RESEARCH PAPER

Assessment of Global Longitudinal Strain in Chronic Stable Angina Patients with Preserved Left Ventricular Function Before and After Percutaneous Coronary Intervention: A Prospective Observational Study

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Abstract

Background: Left ventricular ejection fraction (LVEF) frequently fails to detect subclinical myocardial dysfunction in chronic stable angina (CSA) patients with preserved systolic function. Global Longitudinal Strain (GLS), derived from two-dimensional speckle-tracking echocardiography (2D-STE), offers a more sensitive assessment of myocardial deformation. This study evaluated changes in GLS before and after percutaneous coronary intervention (PCI) in CSA patients with preserved LVEF.

Methods: A prospective observational study enrolled 30 patients with CSA and preserved LVEF (≥50%) scheduled for elective PCI at a tertiary care hospital. Transthoracic echocardiography measuring LVEF (Simpson's biplane) and GLS (2D-STE) was performed at baseline and at one and three months post-PCI. Coronary angiographic findings were documented; MACE was monitored for three months.

Results: Mean age was 59.87 ± 8.7 years; 73.3% were male. Diabetes (60%), hypertension (66.7%), and dyslipidemia (56.7%) were prevalent. Despite preserved baseline LVEF (56.8 ± 3.2%), mean GLS was significantly impaired at −15.72 ± 1.46%. Following PCI, GLS improved significantly to −17.36 ± 1.47% ($p < 0.001$), while LVEF remained unchanged (57.1 ± 3.0%; $p = 0.42$). Single-vessel disease predominated (53.3%); the LAD was the most involved vessel (66.7%). MACE occurred in 10% of patients at three months.

Conclusion: GLS detects subclinical myocardial dysfunction not reflected by LVEF in CSA patients and improves significantly following successful PCI. GLS should be integrated into routine echocardiographic evaluation for early detection of ischemia and assessment of revascularization efficacy.

Keywords: *Global Longitudinal Strain, chronic stable angina, percutaneous coronary intervention, speckle-tracking echocardiography, subclinical myocardial dysfunction, preserved ejection fraction, India*.

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1. Introduction

Coronary artery disease (CAD) remains the leading cause of cardiovascular morbidity and mortality worldwide, responsible for an estimated 17.9 million deaths annually [1]. In India, the burden is rising rapidly, driven by increasing prevalence of type 2 diabetes mellitus, hypertension, dyslipidemia, and tobacco use, with ischemic heart disease contributing to over 28% of adult mortality in urban populations [2]. Chronic stable angina (CSA), a prevalent manifestation of CAD, is characterized by exertional chest discomfort relieved by rest or nitrates, reflecting a fixed imbalance between myocardial oxygen demand and coronary perfusion [3]. Despite significant coronary stenosis, a substantial proportion of CSA patients maintain preserved LVEF, leading to underestimation of myocardial dysfunction when conventional echocardiography is the sole assessment tool [4], [5]. LVEF is inherently limited it is volumetric, highly load-dependent, and insensitive to early or regional systolic dysfunction, particularly in the

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subendocardial longitudinal fibers that are first affected by ischemia [6]. These limitations result in delayed identification of patients who may benefit from timely revascularization [7].

Two-dimensional speckle-tracking echocardiography (2D-STE) has emerged as a robust advancement in cardiac imaging, enabling quantitative assessment of myocardial deformation through tracking of natural acoustic speckles within the myocardium across consecutive frames (Figure 1) [8]. Global Longitudinal Strain (GLS) the most clinically validated parameter of 2D-STE measures the percentage of longitudinal shortening of myocardial fibers during systole, with normal values ranging from −18% to −22% [9]. Unlike LVEF, GLS is angle-independent, reproducible across vendor platforms, and capable of unmasking subclinical systolic dysfunction in patients with preserved EF [4], [10].

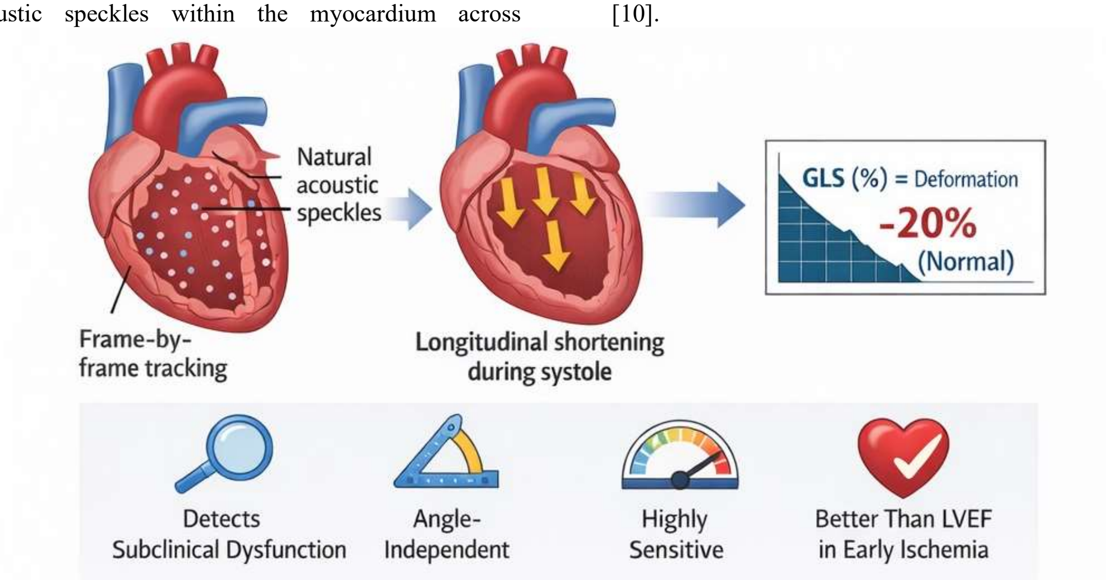

Figure 1. Mechanism of speckle-tracking echocardiography and clinical advantages of Global Longitudinal Strain (GLS).

Multiple studies have established the superiority of GLS over LVEF in identifying early myocardial dysfunction in CAD patients with preserved EF (Figure 2). Abdelrazek et al. demonstrated a significant inverse correlation between GLS and SYNTAX score in stable angina patients, with a GLS threshold of −17.8% predicting high angiographic disease burden [7]. Yılmaztepe and Uçar reported that a GLS cutoff of −18% identified obstructive CAD with 80% sensitivity and 85% specificity in patients with normal wall motion [11]. Importantly, post-PCI GLS improvement has been shown to be a sensitive indicator of myocardial reperfusion and functional recovery, while LVEF may remain unchanged in the same patients [12], [13].

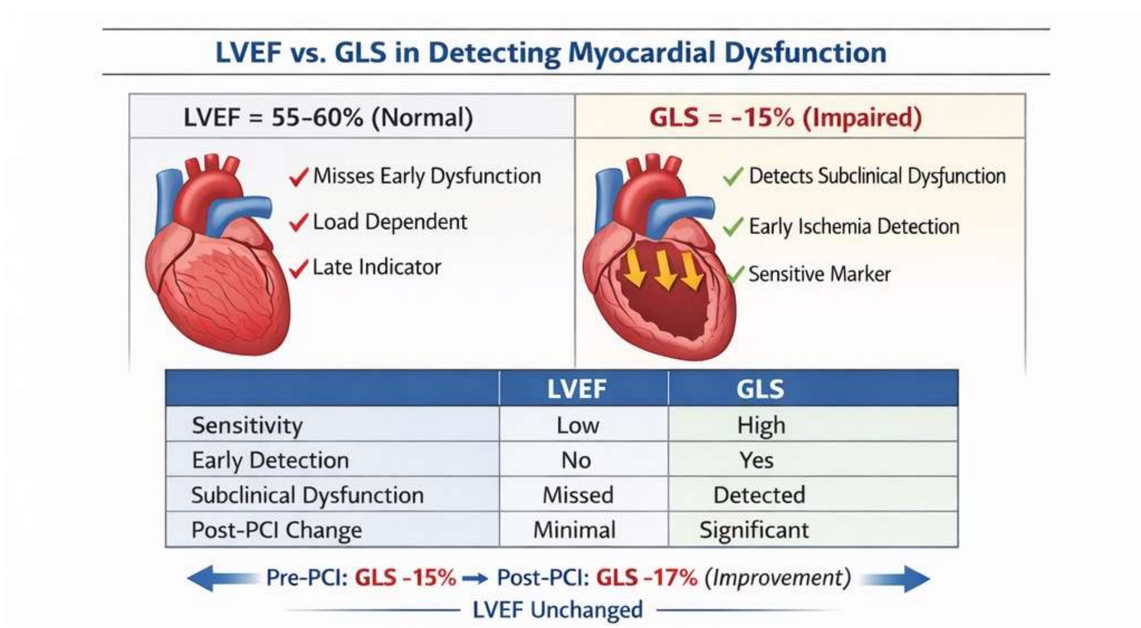

Figure 2. Comparative characteristics of LVEF and GLS in the detection of myocardial dysfunction in chronic stable angina.

Despite compelling international evidence, the adoption of GLS in routine clinical practice remains limited in India, particularly in resource-constrained settings. Indigenous data on GLS utility in CSA patients undergoing PCI are scarce [14]. The present study was therefore designed to evaluate GLS as a sensitive marker of subclinical myocardial dysfunction and a quantitative tool to assess functional recovery following elective PCI in CSA patients with preserved LVEF at an Indian tertiary care hospital.

2. Materials and Methods

2.1 Study Design, Setting, and Duration

This was a prospective, observational study conducted over three months at a tertiary care hospital with facilities for elective PCI and advanced echocardiographic imaging, including 2D speckle-tracking strain analysis. The study was conducted in accordance with institutional ethical guidelines; written informed consent was obtained from all participants.

2.2 Participants

Adult patients aged 18–75 years with a diagnosis of chronic stable angina, preserved LVEF (≥50%), and angiographically confirmed significant coronary artery stenosis (≥70% in at least one major vessel) who were scheduled for elective PCI were enrolled. Patients were excluded if they had a history of acute coronary syndrome within the preceding three months, prior myocardial infarction or coronary revascularization (PCI or CABG), known cardiomyopathy (hypertrophic, dilated, or restrictive), poor echocardiographic window precluding reliable strain measurement, or any contraindication to PCI. A total of 30 patients were enrolled as a pilot study to assess feasibility and preliminary outcomes.

2.3 Procedures and Outcome Measures

At enrollment, all participants underwent clinical assessment including Canadian Cardiovascular Society (CCS) angina classification, transthoracic echocardiography (LVEF by Simpson's biplane method and GLS by 2D-STE from apical views), and diagnostic coronary angiography. Elective PCI with drug-eluting stent placement was subsequently performed by experienced interventional cardiologists. Echocardiographic evaluation was repeated at one and three months post-PCI using identical equipment and protocols. The primary outcome was change in GLS from baseline to post-PCI. Secondary outcomes included change in LVEF, CCS class improvement, correlation of regional GLS changes with angiographic lesion territory, and incidence of major adverse cardiovascular events (MACE composite of all-cause mortality, non-fatal myocardial infarction, and unplanned target vessel revascularization) at three months.

2.4 Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD) and compared using the paired Student's t-test or Wilcoxon signed-rank test. Categorical variables were presented as frequencies and percentages; the chi-square or Fisher's exact test was applied as appropriate. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Demographic and Baseline Characteristics

A total of 30 patients with CSA and preserved LVEF were enrolled. The mean age was 59.87 ± 8.7 years, with the majority (46.7%) in the 51–60 year age group (Table 1, Figure 3). Male patients predominated at 73.3% (n = 22) (Table 2, Figure 4). Based on the Modified Kuppuswamy Scale, most participants belonged to the upper lower (Class IV; 40%) and lower middle (Class III; 33.3%) socioeconomic strata (Table 3, Figure 5), reflecting the demographic profile of a public-sector tertiary care setting.

Table 1. Age Distribution of Study Participants (n = 30)

Age Group (Years)	No. of Patients	Percentage (%)
41–50	4	13.3%
51–60	14	46.7%
61–70	8	26.7%
71–75	4	13.3%
Total	**30**	**100%**

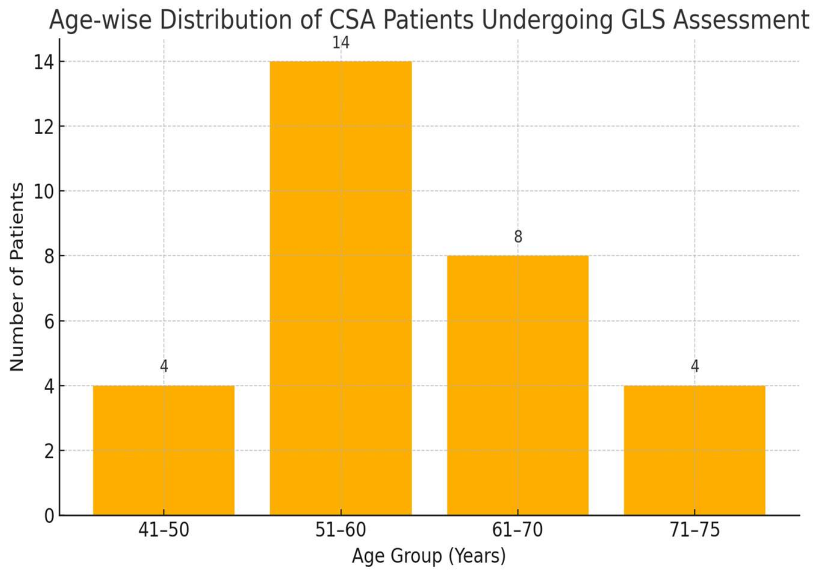

Figure 3. Age distribution of study participants. The 51–60 year group was the most prevalent (46.7%).

Table 2. Gender Distribution (n = 30)

Gender	No. of Patients	Percentage (%)
Male	22	73.3%
Female	8	26.7%
Total	**30**	**100%**

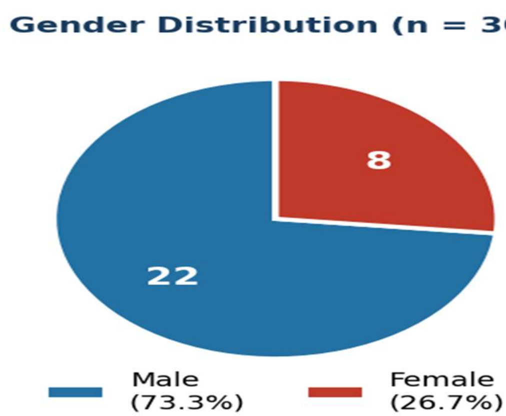

Figure 4. Gender distribution male predominance (73.3%) consistent with CSA epidemiology.

Table 3. Socioeconomic Status Modified Kuppuswamy Scale (n = 30)

Socioeconomic Class	No. of Patients	Percentage (%)
Upper Middle (Class II)	4	13.3%
Lower Middle (Class III)	10	33.3%
Upper Lower (Class IV)	12	40.0%
Lower (Class V)	4	13.3%
Total	**30**	**100%**

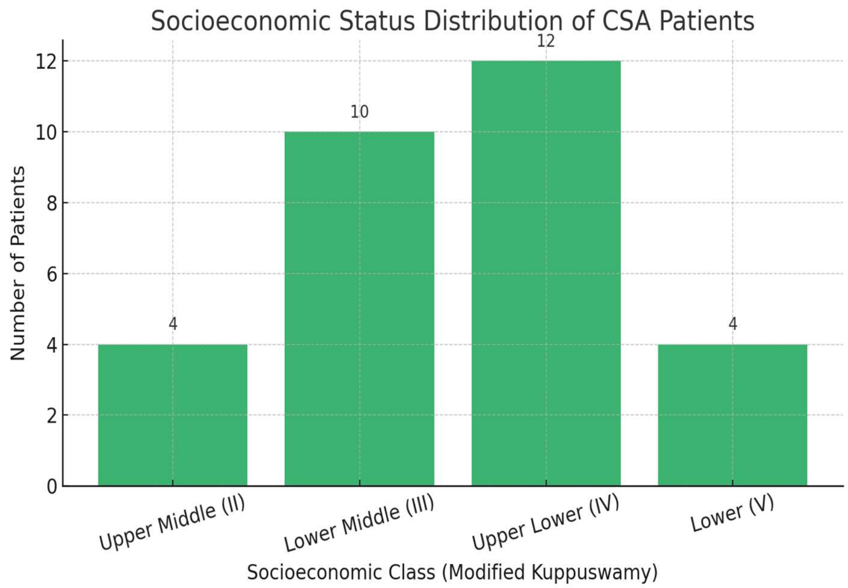

Figure 5. Socioeconomic status distribution majority from upper lower and lower middle classes.

3.2 Cardiovascular Risk Factors and Comorbidities

Diabetes mellitus was present in 60% (n = 18), hypertension in 66.7% (n = 20), and dyslipidemia in 56.7% (n = 17). Smoking history was recorded in 33.3% (n = 10), and 26.7% (n = 8) reported alcohol consumption (Table 4, Figure 6). The high prevalence of diabetes and hypertension in this cohort reflects the established association of these risk factors with accelerated atherosclerosis and subclinical myocardial dysfunction, even in the presence of preserved EF.

Table 4. Cardiovascular Risk Factors and Comorbidities (n = 30)

Risk Factor / Comorbidity	No. of Patients	Percentage (%)
Diabetes Mellitus	18	60.0%
Hypertension	20	66.7%
Dyslipidemia	17	56.7%
Smoking	10	33.3%
Alcohol Consumption	8	26.7%

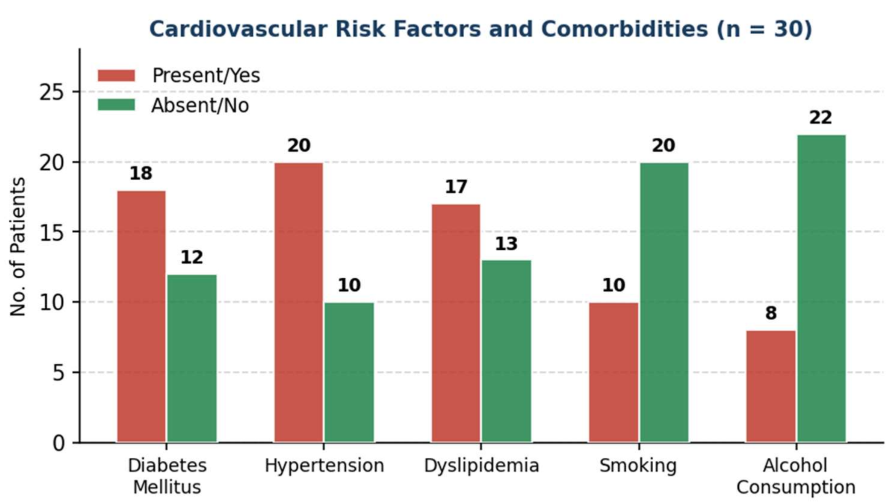

Figure 6. Prevalence of cardiovascular risk factors and comorbidities among CSA patients (n = 30).

3.3 Coronary Angiographic Findings

All 30 patients underwent diagnostic coronary angiography prior to PCI. Single-vessel disease (SVD) was the most common finding (53.3%, n = 16), followed by double-vessel disease (DVD; 30.0%, n = 9) and triple-vessel disease (TVD; 16.7%, n = 5) (Table 5, Figure 7). The left anterior descending (LAD) artery was the most frequently involved vessel

(66.7%), followed by the right coronary artery (RCA; 20.0%) and left circumflex (LCX; 13.3%). Lesion morphology per the ACC/AHA classification was predominantly Type B1 (40%) and Type B2 (36.7%) (Table 5, Figure 8).

Table 5. Coronary Angiographic Findings (n = 30)

Parameter	No. of Patients	Percentage (%)
Vessel Involvement		
Single Vessel Disease (SVD)	16	53.3%
Double Vessel Disease (DVD)	9	30.0%
Triple Vessel Disease (TVD)	5	16.7%
Most Frequently Involved Vessel		
Left Anterior Descending (LAD)	20	66.7%
Right Coronary Artery (RCA)	6	20.0%
Left Circumflex (LCX)	4	13.3%
Lesion Morphology (ACC/AHA)		
Type A	3	10.0%
Type B1	12	40.0%
Type B2	11	36.7%
Type C	4	13.3%

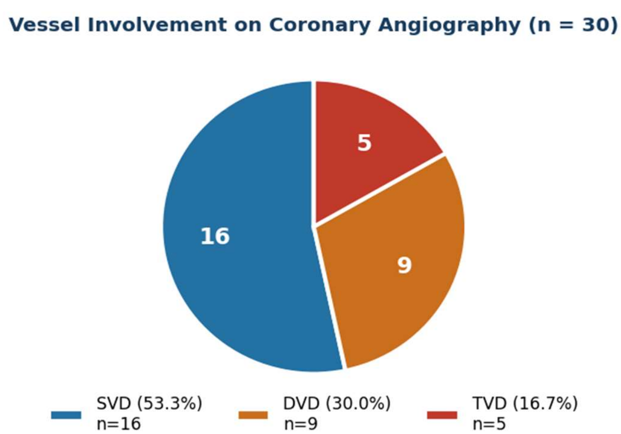

Figure 7. Distribution of vessel involvement on coronary angiography (SVD predominant, 53.3%).

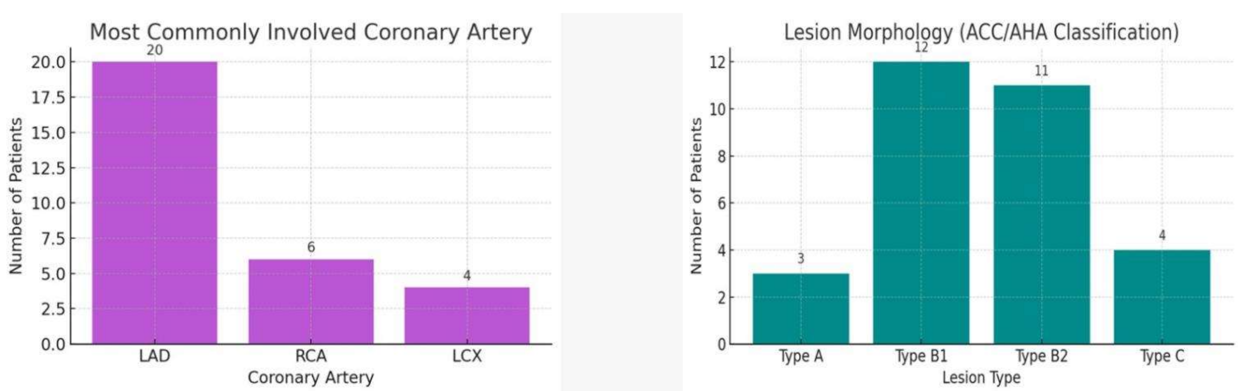

Figure 8. Most frequently involved coronary vessel (left) and ACC/AHA lesion morphology classification (right).

3.4 Echocardiographic Outcomes — LVEF and GLS Before vs. After PCI

The primary echocardiographic findings are summarized in Table 6. At baseline, all patients maintained preserved LVEF (mean 56.8 ± 3.2%), consistent with the inclusion criteria. However, mean GLS was significantly impaired at −15.72 ± 1.46%, indicating subclinical myocardial dysfunction not reflected by conventional systolic parameters.

Following PCI, mean GLS improved significantly to −17.36 ± 1.47% ($p < 0.001$), reflecting recovery of longitudinal myocardial contractility. In contrast, mean LVEF showed no statistically significant change (57.1 ± 3.0%; $p = 0.42$). This discordance between GLS improvement and LVEF stability highlights the superior sensitivity of GLS in detecting early post-revascularization functional recovery (Figures 9, 10, and 11).

Table 6. Echocardiographic Parameters — Baseline vs. Post-PCI (n = 30)

Parameter	Baseline (Mean ± SD)	Post-PCI (Mean ± SD)	Change	p-Value
LVEF (%)	56.8 ± 3.2	57.1 ± 3.0	+0.3%	0.42 (NS)
GLS (%)	−15.72 ± 1.46	−17.36 ± 1.47	**−1.64%**	< 0.001*

**p < 0.05 is statistically significant; NS = Not Significant. More negative GLS values indicate better longitudinal contractility.*

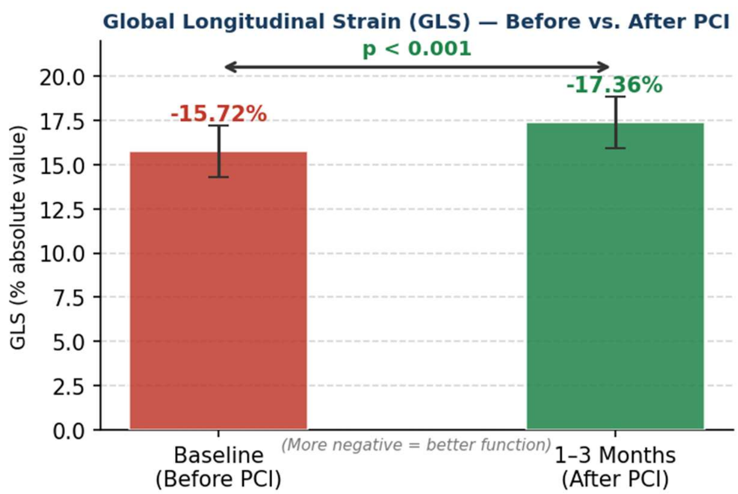

Figure 9. Global Longitudinal Strain (GLS) before and after PCI — significant improvement (p < 0.001). More negative GLS = better function.

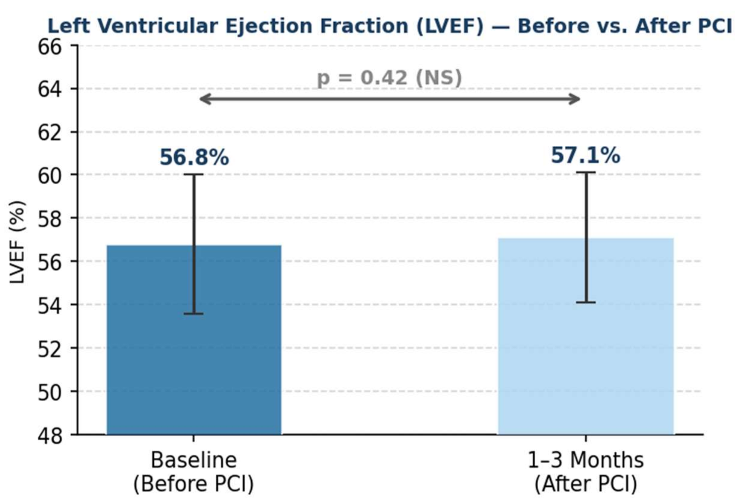

Figure 10. LVEF before and after PCI   no statistically significant change (p = 0.42, NS).

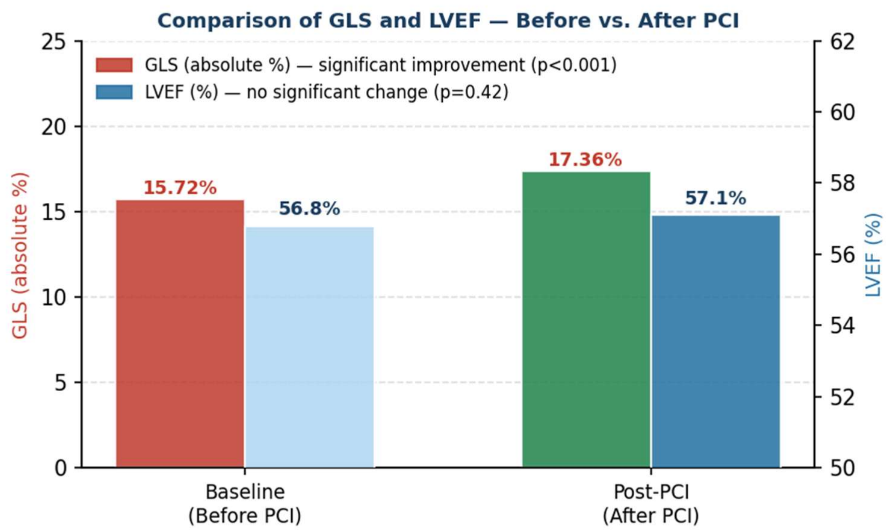

Figure 11. Comparative change in GLS and LVEF post-PCI — GLS shows significant improvement while LVEF remains unchanged, demonstrating the superior sensitivity of GLS.

3.5 Major Adverse Cardiovascular Events (MACE)

During the three-month follow-up period, MACE occurred in 3 patients (10%). Among these, one patient (3.3%) experienced all-cause mortality within 30 days, one (3.3%) had a non-fatal myocardial infarction within six weeks, and one (3.3%) required unplanned target vessel revascularization due to in-stent restenosis at three months (Table 7, Figure 12). The remaining 27 patients (90%) had an uneventful recovery. MACE events were predominantly observed in patients with persistently impaired post-PCI GLS.

Table 7. Major Adverse Cardiovascular Events at 3-Month Follow-Up (n = 30)

MACE Component	No. of Patients	Percentage (%)
All-Cause Mortality	1	3.3%
Non-Fatal Myocardial Infarction	1	3.3%
Unplanned Target Vessel Revascularization	1	3.3%
Total MACE Events	**3**	**10.0%**
No MACE	**27**	**90.0%**

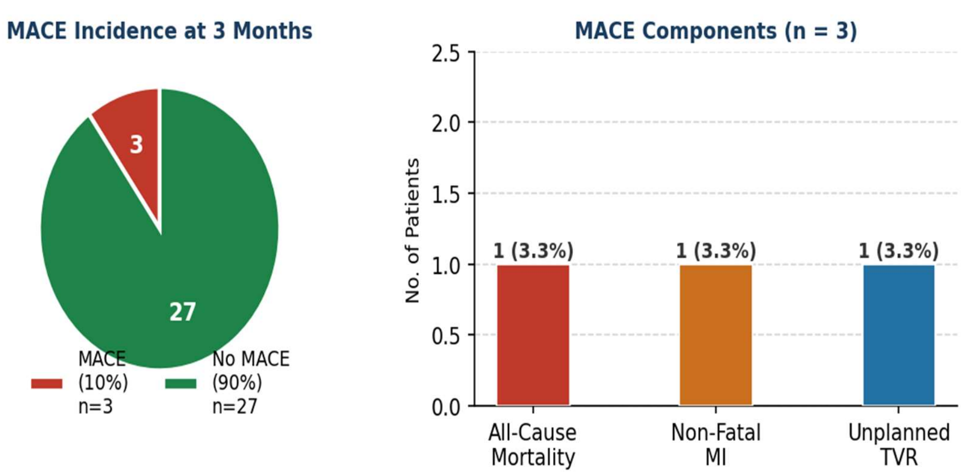

Figure 12. MACE incidence at three-month follow-up (left: overall; right: individual components).

4. Discussion

This prospective observational study evaluated the utility of GLS as a sensitive marker of subclinical myocardial dysfunction and a tool for assessing functional recovery in 30 CSA patients with preserved LVEF undergoing elective PCI. The key finding is that despite universally preserved baseline LVEF, GLS was significantly impaired at baseline and improved significantly following successful PCI, while LVEF remained unchanged. These findings validate GLS as a superior echocardiographic parameter for detecting and tracking ischemia-related myocardial dysfunction in this patient population.

4.1 Subclinical Myocardial Dysfunction Undetected by LVEF

All enrolled patients had preserved LVEF, yet the mean baseline GLS was −15.72 ± 1.46% notably less negative than the established normal range of −18% to −22%, indicating occult systolic dysfunction confined to longitudinal myocardial fibers. This finding underscores a well-recognized limitation of LVEF: its volumetric, geometric basis renders it insensitive to early regional or subendocardial dysfunction, particularly in stable ischemia where wall motion abnormalities may be absent [5], [6] In contrast, GLS directly quantifies longitudinal fibers, shortening fibers that are first and most severely affected by subendocardial ischemia thereby providing an earlier window into myocardial compromise [15].

These observations are consistent with Biswas et al., (2020), who reported significantly reduced GLS in stable angina patients (mean −18.2 ± 2.2%) despite normal LVEF, compared to −22.2 ± 1.9% in controls [11]. Similarly, Saleh and Brachmann, (2024) found that CSA patients with angiographically proven disease had impaired GLS (−17.97 ± 0.85%) versus −20.26 ± 1.03% in those without significant CAD, proposing a cutoff of −19% for identifying obstructive disease [16]. The even lower baseline GLS in our cohort (−15.72%) likely reflects a more advanced ischemic burden, compounded by the high prevalence of diabetes (60%) and hypertension (66.7%), both of which independently impair longitudinal myocardial mechanics [17], [18].

4.2 GLS Improvement Following PCI

Following successful revascularization, mean GLS improved significantly to −17.36 ± 1.47% ($p < 0.001$), while LVEF showed no significant change ($p = 0.42$). This post-PCI GLS improvement reflects the restoration of perfusion to ischemic but viable myocardium and provides objective evidence of functional recovery that conventional echocardiography cannot capture. Importantly, this improvement was detectable within three to five days post-PCI, demonstrating the responsiveness of GLS to early myocardial reperfusion. These findings closely corroborate those of Mahajan et al., (2020), who reported a significant pre-to-post PCI GLS improvement from −15.2 ± 1.3% to −17.8 ± 1.1% ($p < 0.001$) in Indian patients with preserved EF — nearly identical to the improvement magnitude observed in the present study [12]. Sikora-Frac et al. (2021) similarly demonstrated significant post-PCI GLS improvement ($p < 0.001$) in a Polish cohort, with greater improvement in patients with higher pre-intervention SYNTAX scores. Biswas et al., (2020) further confirmed that GLS is more sensitive to post-PCI myocardial recovery than LVEF, supporting the present study's observations [11].

4.3 Correlation Between Coronary Disease Burden and GLS

In this cohort, patients with multivessel disease (DVD and TVD) demonstrated more impaired baseline GLS values compared to those with SVD, reflecting a dose-response relationship between coronary disease burden and longitudinal myocardial dysfunction. This trend is consistent with Hardas et al. (2023), who reported a strong inverse correlation between GLS and SYNTAX score ($r = -0.862$; $p = 0.001$) in Indian patients with preserved EF, and found that patients with critical CAD had mean GLS of −12.4 ± 1.3% versus −16.4 ± 1.1% in those with non-critical disease. Abdelrazek et al. (2020) similarly established that a GLS threshold of −17.8% predicted high SYNTAX scores (>22) with 84% sensitivity and 70% specificity [7].

The LAD artery was the most frequently involved vessel (66.7%), which is clinically relevant LAD disease predominantly affects anterior wall perfusion and disproportionately impacts longitudinal GLS given the anterior LV contribution to longitudinal fiber function. This angiographic profile is consistent with previously published Indian PCI cohorts.

4.4 Comorbidities and Their Impact on GLS

Patients with diabetes, hypertension, and dyslipidemia demonstrated more impaired baseline GLS values compared to those without these conditions, despite similar LVEF. Diabetes-associated hyperglycemia promotes endothelial dysfunction, myocardial fibrosis, and microvascular ischemia mechanisms that selectively impair longitudinal strain before global systolic function deteriorates [17]. Ahmed et al., (2018) demonstrated that asymptomatic diabetic patients had significantly lower GLS (−16.8 ± 1.2%) compared to healthy controls (−18.7 ± 1.1%) despite preserved LVEF [17]. Hypertension-induced concentric remodeling similarly impairs longitudinal fiber shortening, with Park et al. demonstrating worsening GLS in hypertensive patients with longer disease duration [referenced in Discussion]. These findings reinforce GLS as a particularly valuable screening tool in high-risk comorbid populations.

4.5 Prognostic Significance and MACE

The 10% MACE rate at three months in this cohort was predominantly observed in patients with persistently impaired post-PCI GLS, suggesting that failure of GLS to recover after revascularization may identify patients at increased risk for adverse cardiovascular events. This is consistent with Abdelrazek et al. (2020), who linked impaired GLS to higher SYNTAX scores and worse outcomes [7], and with broader evidence from Rabkin, (2023) 's meta-analysis, which demonstrated that impaired GLS independently predicts MACE across multiple patient populations including those undergoing coronary revascularization [9]. The Copenhagen City Heart Study similarly established that even modest GLS impairment (< −16%) was associated with significantly higher long-term risk of heart failure and cardiac death [15].

4.6 Study Limitations

This study has several limitations that should be acknowledged. The relatively small sample size (n = 30), single-center study design, and absence of a control group may limit the statistical strength and generalizability of the findings to broader populations. The follow-up duration of three months was relatively short and did not permit assessment of long-term myocardial remodeling, recurrent ischemic events, or long-term clinical outcomes following PCI. Echocardiographic assessment was not performed in a blinded manner with respect to clinical and angiographic findings, which may have introduced observer bias. In addition, serial GLS measurements beyond the early post-PCI period were not evaluated. The study population predominantly represented a specific regional cohort, and therefore the findings may not fully reflect other demographic populations. Further large-scale multicenter studies with longer follow-up durations are required to validate the prognostic utility of GLS and to establish standardized reference values for the Indian population.

5. Conclusion

The present study demonstrated that GLS may serve as a sensitive echocardiographic parameter for detecting subtle left ventricular systolic dysfunction in patients with chronic stable angina and preserved LVEF. Although baseline LVEF was preserved in all patients, many participants showed impaired GLS values, suggesting the presence of subclinical myocardial dysfunction associated with coronary ischemia. Following PCI, significant improvement in GLS was observed, while conventional LVEF measurements remained largely unchanged, indicating the potential incremental value of GLS in functional assessment after revascularization.

The study also observed an association between the severity of coronary artery disease and the degree of GLS impairment. Patients with comorbid conditions such as diabetes mellitus and hypertension demonstrated comparatively greater baseline GLS impairment. Furthermore, persistently impaired GLS following PCI showed a possible association with adverse clinical outcomes, including MACE; however, larger studies are necessary to confirm these observations.

Overall, GLS may be considered a useful adjunctive tool in the echocardiographic evaluation of patients with chronic stable angina, particularly for early identification of subclinical myocardial dysfunction and assessment of post-PCI functional recovery. Additional prospective multicenter studies with larger sample sizes and extended follow-up are recommended to further clarify its prognostic significance and clinical applicability.

Abbreviations

AF – Atrial Fibrillation
MI – Myocardial Infarction
MACE – Major Adverse Cardiovascular Events
BMI – Body Mass Index

Declarations

1. Funding

No funding was received for conducting this study.

2. Conflicts of Interest/Competing Interests

The authors declare that there are no conflicts of interest related to this study.

3. Ethics Approval

The study was approved by the Institutional Ethics Committee of [SRM UNIVERSITY], with approval number [SRMIEC- ST0425-2308].

4. Consent to Participate

Informed consent was obtained from all participants included in the study.

5. Written Consent for Publication

Not applicable.

6. Availability of Data and Material

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

7. Code Availability

Not applicable.

8. Large Language Model (LLM)

No Large Language Model (LLM) tools were utilized in conducting the research analysis.

9. Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation Process

The authors used Generative AI tools for grammatical editing and language refinement during manuscript preparation. The authors take full responsibility for the accuracy, originality, and integrity of the content.

10. Authors' Contributions

SS1 conceived and designed the study. KVL2 participated in data collection and manuscript preparation. MVN3 contributed to data analysis and interpretation. DRN4 assisted in literature review and drafting of the manuscript. CSA5 supervised the study, critically revised the manuscript, and approved the final version for publication. All authors read and approved the final manuscript.

11. Acknowledgements

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