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PREDILATION BALLOONING IN HIGH THROMBUS LADEN STEMIS: AN INDEPENDENT PREDICTOR OF SLOW FLOW/NO-REFLOW IN PATIENTS UNDERGOING EMERGENT PERCUTANEOUS CORONARY REVASCULARIZATION

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ABSTRACT

Background: ST-segment elevation myocardial infarction (STEMI) is a critical presentation of acute myocardial infarction. Primary percutaneous coronary intervention (pPCI) is the recommended treatment to restore forward blood flow. However, the occurrence of slow-flow/no-reflow (SF/NR) can limit optimal reperfusion, affecting patient outcomes. Among various factors, high thrombus burden (≥4 grade) has been linked to SF/NR.

Objective: This study evaluates the impact of predilation ballooning on the incidence of intraprocedural SF/NR during primary PCI in patients with high thrombus burden.

Material and Methods: This cross-sectional study was conducted at the Department of Cardiology, Federal Govt Polyclinic Hospital, Islamabad, between August 2020 and July 2021. A total of 250 STEMI patients undergoing pPCI with angiographic evidence of high thrombus burden (≥4 grade) were included. Patients were divided into two groups based on the use of predilation ballooning (n = 125 each). Propensity score matching ensured comparability of clinical profiles. Data analysis was performed using IBM SPSS, with $p \leq 0.05$ considered statistically significant.

Results: Patients in the ballooning group exhibited older age, longer ischemic times, higher heart rates, and more advanced Killip class at presentation. They also had a greater prevalence of diabetes, multivessel disease, and complex coronary anatomy. Predilation ballooning significantly increased the incidence of SF/NR (41.3% vs. 27.4%, $p < 0.001$). Despite achieving similar final TIMI III flow

rates, the ballooning group experienced higher in-hospital mortality (8.1% vs. 4.1%, p = 0.018) and a trend toward increased contrast-induced nephropathy.
Conclusion: Predilation ballooning is an independent predictor of intraprocedural SF/NR and is associated with higher in-hospital mortality in STEMI patients with high thrombus burden. These findings emphasize the need to avoid predilation ballooning and minimize procedural hardware to optimize outcomes in this high-risk population.

Keywords: STEMI, primary PCI, predilation ballooning, slow-flow, no-reflow, thrombus burden, intraprocedural complications, emergent percutaneous coronary revascularization.

INTRODUCTION

ST-segment elevation myocardial infarction (STEMI) is the predominant presentation of acute myocardial infarction (AMI). Primary percutaneous coronary intervention (pPCI) within a 12-hour timeframe is the suggested approach for treating individuals with acute STEMI. Prompt reestablishment of forward blood flow is the main objective of pPCI in arteries affected by the heart attack.

However, the presence of the slow-flow or no-reflow phenomenon undermined the advantages of pPCI. Despite employing a successful treatment approach, achieving optimal reperfusion and reaching the desired Thrombolysis in Myocardial Infarction (TIMI) flow grade III is unattainable for all STEMI patients. The condition where a coronary artery remains open but the myocardial tissue experiences inadequate blood flow is referred to as "slow flow/no-reflow (SF/NR)." [1]

The cause and precise mechanism behind this dual state phenomenon are not well understood, and various suggested causal factors include distal coronary embolization, inflammatory reaction, vasospasm, capillary obstruction, endothelial swelling, myocardial edema, and ischemia-reperfusion injury. [2,3] Recent research indicates that in current times, the incidence of Slow Flow/No Reflow (SF/NR) varies between 4% and 30% after primary percutaneous coronary intervention (pPCI) [14–10]Various predisposing factors have been recognized, and several explanatory mechanisms have been proposed for the SF/NR phenomenon along with strategies to mitigate SF/NR in clinical settings. Among numerous clinical factors, a high thrombosis burden (≥4 grade) has been identified as significantly associated with the occurrence of SF/NR during pPCI [5 9–12]. Thrombosuction or predisposition has been linked to an increased risk of SF/NR in some studies [12]. We hypothesize that distal embolization due to microthrombus fragments formed during predilation ballooning is a potential mechanism of SF/NR among patients with a high thrombus burden. Therefore, this study aims to evaluate the impact of predilation ballooning on the occurrence of intraprocedure SF/NR during primary PCI in patients with a high thrombus burden (≥4 grade).

MATERIAL AND METHODS

This cross-sectional research was carried out in the Department of Cardiology, Federal Govt Polyclinic Hospital Islamabad, Pakistan. The study focused on a group of patients diagnosed with STEMI who underwent pPCI between August 2020 and July 2021. We included patients who met specific criteria: diagnosis of STEMI, qualification for pPCI, and angiographic confirmation of substantial thrombus presence (≥4 grade). Patients who had manual thrombus aspiration were not part of this study. Verbal consent was obtained from each patient before they were included. All primary PCI procedures followed established clinical guidelines for STEMI management.

A structured form was used to gather demographic information, clinical details, and procedural specifics for the study. The occurrence of SF/NR during or around the procedure was characterized by insufficient blood flow (TIMI flow grade <III) in the affected artery. Thrombus severity was categorized as grades G0 to G5, with high thrombus burden defined as ≥4, indicating thrombus obstruction in more than half of the vessel's diameter. The decision to place a stent was made by the lead operator based on observing the distal edge of the affected segment following guidewire manipulation or preliminary balloon expansion. Films from angiograms were evaluated for SF/NR by

unbiased consultant cardiologists unaware of the balloon expansion status. All patients were pre-treated in line with guidelines and institutional protocol: unfractionated heparin and dual antiplatelet therapy (DAPT) with an additional dose of glycoprotein inhibitors (IIb/IIIa). Ticagrelor use was restricted to patients with diabetes, high-risk anatomy, or stent thrombosis, while clopidogrel and aspirin were the most common DAPT due to cost considerations.

To address significant differences in the clinical profiles of cohorts with and without balloon expansion prior to the comparison of SF/NR incidence rates, a 1:1 ratio matching was performed using propensity scores. R software version 3.6.1 with the "MatchIt" package was employed for this purpose. Clinical factors used for this matching included age, gender, total ischemic time, systolic blood pressure, heart rate, blood sugar level, Killip class, intubation status, cardiac arrest, diabetes, hypertension, smoking status, history of prior PCI or stroke, left ventricular end-diastolic pressure, left ventricular ejection fraction, use of intra-aortic balloon pump, number of diseased vessels, infarct-related artery, pre- and post-procedure TIMI flow grade, vessel diameter, and lesion length. Group comparisons were made using appropriate statistical tests (independent sample t-test/Mann–Whitney U test or Fisher's exact test/chi-square test) in IBM SPSS version 21, with a significance threshold set at $p \leq 0.05$.

RESULTS

A total of 250 patients were included in this study, evenly divided into two groups: those who underwent predilation ballooning (n = 125) and those who did not (n = 125). Several significant demographic, clinical, and procedural differences were observed between the two groups. Patients in the ballooning group were older on average (55.94 ± 10.2 years vs. 53.76 ± 10.64 years, **p = 0.009**) and experienced significantly longer total ischemic times (370 [245–560] minutes vs. 240 [235–455] minutes, **p = 0.021**), suggesting a potentially more severe clinical presentation. Additionally, the ballooning group had higher heart rates upon admission (86.8 ± 21.8 bpm vs. 82.2 ± 20.4 bpm, **p = 0.021**) and a greater prevalence of advanced Killip class presentations, including Killip class III (11.6% vs. 6.4%) and class IV (6.6% vs. 5.5%), with a significant overall difference in Killip class distribution (**p = 0.021**).

Comorbid conditions such as diabetes mellitus were more frequent in the ballooning group (43.1% vs. 36%, **p = 0.048**), while hypertension showed a trend toward significance (63% vs. 56.1%, **p = 0.053**). Furthermore, there was a higher prevalence of multivessel disease among ballooning patients, particularly three-vessel disease (35% vs. 26.5%, **p = 0.008**), indicating a more complex coronary anatomy. Hemodynamic parameters also differed, with higher left ventricular end-diastolic pressures observed in the ballooning group (22 ± 7.6 mmHg vs. 20 ± 6.7 mmHg, **p = 0.046**). Procedurally, patients undergoing ballooning required longer stent lengths (28.7 ± 11.1 mm vs. 25.2 ± 10.2 mm, **p < 0.001**) and smaller mean stent diameters (2.3 ± 0.3 mm vs. 2.4 ± 0.2 mm, **p < 0.001**), reflecting the complexity of their lesions.

The ballooning group was also associated with a significantly higher rate of intraprocedural complications, including slow flow or no-reflow phenomena (41.3% vs. 27.4%, **p < 0.001**), a key finding of this study. Despite achieving similar final TIMI III flow rates (84.4% vs. 85.4%, **p = 0.686**), the ballooning group demonstrated higher rates of in-hospital mortality (8.1% vs. 4.1%, **p = 0.018**) and a trend toward increased contrast-induced nephropathy (12.4% vs. 8.8%, **p = 0.106**). Other in-hospital complications, such as stroke, arrhythmias, cardiogenic shock, and stent thrombosis, did not differ significantly between the groups.

These findings highlight the potential risks associated with predilation ballooning, particularly the increased likelihood of slow flow/no-reflow and higher mortality rates, emphasizing the need for careful patient selection and procedural planning when managing high thrombus-laden STEMIs in emergent percutaneous coronary revascularization settings. The results underscore the importance of individualized treatment approaches to optimize outcomes in this high-risk patient population.

Table 1: Demographic, clinical, and angiographic characteristics and postprocedure in-hospital complications and outcomes stratified by predilation ballooning status.

	Preballooning Not done (n = 125)	**Done (n = 125)**	***p* value**
Gender			
Female	20.3% (25)	22.8% (28)	0.393
Male	79.7% (100)	77.2% (97)	
Age (years)	53.76 ± 10.64	55.94 ± 10.2	0.009
Total ischemic time (minutes)	240[235–455]	370[245–560]	0.021
Systolic blood pressure (mmHg)	128.8 ± 24.2	130.3 ± 26.1	0.449
Heart rate (bpm)	82.2 ± 20.4	86.8 ± 21.8	0.021
Random glucose level (mg/dL)	150[120–200]	155[125–208]	0.301
Killip class I	76.4% (96)	67.1% (84)	
II	11.7% (15)	14.7% (19)	0.021
III	6.4% (8)c	11.6% (15)	
IV	5.5% (7)	6.6% (8)	
Cardiac arrest	6% (8)	7.8% (9)	0.315
Comorbid conditions Diabetes mellitus	36% (45)	43.1% (54)	0.048
Hypertension	56.1% (70)	63% (79)	0.053
Smoking	32.2% (40)	27.5% (34)	0.153
Prior PCI	7.9% (33)	9.5% (12)	0.415
History of CVA/TIA	2.1% (10)	1.4% (2)	0.470
IABP used	5.5% (7)	7.5% (9)	0.255
ejection fraction (%)	38.5 ± 8.8	37.8 ± 9.5	0.276
end-diastolic pressure (mmHg)	20± 6.7	22± 7.6	0.046
Number of vessels involved Single vessel disease	40.8% (51)	30.9% (39)	
Two vessel disease	32.7% (40)	34.1% (43)	0.008
Three vessel disease	26.5% (34)	35% (44)	
Culprit coronary artery Left main	2% (4)	2.6% (3)	
LAD; proximal	32.6% (140)	32.7% (41)	0.119
LAD; nonproximal	16.4% (68)	21.1% (26)	
Left circumflex artery	9.8% (35)	12.1% (15)	
Right coronary artery	37.2% (150)	31.5% (39)	
Pre-procedure TIMI flow 0	82.6% (103)	85.5% (107)	
I	17.4%(22)	14.5%(18)	0.265
II	0% (0)	0% (0)	
III	0% (0)	0% (0)	
Mean stent diameter	2.4 ± 0.2	2.3 ± 0.3	<0.001
Total stent length	25.2 ± 10.2	28.7 ± 11.1	<0.001
Intraprocedure slow flow/no-reflow	27.4% (34)	41.3% (52)	<0.001
Final TIMI III flow	85.4% (107)	84.4% (106)	0.686
In-hospital complications Stroke	0.7% (1)	0% (0)	0.115

Arrhythmia	5% (6)	6.9% (9)	0.260
Cardiogenic shock	4.3% (5)	4% (5)	0.864
Stent thrombosis	3.3% (10)	2% (3)	0.267
Contrast induced nephropathy	8.8% (11)	12.4% (16)	0.106
In-hospital mortality	4.1% (5)	8.1% (10)	0.018

PCI percutaneous coronary intervention, CVA cerebrovascular accident, TIA transient ischemic attack, IABP intraaortic balloon pump, LV left ventricular, LAD left anterior descending artery, and TIMI thrombolysis in myocardial infarction.

DISCUSSION

Predilation in patients with a substantial clot burden raises the chance of complications during the procedure, such as slow flow or no reflow, likely caused by tiny clot particles breaking off and blocking blood vessels. This risk may escalate during the use of predilation balloons to prepare the clot-laden area in patients undergoing emergency angioplasty. Therefore, we undertook this study to examine how predilation ballooning affects the occurrence of slow flow or no reflow during primary PCI in patients with a high thrombus load (≥4 grade). In our investigation, the group of patients who underwent predilation ballooning exhibited a notably higher occurrence of intraprocedure slow flow/no reflow (SF/NR) compared to the group without predilation. However, the composition of both groups significantly varied in terms of various clinical factors including age distribution, total ischemic time, Killip class III/IV, presence of diabetes, left ventricular end-diastolic pressure (LVEDP), stent diameter, total stent length, and presence of three-vessel disease. Therefore, we established a propensity-matched cohort of patients who did not undergo predilation and compared them with the predilation cohort in terms of intraprocedure SF/NR incidence. Even after accounting for differences in clinical characteristics, we found that the incidence of intraprocedure SF/NR remained significantly higher in the predilation group at 41.3% compared to 30.1% ($p < 0.002$) in the non-predilation group, with a relative risk of 1.64 [95% CI: 1.20 to 2.24].

Subsequent studies have also indicated that a high thrombus burden is a prominent risk factor for SF/NR incidents [13,14]. For instance, in a study involving 794 acute myocardial infarction (AMI) patients, a high thrombus burden emerged as an independent predictor of SF/NR following emergency PCI [15]. Another study highlighted a higher percentage of individuals with high thrombus burden in the SF/NR cohort compared to those with normal flow [5]. The risk of no reflow was significantly associated with pre-procedure TIMI flow grade I, collateral flow, multivessel involvement, and high thrombus burden. Additionally, TIMI flow and thrombus burden were consistently the most related factors to SF/NR compared to other variables. Patients with a large infarct size coupled with a high thrombus burden [16], decreased TIMI flow, and absence of collateral flow [17] are more prone to develop SF/NR [18]. Microembolization post-PCI has been linked to a high thrombus burden as shown in magnetic resonance imaging (MRI) studies within a year of acute myocardial infarction [19]. Recent studies have also identified thrombus burdens of ≥4 prior to PCI as independent predictors of SF/NR [9,10,20,21].

In routine clinical scenarios, prolonged ischemic time often accompanies a high thrombus burden due to delayed reperfusion resulting in increased erythrocytes and thrombus accumulation. Prolonged ischemia can also compromise capillary integrity, leading to polymorphonuclear cell plugging and myocardial cell and capillary bed edema [12,20]. During balloon dilation, red thrombi can fragment, causing distal embolization and reduced myocardial tissue perfusion [12,17,20,22–25]. This microcirculatory dysfunction exacerbates myocardial reperfusion injury and raises the risk of SF/NR and adverse cardiovascular events. Observations by Okamura et al. [26] using Doppler guidewires revealed multiple embolic particles in PCI patients, highlighting the association of embolization with irreversible myocardial blood flow reduction [27]. Apart from thrombus fragmentation, other potential causes of predilation-induced SF/NR include microembolization of older thrombi exacerbated by acute plaque rupture, resulting in more severe artery occlusion and higher coronary wedge pressure

[28]. Therefore, in our study, total ischemic time was a key parameter used for propensity matching between the groups.

This study is the first to assess the impact of balloon dilation on SF/NR incidence in patients with a high thrombus burden. The observational design is a major limitation. Additionally, data on myocardial blush grade (MBG) were lacking for comparison between the cohorts. A randomized study investigating predilation in high thrombus burden cases could provide definitive evidence concerning SF/NR outcomes.

CONCLUSION

In conclusion, pre-dilation ballooning can be associated with an increased risk of incidence of intraprocedure SF/NR during primary PCI in patients with a high thrombus burden. Considering the prognostic significance of SF/NR, it is important to avoid predilation ballooning and limit the hardware used during primary PCI of patients with high thrombus burden to avoid SF/NR.

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