International Journal of Life Sciences, Biotechnology and Pharma Research Vol. 14, No. 3, March 2025 Online ISSN: 2250-3137
Print ISSN: 2977-0122

DOI: 10.69605/ijlbpr_14.3.2025.116

ORIGINAL RESEARCH

Echocardiographic recovery after delayed revascularization: evaluating EF and GLS improvements

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Received: 22 January, 2025 Accepted: 21 February, 2025 Published: 13 March, 2025

ABSTRACT

Background: Delayed percutaneous coronary intervention (PCI) in non–ST-segment elevation myocardial infarction (NSTEMI) patients is often performed beyond 24 hours after the index event for various clinical reasons. Echocardiographic parameters, particularly Ejection Fraction (EF) and Global Longitudinal Strain (GLS), can provide valuable insights into left ventricular (LV) functional recovery. However, the extent of EF and GLS improvement in patients undergoing delayed revascularization remains unclear. **Methods:** This prospective observational study included 120 NSTEMI patients who underwent PCI more than 24 hours after the index event. Baseline demographic data, clinical characteristics, and risk factors were recorded. EF and GLS were assessed by two-dimensional echocardiography both pre- and post-revascularization. Data were analyzed using SPSS v21, with normality tested by Kolmogorov–Smirnov. Comparisons of pre- and post-PCI EF and GLS were done using Wilcoxon signed-rank test, and Pearson correlation coefficients were calculated as appropriate. **Results:** Mean (SD) pre-PCI EF was 39.0% (9.8), increasing to 41.7% (8.96) post-PCI. Improvement in EF was significantly higher among those who underwent PCI earlier (24–48 hours post-event) compared to those who had PCI later ($p<0.05$). GLS scores also showed statistically significant improvement ($p<0.05$), with over 90% of patients who had low or very low GLS at baseline demonstrating substantial recovery post-PCI. Mortality was 4.17%, highlighting the relatively favorable outcomes with delayed revascularization in a carefully selected population. **Conclusion:** Delayed PCI (beyond 24 hours) in NSTEMI patients can still result in meaningful echocardiographic recovery, as evidenced by improvements in EF and GLS. Earlier delayed intervention (within 24–48 hours) was associated with better functional outcomes. Larger, multicenter studies are needed to refine the optimal "delayed" window for intervention based on echocardiographic recovery profiles.

Keywords: Delayed PCI, Echocardiography, Ejection Fraction, Global Longitudinal Strain, NSTEMI

INTRODUCTION

Left ventricular function is one of the most critical determinants of prognosis after an acute coronary syndromes event, including a non–ST-segment elevation myocardial infarction, NSTEMI [1]. Early percutaneous coronary intervention (PCI) is strongly encouraged for ST-elevation myocardial infarction and high-risk NSTEMI. However, a significant number of patients experience revascularization beyond 24 hours because of logistical reasons, late presentation, or indeterminate clinical and anatomical findings [2]. In such scenarios, the potential for myocardial salvage and subsequent functional recovery could be partially preserved, yet it is not as clearly established as in early revascularization [3].

The evaluation of cardiac function following revascularization has traditionally centered on the left ventricular ejection fraction (EF). More recently, Global Longitudinal Strain (GLS) has emerged as a robust and sensitive marker of early systolic dysfunction and recovery [4]. GLS reflects the percentage of myocardial deformation in the longitudinal axis and typically demonstrates subtle alterations in myocardial contractility before EF declines [5]. The improvement in GLS after an intervention is associated with reversal of myocardial dysfunction or "stunned" myocardium, potentially correlating with better clinical results [6].

However, intuitively, sooner is better; yet, a proportion of NSTEMI patients undergo revascularization beyond 24 hours [7]. Such delays may be due to late hospital arrival, hemodynamic stability prompting to conservative management, or may even pose a challenge in diagnosing culprit

DOI: 10.69605/ijlbpr_14.3.2025.116

lesions through initial investigations. The question remains whether such a delay precludes functional recovery. If significant improvement in EF and GLS is still possible with delayed PCI, it may offer clinicians more flexibility in risk stratification and timing of procedures [8]. Moreover, quantifying the magnitude of recovery in EF and GLS can guide long-term management strategies, including the need for cardioprotective medications and cardiac rehabilitation [5].
This study aims to delineate the extent of EF and GLS recovery in NSTEMI patients undergoing delayed PCI more than 24 hours after the index event. We hypothesized that although the recovery may not be as robust as that seen in early revascularization, significant functional gains could still be observed, offering these patients a tangible benefit. By capturing detailed echocardiographic parameters pre- and post-PCI, we hope to elucidate whether delayed PCI remains a viable strategy for preserving LV function and improving clinical outcomes in selected patients.

MATERIALS AND METHODS

Study Design and Period

A prospective observational study was conducted between April 2021 and December 2022. All participants provided informed consent. The study was approved by the institutional ethics committee.

Sample Size and Population

A total of 120 patients were enrolled based on:

- **Inclusion Criteria**
  - Diagnosed with NSTEMI ≥24 hours after symptom onset.
  - Underwent PCI for the infarct-related artery (IRA) more than 24 hours from the index event.
- **Exclusion Criteria**
  - Patients with acute STEMI.
  - Patients on mechanical ventilator support and those in Killip Class IV.

Data Collection Tools

A structured proforma was used to record:

- Demographics (age, sex)
- Medical history, including comorbidities (hypertension, diabetes)
- Risk factors (smoking, obesity, dyslipidemia)
- Clinical presentation (chest pain, dyspnea, etc.)
- 12-lead ECG findings
- General and cardiac examinations
- Echocardiographic measurements (EF and GLS) pre- and post-revascularization

Procedures

- **PCI Procedure:** Standard PCI using drug-eluting stents was performed as per institutional protocol. The decision for PCI timing was determined by the treating cardiologist based on clinical urgency, availability of catheterization facilities, and patient stability.
- **Echocardiographic Assessment:** 2D echocardiography was conducted using a commercially available ultrasound system. EF was calculated using the biplane Simpson's method. GLS was derived using vendor-specific software for speckle-tracking echocardiography.
- **Follow-up Assessments:** Echocardiographic studies were repeated at least once after the PCI (usually within 4–6 weeks) to assess changes in EF and GLS. Clinical outcomes, readmissions, and mortality data were also recorded.

Statistical Analysis

Data were coded into Microsoft Excel 2013 and analyzed using SPSS version 21 (IBM Corp., Armonk, NY). Continuous variables were checked for normality using the Kolmogorov–Smirnov test. Comparisons between pre- and post-PCI EF and GLS were performed using paired t-tests or the Wilcoxon signed-rank test, as appropriate. Correlations were examined using Pearson's correlation coefficients. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Overall Demographics and Clinical Presentation

A total of 120 NSTEMI patients undergoing PCI beyond 24 hours were analyzed. The mean age was 57.03±9.67 years, with the majority (34.2%) in the 61–70 year age group. Males constituted 88.33% of the study population (Table 1). Common symptoms included angina (95.83%), dyspnea (35%), and perspiration (31.67%). Hypertension and diabetes were prevalent in 45% and 49.17% of patients, respectively. Smoking history was also notable (52.5%) (Table 2).

Table 1. Age and Gender Distribution of Patients

Variable	Categories	n	%
Age (years)	<40	4	3.3%
	41–50	31	25.8%
	51–60	37	30.8%
	61–70	41	34.2%
	71–80	6	5.0%
	>80	1	0.8%
Gender	Male	106	88.3%
	Female	14	11.7%

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Table 2. Risk Factors in the Study Population

Risk Factor	n	%
Diabetes	59	49.17%
Hypertension	54	45.00%
Dyslipidemia	20	16.67%
Obesity	35	29.17%
Current Smoke	63	52.50%

EF Improvements After Delayed PCI

Pre-procedure EF ranged from 25% to 50% with a mean of 39.0±9.8%. Following revascularization, the mean EF improved to 41.7±8.96%. Patients who underwent PCI earlier (24–48 hours) demonstrated a significantly higher rate of EF improvement (88.24%) compared to those who underwent PCI at a later interval (>72 hours). Moreover, EF improved more prominently in those with higher baseline EF (≥45%) (Table 3).

Table 3. Changes in LV Ejection Fraction (EF) Before and After PCI

EF Category	Pre-PCI (n=120)	Improved, n (%)	Not Improved, n (%)
<30%	15	5 (33.33)	10 (66.67)
30–<45%	55	28 (50.91)	27 (49.09)
≥45%	50	42 (84.00)	8 (16.00)

GLS Improvements

Global Longitudinal Strain (GLS) was categorized into good (> –20%), borderline (–15% to –20%), low (–10% to –15%), and very low (< –10%). Post-PCI assessment revealed significant recovery across all categories, with borderline and low GLS groups exhibiting nearly 97% improvement. Even the "very low" GLS group had a remarkable 90.7% rate of improvement (Table 4).

Table 4. Comparison of Pre- and Post-PCI GLS Scores

GLS Category	Pre-PCI, n (%)	Improved, n (%)	Not Improved, n (%)
Good (> –20%)	4 (3.33)	3 (75.00)	1 (25.00)
Borderline (–15%—20%)	34 (28.33)	33 (97.06)	1 (2.94)
Low (–10%—15%)	39 (32.50)	38 (97.44)	1 (2.56)
Very Low (< –10%)	43 (35.80)	39 (90.70)	4 (9.30)

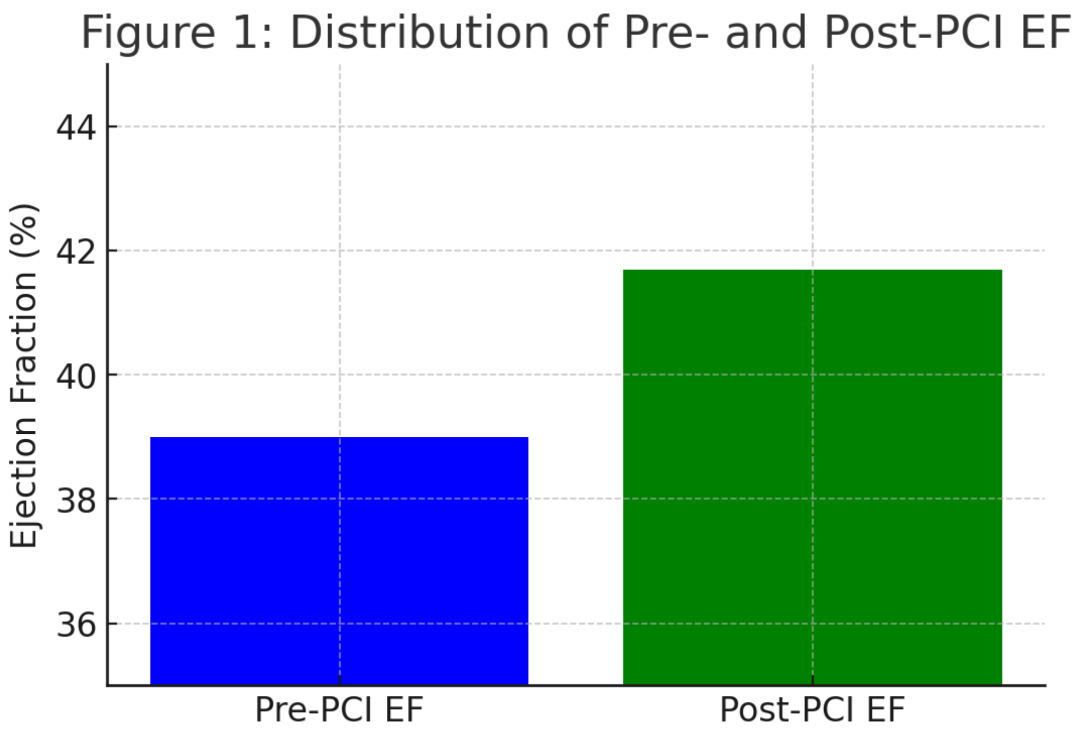

Figure 1. Distribution of Pre- and Post-PCI EF

(A bar or line chart illustrating average EF improvement from 39% to 41.7%.)

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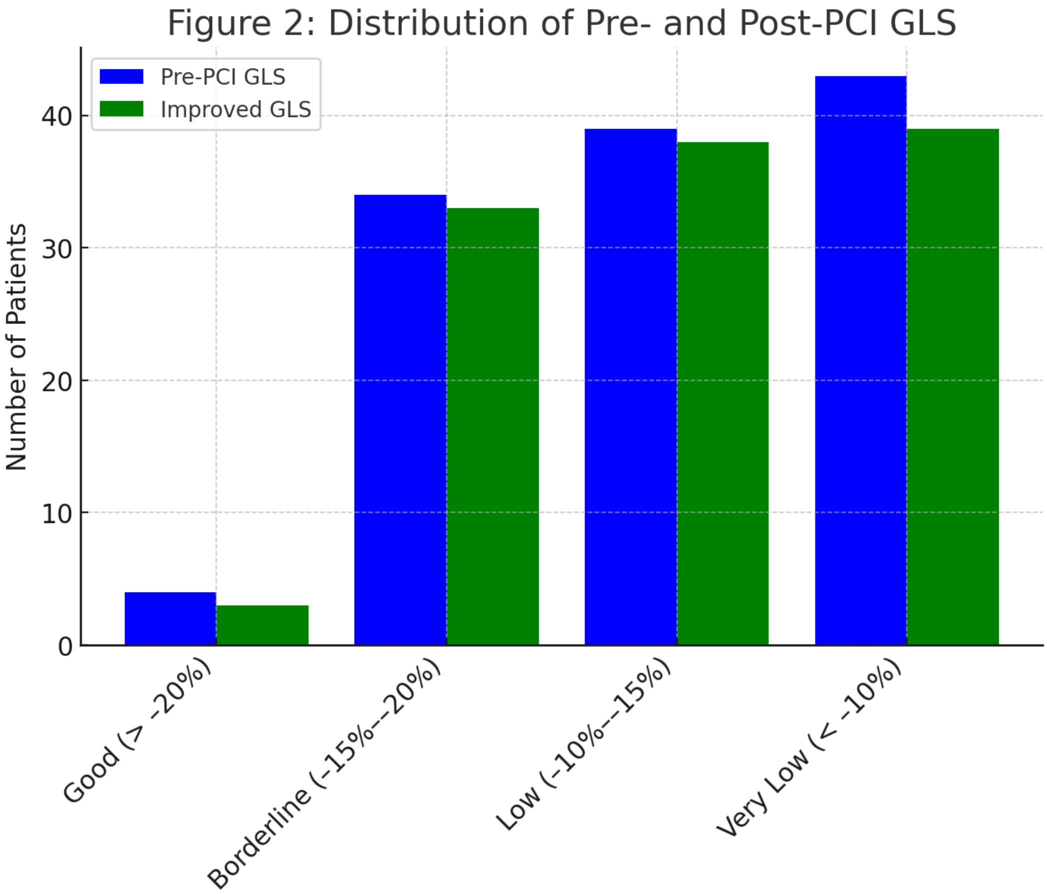

Figure 2. Distribution of Pre- and Post-PCI GLS

(A chart illustrating the shift of GLS scores from borderline/low/very low to improved categories.)

DISCUSSION

Improvement in left ventricular function after delayed PCI has gained more attention as the world population of patients with ACS increases [9]. Our results show a significant improvement in both EF and GLS even when revascularization is done beyond the first 24 hours. These findings indicate that a portion of the myocardium remains viable, or at least "stunned," and can recover function with delayed reperfusion [10]. This is consistent with previous observations that viable myocardial segments, although hibernating or stunned, can regain contractility once blood flow is restored [11].

The relatively greater improvement in GLS, as compared to EF, underscores the sensitivity of strain imaging. Several studies have indicated that strain parameters may detect subclinical changes earlier than EF, making GLS a more robust index of early recovery [12]. Our study corroborates these findings: borderline and low GLS groups showed near-complete improvement in over 90% of cases. This emphasizes the potential of speckle-tracking echocardiography as a valuable adjunct in the follow-up of patients with late revascularization [13].

Timing is still an important factor. Patients who had PCI within 24 hours of symptom onset showed more significant improvements. Delays longer than 72 hours were associated with significantly lower, though still significant, EF and GLS gains [14]. These findings are consistent with previous work showing that while "time is muscle," salvage can still be meaningful beyond the traditionally defined window if the myocardium is not fully necrotic [15].

Nevertheless, not all patients benefited equally, as those with significantly reduced EF (<30%) at baseline demonstrated only modest improvements post-PCI. Additionally, the modest mortality rate (4.17%) suggests that delayed PCI in a carefully selected NSTEMI population may confer a reasonable safety profile, further supporting its utility [16]. Taken together, these findings support the notion that delayed PCI can improve LV function, particularly for patients whose coronary anatomy and clinical status allow a window of opportunity. Future research should focus on elucidating the molecular and hemodynamic factors that differentiate patients who respond favorably from those who do not, and on optimizing post-revascularization medical therapy to maximize recovery in myocardial function.

CONCLUSION

In this prospective observational study of NSTEMI patients undergoing PCI beyond 24 hours, significant improvement in both EF and GLS was observed. Earlier delayed intervention (24–48 hours) yielded the best functional outcomes, while substantial gains were

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still noted in later presenters. These findings emphasize the fact that if early revascularization cannot be achieved, PCI remains a very viable option as long as careful risk stratification, viability assessment, and extensive follow-up take place. There is a necessity for larger prospective studies to improve the optimal delay window for late PCI and provide personalized treatment in late-presenting NSTEMI patients.

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