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Original Article

Effect on Thrombolysis in Myocardial Infarction Flow by Stent Post-Dilatation in Patients with ST-Segment-Elevated Myocardial Infarction Undergoing Primary Percutaneous Coronary Intervention

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ABSTRACT

The common intervention for ST-segment elevation myocardial infarction is primary percutaneous coronary intervention (PCI). Post-dilatation of the stent is commonly used to obtain the best stent expansion, but its effect on end-tidal thrombolysis of myocardial infarction flow and microvascular perfusion is not clear in low-resource settings, e.g., Pakistan. **Objectives:** The study will assess the effectiveness of stent post-dilatation on end-TIMI flow in patients undergoing primary PCI in STEMI, and the relationship between stent post-dilatation and no-reflow and in-hospital outcome measures. **Methods:** The research was a prospective cohort study conducted in the department of cardiology, Sheikh Zayed Medical College/hospital, Rahim Yar Khan, in a span of four months. The non-probability consecutive sampling included 193 patients with STEMI undergoing primary PCI. Patients were assigned to post-dilatation (n = 96) and no post-dilatation (n=97) based on operator discretion according to angiographic findings. Clinical measurements, angiographic, and echocardiographic measurements were obtained. **Results:** TIMI 3 flow during the last time was also achieved in 68.7/80.4% of the post-dilated group and non-post-dilated group, respectively (p=0.036). There was a higher incidence of no-reflow or slow-flow post-dilatation (19.8% vs 9.3, p=0.029). Mean ejection fraction was lower with post-dilatation (45.1 ± 7.8% vs 47.3 ± 7.0%, p=0.046). Suboptimal final TIMI flow was predicted by post-dilatation alone (OR 2.03, 95% CI 1.05–3.91, p=0.034). **Conclusions:** Post-dilatation stent in this Pakistani STEMI cohort was associated with lower final TIMI 3 flows and greater no-reflow, and was an independent predictor of suboptimal epicardial reperfusion after primary PCI.

INTRODUCTION

Cardiovascular disease is the leading cause of death in the world, and South Asia is overburdened with it. Based on the latest estimates provided on the whole of the planet, ischemic heart disease is the most common cause of cardiovascular mortality, with rising statistics in low- and middle-income countries [1]. The latest local data indicate that ST-segment elevation myocardial infarction is a major cause of acute coronary syndrome in Pakistan, where primary access to percutaneous coronary intervention is still scarce [2]. The fact that there is a lack of resources and reperfusion delays in this population of people further exacerbates the situation. ST-segment elevation myocardial infarction (STEMI) is a type of myocardial infarction that occurs when there is an acute occlusion of a coronary artery, causing extended myocardial ischemia. The most appropriate intervention in this situation is

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primary percutaneous coronary intervention (PCI) to restore the supply to the heart, relieve infarction, and limit it. A frequently used measure of myocardial reperfusion is the Thrombolysis in Myocardial Infarction (TIMI) flow grade that determines coronary blood flow after intervention [3]. The absence of best reperfusion (TIMI grade 3) is related to an increased likelihood of heart failure, arrhythmias, and mortality. Even though the use of stents is standard therapy in primary PCI, there is still uncertainty about whether post-dilatation can positively or negatively impact microvascular perfusion and final TIMI flow [3]. Variable results have been reported in Asian populations after primary PCI in patients with STEMI. A systematic review has suggested that post-dilatation following stent implantation during primary PCI can be associated with an increased risk of no-reflow but might decrease major adverse cardiovascular events (MACE) in the long term [4]. It has also been observed in observational studies that impairment of TIMI flow is associated with longer stent length, higher inflation pressures, and inadequate stent expansion [5]. Despite these findings, the evidence remains inconsistent. There are reports of better stent expansion and improved long-term outcomes with post-dilatation, as well as poor immediate perfusion outcomes [6]. In Pakistan, there is limited information on the effect of stent post-dilatation in STEMI. This may not be suitable for generalizing findings from elsewhere to the local population due to disparities such as delayed presentation, smaller coronary vessel size, and limited catheterization laboratory facilities. This research has been conducted to fill these gaps. Even though the literature on primary PCI in STEMI is rich, little has been done on the evaluation of the impact of stent post-dilatation on TIMI flow in the acute phase of STEMI, especially in the South Asian or Pakistani population [7]. This study was done not simply to define the frequency of outcomes but also to find out whether the post-dilatation affects end-to-end angiographic reperfusion, as indicated by TIMI flow grade, and whether it should be included in the strategy of the procedures in the low-resource environment [8]. Western and Pakistani populations may not have interchangeable post-dilatation outcomes because of differences in the door-to-balloon time and probably overestimated microvascular dysfunction in late presenters [9].

Considering the fact that there is no international evidence and regional data are unavailable, the study fills a significant gap in the Pakistani population. This setting can be used to generate evidence to inform local interventions and quantify better patient outcomes. Thus, the study aimed to determine the impact of stent post-dilatation at the end of inflation in primary PCI in Pakistani patients with STEMI. The main objective was to compare the results between the post-dilatation and no-post-dilatation groups, such as myocardial blush grade, no-reflow, and in-hospital major adverse cardiovascular events.

METHODS

This prospective comparative observational study was conducted at the Department of Cardiology, Sheikh Zayed Medical College/Hospital, Rahim Yar Khan, Pakistan, between 1 July 2025 and 30 October 2025. The Institutional Review Board gave ethical approval (Approval No. 132/IRB/SZMC/SZH; dated 18th July 2024). All participants were eager to participate with written informed consent. This research was carried out based on the principles of the Declaration of Helsinki. The sample size was determined by using the World Health Organization sample size calculator at 95% level of confidence and 80% power. Based on previous literature reporting suboptimal TIMI flow in 17.8% of patients undergoing primary PCI [10], and assuming a clinically meaningful absolute difference of 12% between groups (estimated from available observational data), the required sample size was 96 patients per group. After adding 10% for potential attrition, the target sample was set at 193 patients. [10]. Given that there was no trustworthy local comparative data of post-dilatation and no post-dilatation groups at the time of the study design, the calculation was made using the general prevalence of events and not a predicted difference between the groups. The number of patients needed was estimated to be 193. The maximum sample size was the target sample and was sampled using non-probability. Intervention (primary percutaneous coronary intervention) was confirmed by able-bodied adults aged 18 years to 65 years old, and those with acute myocardial infarction of ST-segment elevation, with electrocardiographic changes and cardiac biomarker concentrations in place. Patients who had coronary artery bypass graft, had severe left ventricular dysfunction (ejection fraction below 30%), cardiogenic shock, or were placed on dialysis, or were a patient choice, were excluded. Baseline demographic and clinical data were followed, such as age, sex, BMI, cigarette smoking, bidi smoking, hookah use, and naswar use, diabetes mellitus, hypertension, dyslipidemia, and family history of early coronary artery disease. The modified Kuppuswamy scale was used to measure socioeconomic status. Measures were of heart rate, blood pressure, Killip class, infarct site, onset of symptoms, and door-to-wire interval. Random blood sugar, serum creatinine, lipids, and hemoglobin lab measures were carried out using a fully automated apparatus (Sysmex XN-550, Japan). The laboratory parameter clinical cut-off values were according to the modern guidelines of the American Heart Association and the European Society of Cardiology. The percutaneous coronary intervention and coronary angiography

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procedures were performed by the senior interventional cardiologists according to the procedures used in the institute. All the patients were treated with drug-eluting stents. The decision to be post-dilated was given by operators based on angiographic literature of stent expansion, post-stent residual stenosis, and thrombus load evaluation. Post-dilatation was performed at the operator's discretion based on angiographic assessment of stent expansion, residual stenosis, and thrombus burden. When performed, post-dilatation was carried out using non-compliant balloons sized at a 1:1 ratio to the reference vessel diameter (balloon-to-vessel ratio 1.0-1.1). Inflation was performed at high pressure (16-20 atm) for 10-15 seconds per inflation, with a maximum of two inflations per lesion. Post-dilatation was avoided if there was evidence of extensive thrombus burden, dissection, or distal embolization. Peak inflation pressure and balloon size were recorded for all patients. At the end of the procedure, the operator evaluated TIMI flow grade and myocardial blush grade. There was also no-reflow or slow-flow effect. The transthoracic echocardiography was carried out to identify the left ventricular ejection fraction before discharge (Philips EPIQ 7, Netherlands). The outcome was mainly primary percutaneous coronary intervention followed by final TIMI flow grade. The secondary outcomes included no-reflow, myocardial blush, in-hospital major adverse cardiovascular events (death, reinfarction, or heart failure), and left ventricular ejection fraction during discharge.

SPSS version 26.0 (IBM Corp., Armonk, NY, USA) was used to perform the statistical analysis. Normality of the continuous variables was tested by the use of the Shapiro-Wilk test. The variables of normally distributed values were represented as mean, standard deviation, and compared with the help of an independent t-test. Median (interquartile range) was used to characterize variables that were not normally distributed and compared with each other using the Mann-Whitney U test. The frequencies and percentages were used to summarize categorical variables, and the chi-square test or Fisher's exact test were used to compare them. The final TIMI flow grade was a categorical variable that was ordinal in nature. To realize the regression analysis, this was dichotomized into suboptimal (0-2) and optimal (grade 3), and subject to binary logistic regression to identify predictors of impaired reperfusion that were independent. The Spearman rank correlation was used to determine associations between ordinal TIMI flow grade and continuous procedural variables. The p-value of less than 0.050 (two-tailed) was considered to be significant.

RESULTS

Patients who received primary percutaneous coronary intervention (PCI) were 193 (ST-segment elevation myocardial infarction (STEMI)). Among them, 96 (49.7%) underwent stent post-dilatation, while 97 (50.3%) did not. Hospitalization had no loss to follow-up. The subjects were aged 55.8 +/- 10.7 years, with an upper age limit of 75 years. The mean age was 56.3 ± 9.9 years in the post-dilatation group and 55.2 ± 11.5 years in the no post-dilatation group (t = 0.68, p = 0.496). The sampling size was 142 (73.6) men and 51 (26.4) women, and the sex distribution between the groups was not significantly different (2 = 0.14, p = 0.710). The baseline demographic characteristics of the two groups were similar, with no significant differences. The similarity in the characteristics of the baseline was based on the age, body mass index (BMI), and gender. These were predominantly middle-aged males who pertained to the lower-middle socioeconomic group as per the modified Kuppuswamy scale. Our group comprised a fairly middle-income group with a mean socioeconomic score of 14.6 ± 4.2, which aligned with the typical sample results of tertiary care hospitals in Pakistan. The age, BMI, systolic blood pressure, heart rate, and ejection fraction were normally distributed, and the time when the patient had first experienced the symptoms was not normally distributed, as well as the time from door to wire time. The independent samples t-test was used to calculate the comparison of the normally distributed variables with us compared to the non-normally distributed variables using the MannWhitney U test. First medical contact was lower and door to wire was lower in the post-dilatation group, implying that a decision on procedural action was made more often in the patients presented earlier. No notable difference between the groups was found as far as the prevalence of major comorbidities, i.e., hypertension and diabetes, is concerned. Angiography has shown that nearly two-thirds of patients had the culprit vessel in the left anterior descending (LAD) artery. Three-fourths of the overall sample was TIMI 3 final flow, which was not more so in the post-dilatation (p=0.036). The percentage of no-reflow/slow-flow was also a high phenomenon in the post-dilatation group (19.8% vs 9.3%). Post-dilatation and dilatation induced a statistically significant, but slightly reduced ejection fraction on discharge (45.1 ± 7.8% vs. 47.3 ± 7.0%, p=0.046). The no post-dilatation group had a higher myocardial blush grade, which was not statistically significant. Laboratory parameters showed no significant difference, and random blood sugar and serum creatinine showed no difference between them, suggesting that data on the biochemical profile do not differ between the groups. Correlation analysis revealed an inverse relationship between the final TIMI flow grade and balloon-

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to-vessel ratio, with the rate of balloon-to-vessel ratio being higher, the worse the TIMI flow. Binary logistic regression analysis revealed no difference in post-dilatation according to the suboptimal final flow in comparison to TIMI (OR=2.03, 95% CI=1.053.91, p=0.034). In the multivariate analysis, time to presentation, hypertension, and diabetes were also controlled, and none of the variables had a significant relationship with suboptimal flow. TIMI 2 circulation was slightly higher in anterior STEMI compared to non-anterior infarction (21.4% vs 13.7%, p=0.088). The mastery of door to wireless and ejection fraction of the heart was negatively correlated (Spearman rho=-0.312, p=0.001), i.e., the longer the period of reperfusion was, the more difficult it was to drink worse the ventricular work. Generally, no exact associations were found between end TIMI flow and demographic and biochemical factors, but post-dilatation and balloon-to-vessel ratio were associated with the quality of angiographic reperfusion. There was a higher prevalence of the major adverse cardiovascular events in the hospital, although they were not significantly different in the post-dilatation cohort. This is similar to other low and middle-income countries and South Asian reported trends, which have shown variability of TIMI flow recovery after aggressive post-dilatation of the procedure. Table I presents the distributions of continuous variables in the two groups, mean, standard deviation of normally distributed variables, in addition to the median and inter-quantile range of non-normally distributed variables. The test of whether the data were normal was performed by the Shapiro-Wilk test. Independent t-tests and non-normally distributed variables were analyzed using the Mann-Whitney U test, where the level of statistical significance of the results was predetermined before analyzing the variables to be less than 0.5 a priori. Most of the continuous variables were normally distributed, and they were age, systolic blood pressure, ejection fraction, and heart rate. They were not normally distributed: time to first medical contact and door-to-wire time. The difference between the non-normally distributed variable (p=0.041 and p=0.034, respectively)(Table 1)was significant.

Table 1: Comparison of Continuous Variables Between Post-Dilatation and No-Post-Dilatation Groups

Variables	Shapiro–Wilk W (p)	Post-Dilatation (n=96)	No post-dilatation (n=97)	Test Value	p-value
Age (years)*	0.983 (0.078)	56.3 ± 9.9	55.2 ± 11.5	t=0.68	0.496
BMI (kg/m^2) *	0.987 (0.112)	27.6 ± 3.4	27.2 ± 3.8	t=1.01	0.315
Systolic BP (mmHg)*	0.978 (0.089)	124.8 ± 14.2	126.3 ± 13.6	t=0.69	0.493
Heart Rate (bpm)*	0.984 (0.071)	82.5 ± 11.3	80.6 ± 12.1	t=1.11	0.268
Symptom Onset to FMC (hrs)†	0.903 (<0.001)	3.8 (2.9–5.4)	4.4 (3.5–6.2)	U=4361.5	0.041
Door-to-Wire Time (min)S †	0.899 (<0.001)	82 (68–110)	94 (76–124)	U=4423.0	0.034
Ejection Fraction (%) *	0.976 (0.060)	45.1 ± 7.8	47.3 ± 7.0	t=2.01	0.046

*Independent t-test; †Mann–Whitney U test. FMC = First Medical Contact

The categorical data are presented as n (%). Where cells were few, the chi-square test or Fisher's exact test was employed to compare groups. A level of significance of 0.050 was taken. The distribution of genders and comorbidities did not vary across groups. The end-TIMI 3 flow was, however, much lower among patients who underwent post-dilatation (68.7% vs 80.4, 84.10%, p=0.036). The incidence of no-reflow was significantly higher in this group (19.8% vs 9.3%; χ^2=4.79; p=0.029)(Table 2).

Table 2: Categorical Variables and Angiographic Findings in Both Study Groups

Variables	Post-Dilatation (n=96)	No post-dilatation (n=97)	χ^2/F	p-value
Male Gender	71 (73.9%)	71 (73.2%)	0.14	0.710
Hypertension	55 (57.3%)	53 (54.6%)	0.37	0.542
Diabetes Mellitus	39 (40.6%)	33 (34.0%)	1.14	0.285
Smoking	48 (50.0%)	38 (39.2%)	2.12	0.145
Modified Kuppuswamy Lower Middle	41 (42.7%)	43 (44.3%)	0.21	0.842
Anterior STEMI	62 (64.6%)	56 (57.7%)	0.98	0.323
Final TIMI 3 Flow	66 (68.7%)	78 (80.4%)	4.41	0.036
Myocardial Blush Grade 3	52 (54.2%)	64 (65.9%)	3.10	0.078
No-Reflow Phenomenon	19 (19.8%)	9 (9.3%)	4.79	0.029
In-Hospital MACE	11 (11.5%)	5 (5.1%)	3.16	0.075

Data represented as n (%); p < 0.05 considered significant

Binary logistic regression equation using independent variables when predicting suboptimal TIMI flow (≤ 2) post-primary PCI. The model was age, diabetes, hypertension, and door-to-wire time adjusted. The odds ratios (OR), the 95% confidence intervals, and the p-values are given. On its own, stent post-dilation was forecasting poor TIMI flow (OR = 2.03, p=0.034). All the other variables were adjusted to be not statistically significant (Table 3).

Table 3: Binary Logistic Regression for Predictors of Suboptimal Final TIMI Flow (≤ 2)

Predictor Variables	Adjusted OR (95 % CI)	Wald #	p-value
Stent post-dilatation#	2.03 (1.05 – 3.91)	4.48	0.034
Age > 60 years#	1.22 (0.62 – 2.43)	0.42	0.517

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Diabetes Mellitus#	1.35 (0.71 – 2.56)	0.75	0.387
Hypertension#	1.12 (0.59 – 2.15)	0.10	0.751
Door-to-Wire > 120 min#	1.46 (0.74 – 2.90)	1.03	0.310

Binary logistic regression model adjusted for age, diabetes, hypertension, and door-to-wire time. Dependent variable = final TIMI flow ≤ 2

Correlation and subgroup analysis of the key continuous variables, including door-to-wire time, ejection fraction, and post-dilatation balloon-to-vessel ratio, are presented in the paper. The correlation used by Pearson was in variables that were normally distributed, whereas non-normally distributed ones used Spearman correlation. Door-to-wire time and ejection fraction (r=-0.312, p=0.001) had a moderate negative correlation, and balloon-to-vessel ratio and final TIMI flow had a weak negative correlation (r=-0.242, p=0.001). There were no important correlations between ejection fraction and age (Table 4).

Table 4: Correlation and Subgroup Analyses Among Continuous and Angiographic Variables

Variable Pairs	Normality (Test)	Correlation Coefficient (r / ρ)	95 % CI	p-value	Test Used
Door-to-Wire Time vs Ejection Fraction	Non-normal (p<0.001)	ρ=–0.312	–-0.42 to –0.19	<0.001	Spearman
Balloon-to-Vessel Ratio vs Final TIMI Flow	Non-normal (p<0.001)	ρ=–0.242	–-0.34 to –0.13	0.001	Spearman
Age vs Ejection Fraction	Normal (p=0.078)	r = –0.091	–0.23 to 0.05	0.204	Pearson
BMI vs Ejection Fraction	Normal (p=0.112)	r = –0.118	–-0.26 to 0.03	0.120	Pearson

Correlation coefficients interpreted as weak (± 0.1–0.3), moderate (± 0.3–0.5), or strong (> ± 0.5)

DISCUSSION

The present study has discussed the association between post-dilatation and ultimate Thrombolysis in Myocardial Infarction (TIMI) flow in patients who received primary percutaneous coronary intervention of ST-segment elevation myocardial infarction. We found that after dilatation, there was lower final TIMI 3 flow with a higher rate of no-reflow. Additionally, post-dilatation was a predictor of suboptimal epicardial reperfusion in an adjusted manner to clinical confounds. One of the concerns of primary PCI that has yet to be addressed is no-reflow. Recent findings indicate that critical microvascular obstructive phenomena and distal embolization are mechanisms that lead to the inability to restore impaired reperfusion despite sufficient restoration of epicardial patency [11]. Thrombus burden, complex lesions, and procedural aspects such as balloon inflation characteristics are predictors of no-reflow [12]. This has highlighted the continued clinical importance of no-reflow as a key factor that predicts infarct size and ventricular recovery in STEMI patients [13]. Current findings are in line with current meta-analytic data on post-dilatation in acute coronary syndromes. Matsuoka *et al.* have reported that post-dilatation may increase procedural manipulation and has been associated with an increased risk of slow-flow or no-reflow in specific risk groups [14]. Similarly, recent evidence has also shown measurable changes in coronary flow parameters following post-dilatation during primary PCI [15]. Recent analyses also support the view that one of the limitations of mechanical reperfusion strategies is still microvascular dysfunction [16]. Microvascular damage may accumulate in the form of distal embolization and endothelial injury due to forceful balloon expansion, dislodging thrombotic or atheromatous debris. Experimental findings assessing microcirculatory indices after post-dilatation show that although luminal gain may improve, paradoxical worsening of microvascular perfusion occurs in some cases [17]. Recent pooled meta-analyses have demonstrated that post-dilatation improves stent geometry but does not necessarily improve immediate flow indices and should be used on an ad hoc basis rather than in a lesion-specific routine manner [18]. Regional data further emphasize the importance of procedural predictors of no-reflow. A recent study conducted in Pakistan indicated that no-reflow during primary PCI remains common and is strongly influenced by thrombotic and procedural factors [19]. This is also consistent with a recent systematic review concluding that post-dilatation is not universally associated with optimal short-term perfusion and may increase mechanical stress on the infarct-related artery [20]. The biological plausibility of our results is supported by the current understanding of microvascular obstruction in acute myocardial infarction. Microvascular damage involves endothelial dysfunction, inflammatory cascades, vasoconstriction, and capillary plugging, which may be exacerbated by excessive mechanical intervention [21]. Current European practice emphasizes restoration of optimal epicardial flow while minimizing distal embolization and procedural injury during primary PCI [22]. Although a small reduction in left ventricular ejection fraction in the post-dilatation group was observed in our cohort, it may reflect microvascular injury and greater myocardial damage. Previous studies have shown that poor TIMI flow is associated with larger infarct size and reduced ventricular recovery [12, 17]. In addition, the negative correlation between door-to-wire time and ejection

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fraction was also observed, supporting the importance of timely reperfusion in line with current guidelines [22].

The study provides useful evidence from a tertiary care center in Pakistan, where a gap exists in local data. Our results strengthen validity through the use of standardized angiographic measures and multivariate adjustment. However, several limitations must be considered. The sample size was based on overall prevalence rather than expected intergroup differences, which may reduce the precision of comparative effect estimates. Assignment to post-dilatation was based on operator discretion rather than randomization, introducing potential selection bias, as operators may have chosen post-dilatation for more complex lesions. The single-center design limits generalizability. Intravascular imaging was not routinely available, and objective assessment of stent expansion was not possible. Thrombus burden grading was not performed systematically. This was an angiographic outcome-powered study and not a long-term clinical outcome trial. Larger multicenter or randomized studies are needed to further clarify the role of post-dilatation during STEMI intervention. The sample size was based on overall prevalence rather than expected intergroup differences, which may reduce the precision of comparative effect estimates.

CONCLUSIONS

Stent post-dilatation after primary percutaneous coronary intervention was related to the reduced rates of final Thrombolysis in Myocardial Infarction grade 3 flow and increased incidence of no-reflow in patients with ST-segment-elevated myocardial infarction. Post-dilatation was an independent predictor of suboptimal epicardial reperfusion. This fact supports the need to exercise caution in the application of regular or aggressive post-dilatation in settings where microvascular protective actions are kept to a minimum.

Authors' Contribution

Conceptualization: MWA
Methodology: AM, ZUAA
Formal analysis: BB, IA
Writing and Drafting: MWA, JNN
Review and Editing: MWA, AM, BB, IA, JNN, ZUAA

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflict of Interest

All the authors declare no conflict of interest.

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