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Effect of different reperfusion strategies on recovery of ventricular function after ST-segment elevation myocardial infarction: A longitudinal single-center study

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Abstract

Background and Aims: Although the clinical benefit of percutaneous coronary intervention (PCI) on cardiovascular outcomes has been widely investigated, the impact of this revascularization strategy compared to other alternatives on the degree of left ventricular function recovery is poorly demonstrated. In this regard, we investigated whether time delays between the presentation of ST-segment elevation myocardial infarction (STEMI) and PCI in reperfusion strategies have different impacts on left ventricular function recovery.

Methods: In this single-center study, all the patients who presented with STEMI and a reduced left ventricular ejection fraction (LVEF ≤ 40%) were enrolled. Included patients were subjected to four different treatment groups of primary, rescue (immediate transfer for angioplasty due to failed fibrinolytic therapy), facilitated (fibrinolytic therapy followed by angioplasty within 24 h), and deferred (successful fibrinolytic therapy and PCI after 24 h) PCI based on hospital facilities. Echocardiography was performed for all the patients at the time of hospitalization and 6 months later.

Results: A total of 128 patients were included in this study. The LVEF improved by 15.3 ± 6.3%, 11.5 ± 3.61%, 4.0 ± 1.0%, and −1.3 ± 7.0% in primary, rescue, facilitated, and deferred PCI groups, respectively ($p < 0.001$). Patients undergoing deferred PCI experienced a significantly lower improvement in LVEF compared with primary and rescue PCI ($p < 0.001$).

Conclusion: Primary PCI demonstrated the most promising recovery in left ventricular function following STEMI compared to other alternative strategies. Performing PCI as soon as possible provides better recovery of LVEF.

KEYWORDS

facilitated PCI, left ventricular ejection fraction, percutaneous coronary intervention, primary PCI, rescue PCI, ST-segment elevation myocardial infarction

1 | INTRODUCTION

Percutaneous coronary intervention (PCI) has been proposed as a superior substitute to thrombolysis in patients with ST-segment elevation myocardial infarction (STEMI) as thrombolysis alone, can lead to suboptimal results when compared to primary PCI.[1,2] Logistical issues and delays from the first medical contact (FMC) to device time have been major challenges that can hinder the benefits of PCI. Timely PCI has been shown to have favorable outcomes since up to 6 h delay for PCI increases the long-term mortality by 15% when compared to delivery for PCI in an hour (30.8% vs. 15.4%).[3] To address this issue, several clinical trials have investigated if the administration of intravenous fibrinolytics coupled with subsequent PCI can yield similar results to primary PCI. The STREAM study compared the outcomes of fibrinolytic therapy before transportation for PCI with primary PCI, and the results showed that the groups were similar regarding short-term clinical outcomes except for a slight increase in the risks of intracranial hemorrhage in the group receiving thrombolytics.[4] Consistent with the previous study, the results of the FAST-MI study suggested that a pharmacoinvasive strategy has a similar 1-year survival rate compared to primary PCI.[5] The delay from administering thrombolytics to PCI can also affect the outcomes of STEMI patients as well. In TRANSFER-AMI, the investigators noted that urgent PCI within 6 h of thrombolytic therapy is associated with fewer adverse events than patients undergoing rescue or delayed PCI.[6]

It is demonstrated that performing angioplasty 3–12 h following thrombolytic therapy is associated with similar improvement in ejection fraction and indexed end-systolic volume at 6 weeks compared with primary angioplasty.[7] To date, the effect of different timings from thrombolytic therapy to delivery for PCI on echocardiographic indices has not been widely studied. Furthermore, it has been previously studied that several predictors such as baseline left ventricular ejection fraction (LVEF),[8] lesion characteristics,[8] HALP score,[9] and white blood cell count to mean platelet volume ratio[10] are correlated with prognosis in STEMI patients. In the present study, we focused on comparing changes in echocardiographic indices including LVEF, ventricular volumes and diameters at end-systole and -diastole, and also global longitudinal strain (GLS) at 6-month follow-up after STEMI in patients undergoing reperfusion strategies with different delays from presentation to device time. We also evaluated if the type of reperfusion strategy could independently predict ventricular function recovery.

2 | MATERIALS AND METHODS

2.1 | Study design and population

This was a prospective single-center observational study that obtained ethics approval from the Institutional Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.MED.REC.1401.067). Eligible participants were among the patients with a diagnosis of anteroseptal STEMI who had a reduced LVEF (LVEF < 40%) referred to Al-Zahra Heart Hospital from January 2022 to March 2023. Reasons for exclusion were: history of heart failure with reduced ejection fraction, bleeding events, previous acute myocardial infarction, thrombolysis in myocardial infarction (TIMI) flow grade <3 after coronary angioplasty, and missing data on echocardiographic studies. All the potentially eligible patients were asked to provide written informed consent before inclusion.

Participants received one of the four reperfusion strategies based on the availability of PCI and the institution's treatment protocols. These revascularization methods were as follows: 1) patients undergoing primary PCI within 90 min of presentation (primary PCI group), 2) the second group were those treated with thrombolytic agents and then underwent emergent PCI due to failed response to the treatment (rescue PCI group), 3) participants who received successful thrombolytic therapy and then were referred for PCI within 2–24 h of presentation (facilitated PCI group), and 4) initial treatment with successful thrombolytics followed by PCI after 24 h during the same hospitalization (deferred PCI group). Reteplase (18 mg) (10 units) bolus intravenously in 2 min followed by another 18 mg after 30 min) was given as the fibrinolytic therapy in adjunction to unfractionated heparin (enoxaparin 30 mg intravenous infusion before fibrinolytic therapy then 1 mg/kg up to 100 mg of subcutaneous administration followed by 1 mg/kg every 12 h) in the present study. Success in fibrinolytic therapy was considered as a more than 75% reduction in the summation ST-Segment elevation and resolution of chest pain. Success in PCI was defined as maintaining a TIMI flow III with stenting and less than 30% residual stenosis. Patients who needed PCI on other non-culprit lesions were excluded to minimize the effect of confounding factors. The investigators did not interfere with the treatment options, and the reperfusion strategy was chosen based on the local availability of treatment options and local physician discretion.

2.2 | Echocardiographic markers

Transthoracic echocardiography (TTE) was performed using GE vivid 9 ultrasound scanners. All the participants underwent standard TTE at the time of admission and also 6 months following hospital discharge performed by a trained cardiologist blinded to the revascularization strategy. Patients were at rest and left lateral decubitus position at the time of echocardiography. Left ventricular diameters and volumes (left ventricular end-systolic diameter and volume [LVESD and LVESV] and left ventricular end-diastolic diameter and volume [LVEDD and LVEDV]) were obtained in apical two- and four-chamber views. LVEF was calculated by Simpson's biplane method. Left ventricular GLS was acquired for all the patients using two-dimensional speckle-tracking echocardiography.

2.3 | Statistical analysis

The continuous variables were described as mean and the corresponding standard deviation (SD). Categorical variables were

presented as numbers and its percentages. The normality of data distribution was analyzed by Kolmogorov–Smirnov test. The significance of differences between studied groups was tested using one-way analysis of variance (ANOVA) test if the data were normally distributed and if not Kruskal-Wallis test was used. In the case of between-groups statistical difference, a post hoc analysis was performed (Bonferroni test). The mean difference (MD) and the associated 95% confidence interval (CI) were presented as estimates of effect size. The relevant baseline variables and study endpoints were entered in a multivariable logistic regression analysis to find the potential predictors of a significant improvement in LVEF (defined as ≥5% increase after 6 months) following STEMI. An odds ratio (OR) with 95% CI were reported for the logistic regression results. A two-tailed *p*-value of ≤0.05 was set as statistically significance. All the analyses were conducted using SPSS Statistics for Windows, version 24.0 (IBM Corp).

3 | RESULTS

Among 297 patients diagnosed with anteroseptal STEMI screened for inclusion, 128 were finally enrolled in the study. The reasons for exclusion included insufficient data, previous history of coronary events, and no available echocardiographic studies at follow-up. A total of 40 patients received primary PCI, 32 underwent rescue PCI, and 24 and 32 participants received facilitated PCI and deferred PCI, respectively. The mean age of the participants was 56.97 ± 7.15 years and 79% were male. There was no statistical difference in age ($p = 0.30$) or gender ($p = 0.40$) between groups. All the patients suffered from variations of anterior wall STEMI and the culprit lesion was left anterior descending (LAD) in all. Baseline demographics and clinical characteristics are presented in Table 1.

3.1 | Echocardiographic indices and clinical outcomes based on the reperfusion strategy

Baseline LVEF was similar across patient groups (Primary: 36.50 ± 5.21%, Rescue: 37.38 ± 2.1%, Facilitated: 37.96 ± 2.83%, Deferred: 34.19 ± 2.48%; $p = 0.10$). The primary PCI group had the highest amount of increase in LVEF in the follow-up period (15.33 ± 6.3%, $p = 0.12$ vs. rescue and $p < 0.001$ vs. facilitated PCI and deferred PCI). At 6 months of follow-up, the deferred PCI group experienced the lowest improvement in LVEF compared to other groups (−1.3 ± 6.97%, $p > 0.05$ vs. facilitated PCI and $p < 0.001$ vs. primary and rescue PCI). The LVEF changed by 4.00 ± 1.02% in the facilitated group which was statistically different compared to the primary and rescue PCI group ($p < 0.001$) (Figure 1). The baseline GLS reached from −10.02 ± 2.25% to −13.80 ± 2.61% in the total population. There was a statistically significant difference regarding

TABLE 1 Baseline characteristics of the patients.

Variables	Primary PCI (*n* = 40)	Rescue PCI (*n* = 32)	Facilitated PCI (*n* = 24)	Deferred PCI (*n* = 32)	*p*-Value
Age	56.5 ± 8.9	55.2 ± 3.2	55 ± 7.6	60.8 ± 9.5	0.30
Male gender (%)	30 (76)	26 (82)	20 (82)	25 (78)	0.40
Diabetes (%)	4 (10)	6 (19)	1(4)	5 (16)	**0.01**
Hypertension (%)	12 (30)	10 (31)	7 (29)	9 (28)	0.10
Dyslipidemia (%)	11 (28)	8 (25)	7 (29)	9 (28)	0.20
Smoking (%)	14 (35)	11 (34)	9 (38)	11 (34)	0.50
WBC (cells/microliter)	9870 ± 2291	9875 ± 1296	10,350 ± 5161	8150 ± 1870	0.06
Hemoglobin (g/dL)	13.6 ± 1.5	13.7 ± 1.0	13.8 ± 1.8	12.8 ± 1.1	0.50
Platelets (cells/mm^3)	234,500 ± 89,772	235,250 ± 51,312	184,250 ± 47,792	238,500 ± 67,487	0.01
Blood Urea Nitrogen (mg/dL)	15.7 ± 3.5	16.0 ± 1.9	21.8 ± 5.9	13.2 ± 5.7	<0.001
Creatinine (mg/dL)	1.4 ± 0.6	1.2 ± 0.2	1.0 ± 0.2	1.1 ± 0.2	0.50
Na (mmol/L)	139.1 ± 3.2	136.8 ± 3.5	141.0 ± 4.1	139.8 ± 2.6	0.06
K (mmol/L)	4.2 ± 0.4	3.9 ± 0.4	3.7 ± 0.2	4.1 ± 0.8	0.110
Systolic BP (mmHg)	134.5 ± 21.5	130.8 ± 11.9	125.5 ± 13.8	154.0 ± 12.3	0.060
Diastolic BP (mmHg)	87.0 ± 12.3	83.8 ± 12.1	75.0 ± 8.8	90.5 ± 10.0	0.070
Time to successful reperfusion[a] (min)	93.4 ± 67.2	172.4 ± 74.3	52.4 ± 16.6	45.4 ± 14.3	0.001

Note: Data are presented as mean ± SD or number (percentage). Abbreviations: BP, blood pressure; PCI, percutaneous coronary intervention; SD, standard deviation; TIMI, thrombolysis in myocardial infarction.

[a]Successful reperfusion was defined as achieving a TIMI flow III after primary or rescue PCI and resolution of chest pain accompanied by more than 75% reduction in the summation of ST-segments elevation.

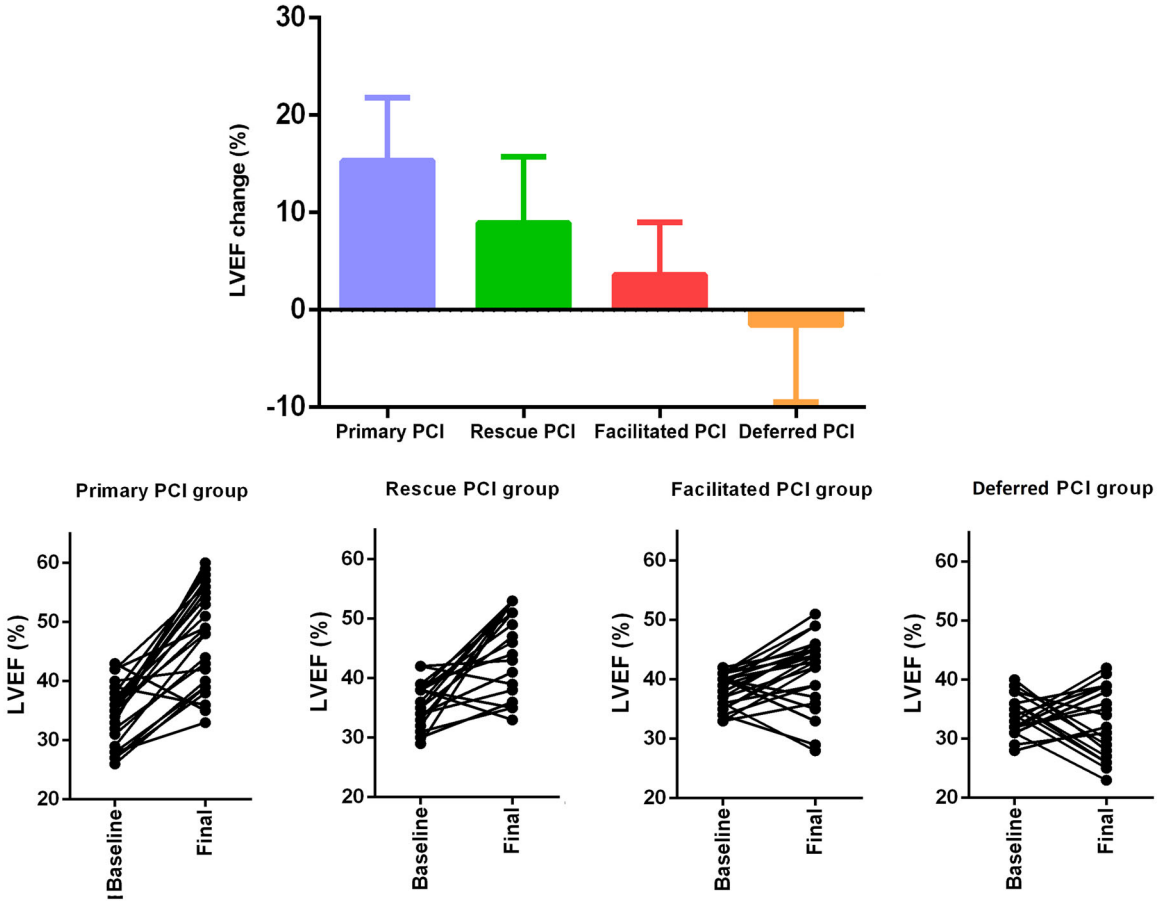

FIGURE 1 LVEF values of baseline, final, and 6-month change among the four revascularization strategies. LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention.

GLS change at 6 months following admission among groups (Primary: −4.11 ± 2.70%, Rescue: −2.91 ± 1.71%, Facilitated: −2.88 ± 0.13%, Deferred: −2.20 ± 0.72%; $p = 0.003$). The primary PCI group had a greater improvement in GLS compared to rescue and deferred PCI but not the facilitated PCI group. On the other hand, patients undergoing deferred PCI after 24 h experienced a lower amount of GLS change only compared to the primary PCI group (MD [95% CI] = 1.91 [0.42–3.41]; $p = 0.001$). The details regarding baseline and final echocardiographic indices are shown in Table 2. During the 6-month follow-up, one myocardial infarction in the facilitated PCI and two congestive heart failures in the deferred PCI group occurred.

3.2 | Predictors of ventricular function recovery

Several potential variables including baseline characteristics and comorbidities and also relevant study endpoints were used for a multivariable logistic regression analysis. The results showed that for each percent increase in baseline LVEF (OR [95% CI]: 1.12 [1.07–1.14], $p = 0.045$) and baseline GLS (OR [95% CI]: 1.19 [1.06–1.34], $p = 0.001$), the odds of significant improvement in LVEF increased by 12% and 19%, respectively. The reperfusion strategy (primary vs. deferred) (OR [95% CI]: 3.68 [1.06–12.83], $p = 0.001$) and time to reperfusion (OR [95% CI]: 2.45 [1.12–3.30], $p = 0.02$) were also among the predictors of significant LVEF increase in the follow-up (Table 3).

4 | DISCUSSION

Limited access to PCI-capable centers and delays in FMC-to-device time have brought up substantial challenges in the management of patients with STEMI as timely PCI is of paramount importance and these issues can attenuate the effectiveness of primary PCI. This inevitable delay from the time of presentation to the device time (>2 h) can be bridged by performing angioplasty preceded by administration of intravenous fibrinolytics as soon as possible.[11] Facilitated PCI is one of the promising approaches in this regard and is referred to treatment with fibrinolytic medications followed by early PCI.[12,13] ASSENT-4 PCI was a randomized clinical trial that compared tenecteplase-facilitated versus primary PCI in over 1500 patients with STEMI. The trial was terminated earlier than expected due to a significantly higher primary endpoint of death, heart failure, or shock within 90 days in the facilitated group.[14] Other individual

TABLE 2 Baseline, final, and changes of echocardiographic parameters in different treatment groups.

Variables	Primary PCI ($n = 40$)	Rescue PCI ($n = 32$)	Facilitated PCI ($n = 24$)	Deferred PCI ($n = 32$)	p-Value
LVEF (%)					
Baseline	36.5 ± 5.27	37.38 ± 2.09	37.96 ± 2.83	34.19 ± 2.48	0.10
Six months	51.83 ± 5.74	46.31 ± 6.12	41.95 ± 3.14†	32.65 ± 6.57,*†	<0.001
Change	15.33 ± 6.31	11.50 ± 3.61	4.00 ± 1.02	−1.3 ± 6.97,*†	<0.001
LVEDD (mm)					
Baseline	50.22 ± 5.05,†§	56.50 ± 5.10*	55.25 ± 3.84*	52.67 ± 8.68	<0.001
Six months	54.60 ± 4.20	54.00 ± 5.88	54.50 ± 2.75	58.50 ± 4.39,*,†§	<0.001
Change	5.22 ± 6.99,†§	−2.50 ± 5.10*	−0.75 ± 3.17*	6.33 ± 11.01,†§	<0.001
LVESD (mm)					
Baseline	34.00 ± 5.23	41.75 ± 5.29	33.56 ± 4.48	45.67 ± 4.11	<0.001
Six months	38.30 ± 4.87†	45.25 ± 11.45,*§	34.50 ± 1.53†	44.25 ± 8.07,*§	<0.001
Change	4.77 ± 6.39	3.50 ± 12.74	0.56 ± 11.2	0.66 ± 12.15	0.30
LVEDV (cc)					
Baseline	98.22 ± 22.60	100.67 ± 23.38	97.00 ± 9.63	89.33 ± 18.39	0.20
Six months	96.40 ± 26.37,†§	116.50 ± 18.87*	123.75 ± 7.65,*†	102.00 ± 18.07,†§	<0.001
Change	0.22 ± 22.05,*†	19.00 ± 13.93*	26.75 ± 7.95*	12.33 ± 27.84	<0.001
LVESV (cc)					
Baseline	56.50 ± 15.41	57.28 ± 21.65	56.57 ± 9.22	51.60 ± 9.83	0.50
Six months	46.30 ± 15.63§	53.75 ± 12.11§	67.05 ± 8.47,*†	59.00 ± 17.01*	<0.001
Change	−8.50 ± 15.96§	−1.61 ± 9.42§	10.48 ± 4.16,*†	8.73 ± 17.58*	<0.001
GLS (%)					
Baseline	−10.24 ± 2.91	−11.32 ± 1.40§	−9.37 ± 1.04,*†	−7.85 ± 0.98†	<0.001
Six months	−14.79 ± 2.70§	−14.23 ± 0.90§	−12.25 ± 1.07,*†	−13.27 ± 3.67	0.001
Change	−4.11 ± 2.70†	−2.90 ± 1.71*	−2.87 ± 0.13	−2.20 ± 0.72*	0.001

Note: Data are presented as mean ± SD. Abbreviations: GLS, global longitudinal strain; LVEDD, left ventricular end-diastolic diameter; LVEDV, left ventricular end-diastolic volume; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter; LVESV, left ventricular end-systolic volume; PCI, percutaneous coronary intervention; SD, standard deviation.

*$p < 0.05$ versus primary PCI.

†$p < 0.05$ versus rescue PCI.

§$p < 0.05$ versus facilitated PCI.

studies explored the clinical outcomes in patients with facilitated PCI and primary angioplasty and concluded that the facilitated approach can be implemented in case of limited access to primary PCI as both approaches show similar clinical outcomes.[15-17] In a randomized non-inferiority trial, a half dose alteplase plus early routine catheterization was superior to primary PCI in a composite endpoint of TIMI flow grade 3, thrombolysis in myocardial infarction myocardial perfusion grade 3, and ≥70% ST-segment resolution.[18] In a meta-analysis of randomized studies comparing prehospital fibrinolysis and following PCI with primary PCI alone, primary clinical outcomes including short- and long-term mortality and occurrence of myocardial infarction were the same between studied groups although the rate of stroke was higher in the group with pre-hospital fibrinolysis.[19] Another meta-analysis conducted by Fazel et al. revealed that among the various treatment options for STEMI, primary PCI demonstrated the lowest rates of adverse clinical outcomes. Furthermore, the findings indicated that the reinfarction rates of the pharmaco-invasive (defined as fibrinolysis followed by PCI 2–24 h after) and facilitated (defined as fibrinolysis followed by PCI within 2 h) approach were significantly lower than fibrinolysis alone but the mortality data were not different.[20]

Although the majority of the studies on this topic have widely compared clinical outcomes between primary angioplasty and alternative approaches in case of limitation for PCI, scant data are available comparing echocardiographic indices between different reperfusion strategies. In this study, we sought to investigate the

TABLE 3 Multivariable logistic regression analysis showing predictors of a significant improvement in LVEF (≥5% increase) in the follow-up visit.

Variable	OR	95% CI	*p*-Value
Age	1.037	0.780–1.043	0.30
Gender, male	1.564	0.650–2.888	0.60
Diabetes Mellitus	0.890	0.640–1.252	0.07
Smoking	1.588	0.875–2.881	0.07
Baseline LVEF	1.118	1.070–1.144	0.04
Baseline GLS	1.193	1.060–1.342	0.001
Reperfusion strategy	3.680	1.055–12.833	0.001
Time to reperfusion	2.454	1.123–3.291	0.02

Abbreviations: CI, confidence interval; GLS, global longitudinal strain; LVEF, left-ventricular ejection fraction; OR, odds ratio.

changes in echocardiographic indices across different reperfusion strategies. In our experience, all the included groups had a significant improvement in LVEF at 6 months except patients treated with thrombolytics who underwent PCI after 24 h of presentation (deferred PCI). The improvements in LVEF were similar among primary, rescue, and facilitated PCI groups and significantly higher than deferred PCI. It should be mentioned that the primary PCI group showed the most promising results (+15% recovery in LVEF) compared to other alternatives. This finding is in accordance with the results of the previously mentioned meta-analysis [20] showing the most favorable clinical outcomes in patients undergoing primary PCI and one can conclude that higher improvement in LVEF in the primary group may be translated into better clinical outcomes in the future. The change in GLS at 6 months was also significantly higher in the primary PCI group when compared to the deferred PCI group. Based on our results, it appears that performing emergent PCI after a failed response to thrombolytics and a facilitated PCI (thrombolytic therapy and performing PCI within 24 h) are both effective alternatives to primary PCI although primary PCI remains the most effective approach. It may be implied that in case of limited access to timely PCI, coronary angioplasty should be performed even after fibrinolytic therapy regardless of the results. Our findings also confirm that widening the time window from FMC to device time up to 24 h may be reasonable after administering thrombolytics in case of logistical problems and possible time delays. Consistent with our results, a study on 212 STEMI patients demonstrated that there were no differences in 6-month LVEF between patients with primary PCI and the ones undergoing routine angioplasty up to 12 h after fibrinolytic therapy.[7] In a study of 237 participants with acute STEMI, patients were classified in two groups of primary PCI and fibrinolytics followed by rescue or facilitated PCI. The results showed similar mortality and final LVEF compared between the groups.[21] Consistent with this study, the improvement in LVEF was similar between primary, rescue, and facilitated PCI in our study. We included patients with deferred PCI as well and found that deferred PCI could not improve LVEF after 6 months compared with the other three groups. Our results further showed that although baseline characteristics and comorbidities including age, sex, diabetes, and smoking status could not predict the ventricular recovery, patients with higher baseline LVEF and GLS were more likely to have ventricular recovery. Also, the type of reperfusion strategy showed a great association with 6-month recovery (OR: 3.68). It is noteworthy that since LVEF is among the strong predictors of adverse events in patients with myocardial infarction,[22] one can conclude that when primary PCI is not available promptly and delays are inevitable, rescue and facilitated PCI are both effective alternatives and may yield similar improvement in echocardiographic indices and hence, clinical outcomes.

In patients undergoing deferred PCI, no LVEF recovery was observed in the follow-up period (mean change: −1.3 ± 6.97%). Contrary to this group, all the other three groups (primary, rescue, and facilitated group) had at least modest LVEF recovery. It has been shown that patients with a first occurrence of myocardial infarction and no improvement in LVEF have a greater chance of presenting with sudden cardiac death, all-cause death, and cardiac-related mortality than patients with modest (1%–9%) or large (≥10%) LVEF recovery in the long-term follow-up.[23] One can conclude that in our study, patients with no ventricular function recovery may be more susceptible to adverse clinical outcomes than other groups in the future. As a result, expected delays of more than 24 h for PCI following fibrinolytic therapy may be associated with poor outcomes after acute myocardial infarction.

As a limitation of this study, we were not able to track the bleeding data during the follow-up period. This could help us have a better understanding to see if similar results regarding changes in echocardiographic indices that could be translated into similar clinical outcomes. Another limitation of this study was the absence of randomization. Subsequent investigations should consider implementing multi-centered randomized clinical trials. However, it is important to acknowledge that conducting such studies may not be ethically feasible in centers where primary PCI is available. In our center, as primary PCI was not feasible for all the patients, the selection of the four options was based on the available facilities. Nevertheless, in our study, the initial and pre-PCI variables about patients, such as age, gender, prevalence of underlying diseases, and initial LVEF, did not exhibit significant differences among the four groups. Data on peak creatine kinase and details regarding complete revascularization were not available and this could have potential impacts on the measured endpoints.

5 | CONCLUSION

Primary PCI demonstrated the most promising results in left ventricular function recovery after STEMI. Delays in performing primary PCI for patients with STEMI are inevitable in real-world practice. In this regard, administering fibrinolytics before coronary angioplasty appears as a feasible and effective alternative. We

concluded that based on health care facilities and availability of PCI-capable centers, widening the window between the presentation of STEMI and device time up to 24 h preceded by immediate administration of fibrinolytics (facilitated PCI) may be an effective alternative although primary PCI remains the most promising revascularization strategy. Also, a delay from FMC to device time of more than 24 h (deferred PCI) was associated with a significantly lower LVEF recovery when compared to primary and rescue PCI. Baseline LVEF, initial GLS, and type of reperfusion strategy could independently predict 6-month ventricular recovery. Future studies should focus on echocardiographic indices and clinical outcomes concomitantly to observe if improvements in echocardiographic indices of STEMI patients are consistent with future adverse clinical outcomes across different reperfusion strategies.

AUTHOR CONTRIBUTIONS

Armin Attar: Conceptualization; methodology; writing—review and editing; formal analysis; data curation; software; supervision; funding acquisition; visualization; project administration. **Soheila Namvar**: Conceptualization; investigation; data curation. **Alireza Hosseinpour**: Data curation; writing—original draft; writing—review and editing; visualization. **Pouria Azami**: Writing—original draft. **Arash Shekari**: Writing—original draft. **Leila Jamali**: Writing—original draft. **Neda Goudarzi**: Writing—original draft. All authors have read and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The corresponding author had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

The lead author Alireza Hosseinpour affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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