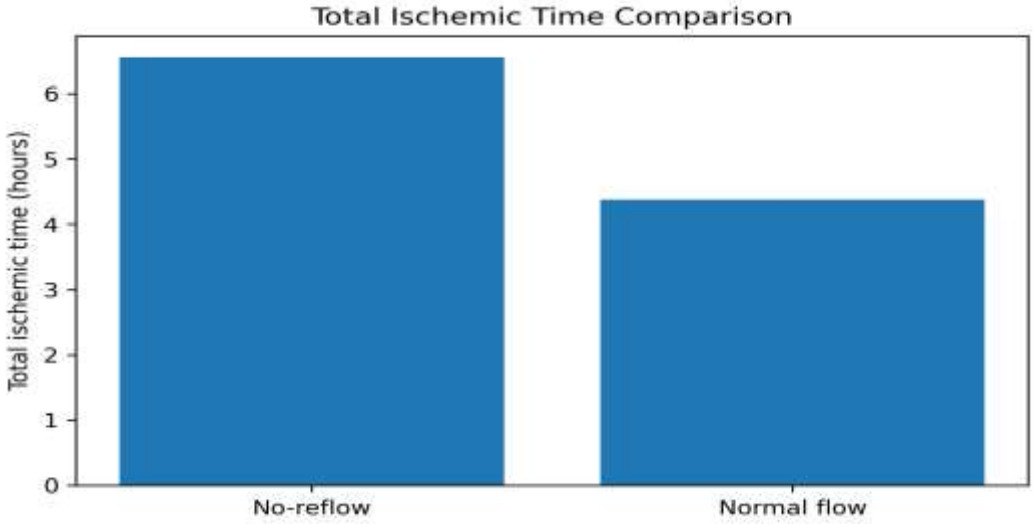

Figure 3. Comparison of total ischemic time between groups.

DISCUSSION

A prospective single-center cohort study found that 20.0% of patients with STEMI who received primary PCI were accompanied by angiographic no reflow. In unadjusted analyses, old age, diabetes mellitus and prolonged total ischemic time were significantly associated with no-reflow, but smoking and hypertension were not. The observed frequency falls within wide ranges reported in clinical studies but there is significant variation depending on the patient population, reperfusion delay, angiographic definition, burden of the thrombus, and sensitivity of the method used to detect microvascular injury (Harrison et al., 2013; Mazhar et al., 2016; Tasar et al., 2019).

Biological plausibility exists between the relationship of PIT and no-reflow. The longer coronary occlusion is maintained, the more likely the capillaries are to become damaged, edema is to develop, leukocytes will plug the capillaries, intramyocardial hemorrhage will occur, and irreversible microvascular injury will result, making it unlikely that the tissue level will be restored by epicardial recanalization (Ambrosio et al., 1989; Reffelmann et al., 2002; Jaffe et al., 2008; Konijnenberg et al., 2020). Rapid reperfusion also is a key determinant of clinical outcome in STEMI, as evidenced by clinical data (De Luca et al., 2004; Nallamothu et al., 2007).

More than double the unadjusted odds of no-reflow were present with diabetes mellitus. Endothelial dysfunction, chronic inflammation, oxidative stress, platelet hyperreactivity, impaired vasodilator reserve and structural microangiopathy are characteristics of diabetes. These abnormalities can decrease the microcirculatory resilience seen in acute ischemia and reperfusion (Niccoli et al., 2016; Rezkalla et al., 2017; Kloner et al., 2018). The current finding confirms previous clinical investigations that showed various metabolic and clinical risk factors to be correlated with impaired post-PCI flow (Kirma et al., 2008; Wang et al., 2015; Ipek et al., 2016).

No-reflow was also related to older age. Older age may represent increased atherosclerotic burden, endothelial dysfunction, microvascular rarefaction, renal dysfunction, frailty and delayed presentation. However, since age, diabetes and ischemic time may be interrelated, their individual contribution needs to be determined by multivariable modelling. Other previous studies have also shown that lesion morphology, high thrombus burden, distal embolization and poor baseline flow are significant determinants (Iwakura et al., 2001; Yip et al., 2002; Tanaka et al., 2002; Fokkema et al., 2009; Soeda et al., 2017).

No-reflow was defined by the authors as final TIMI flow. This is pragmatic and widely available, but could underestimate microvascular obstruction in patients who have TIMI 3 epicardial flow. Corrected TIMI frame count and myocardial blush grade are more detailed angiographic measures, while cardiac magnetic resonance and contrast echocardiography are direct measures of tissue level injury and its temporal evolution (Gibson et al., 1996; Rochitte et al., 1998; van't Hof et al., 1998; Wu et al., 1998; Hamada et al., 2001; Galiuto et al., 2003; Ohara et al., 2005; Kampinga et al., 2010).

Identification of high-risk patients could assist operators to plan preventive and rescue strategies, while standard adjunctive therapy is questionable. Contemporary reviews suggest that first one should rule out mechanical causes and then one should use intracoronary vasodilators, antiplatelet therapy and hemodynamic support on an individual basis based on the clinical and angiographic context (Rezkalla et al., 2017). Management should stay up to date with the latest acute coronary syndrome guidelines and catheterisation-laboratory practice standards (Byrne et al. 2023; Rao et al. 2025).

The implications for the practical application of the findings are that age, diabetes status and total ischemic time can be obtained before or during PCI. Despite this, a clinically useful prediction model must include prespecified candidate variables, handle missing data appropriately, evaluate for nonlinearity, perform multivariable regression analysis, validate internally, discriminate, calibrate, and validate externally. Current risk scores are examples of how this can be done but should not be used until they are validated in the desired target population (Wang et al., 2015).

STRENGTHS AND LIMITATIONS

This study has a few strengths, such as the use of a clinically meaningful angiographic endpoint and the prospective enrollment of a consecutive STEMI cohort. Looking at the results of the study, the P values are provided, and along with them the analysis reports effect estimates and confidence intervals.

There are a number of restrictions which should be noted. One limitation is the single-center design, which restricts the generalizability. Second, no-reflow was evaluated using only final TIMI flow without myocardial blush grade, corrected TIMI frame count, cardiac magnetic resonance or contrast echocardiography. Third, the study record contains other angiographic and procedural information that was not available for use in the current analysis: Killip class, left ventricle ejection fraction, infarct related artery, thrombus burden, multivessel disease, and procedural characteristics. Fourthly, long-term clinical outcomes were not available. Fifth, the analysis did not consider comparisons with adjusted metrics, which could introduce a significant amount of confounding. Sixth, there was no documented prespecified sample-size calculation nor missing-data report. Lastly, the definitions of the operational variables (smoking, hypertension and diabetes mellitus) should be checked with the approved protocol or original data collection instrument.

CONCLUSION

The proportion of patients with STEMI who developed no-reflow was 20%, as determined by angiography. In the unadjusted analyses, older age, diabetes mellitus and long total ischemic time were significantly associated with no-reflow. These easily available variables could be used to raise risk awareness early in the process, but their potential to be independent predictors or used as part of a clinical prediction tool needs to be modelled with a number of variables and validated externally.

CONFLICTS OF INTEREST

The authors declared that there are no conflicts of interest / specify all relevant conflicts.

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DATA AVAILABILITY

De-identified data may be obtained from the corresponding author upon reasonable request and subject to institutional approval.

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