

The Echocardiographic Assessment of Subclinical Left Ventricular Dysfunction Due to Permanent Pacemaker Implantation Using Global Longitudinal Strain-An Observational Study

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Abstract

Background: Permanent pacemaker implantation is an established treatment for symptomatic bradyarrhythmias. However, chronic right ventricular (RV) pacing, particularly from the RV apex, may cause abnormal ventricular activation and mechanical dyssynchrony, leading to progressive left ventricular (LV) dysfunction. Conventional assessment using LV ejection fraction (LVEF) may remain normal during early myocardial impairment. Global longitudinal strain (GLS) assessed by two-dimensional speckle-tracking echocardiography can detect subtle myocardial dysfunction before a decline in LVEF becomes evident. The aim is to evaluate the effect of permanent pacemaker implantation on LV myocardial function using GLS and determine the occurrence of subclinical LV dysfunction following RV pacing. **Material and Methods:** A hospital-based, prospective observational study was conducted in the Department of Cardiology, IPGME&R and SSKM Hospital, Kolkata, over 18 months. Fifty-seven consecutive adults aged ≥ 18 years undergoing permanent pacemaker implantation for symptomatic bradyarrhythmias were included. LVEF, LVIDd, LVIDs, and GLS were assessed at baseline and after 3 months. **Results:** The mean age was 66.5 ± 6.2 years, with males comprising 61.4%. Complete heart block was the commonest indication (59.6%), while RV apical pacing predominated (91.2%). LVEF, LVIDd, and LVIDs showed no significant changes at 3 months ($p > 0.05$). In contrast, GLS significantly worsened ($p < 0.001$). Higher RV pacing burden, prolonged paced QRS duration, and RV apical pacing were significantly associated with greater GLS deterioration ($p < 0.001$). ROC analysis showed good predictive performance for RV pacing burden (AUC=0.896) and paced QRS duration (AUC=0.845). **Conclusion:** GLS detected early subclinical LV dysfunction despite preserved LVEF following permanent RV pacing. Serial GLS assessment may enable earlier identification of patients at risk of pacing-related ventricular deterioration.

Keywords: Permanent pacemaker; Right ventricular pacing; Global longitudinal strain; Subclinical LV dysfunction; Echocardiography.

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INTRODUCTION

Symptomatic bradyarrhythmias are an important cause of cardiovascular morbidity, particularly among older adults. The major causes are sinus node dysfunction and atrioventricular conduction block, which may present with fatigue, dizziness, presyncope, syncope, dyspnoea, or severe cardiovascular compromise. Permanent pacemaker implantation is the definitive treatment for clinically significant symptomatic bradyarrhythmias.^[1,2]

The right ventricular (RV) apex has traditionally been the preferred ventricular pacing site because of its technical ease and lead stability. However, chronic RV apical pacing produces an abnormal ventricular activation pattern resembling left bundle branch block, leading to electrical and mechanical ventricular dyssynchrony. This may adversely affect LV contraction, filling, myocardial strain, and ultimately LV systolic function.^[3,4]

Evidence from the MOST trial demonstrated that a high

cumulative percentage of RV pacing was associated with increased heart-failure hospitalization, particularly when ventricular pacing exceeded 40% in DDDR patients and 80% in VVIR patients.^[5] Similarly, the DAVID trial showed that excessive ventricular pacing was associated with a higher risk of death or hospitalization for heart failure.^[6] These findings suggest that frequent RV pacing may have clinically important adverse effects beyond correction of bradycardia.

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RV apical pacing causes asynchronous ventricular activation and regional differences in myocardial contraction, resulting in interventricular and intraventricular dyssynchrony. Chronic exposure may lead to adverse LV remodelling and pacing-induced cardiomyopathy (PICM), generally characterized by a significant decline in LVEF attributable to RV pacing in the absence of another cause.^[7,8]

Although left ventricular ejection fraction (LVEF) is routinely used to assess systolic function, it may remain preserved despite early myocardial dysfunction. Two-dimensional speckle-tracking echocardiography and global longitudinal strain (GLS) can detect subtle abnormalities in myocardial deformation before a significant reduction in LVEF becomes apparent. Studies have shown that early deterioration in GLS after pacemaker implantation may predict subsequent pacing-induced LV dysfunction.^[9,10]

Therefore, assessment of LV-GLS may provide an early and sensitive marker of subclinical LV dysfunction following permanent pacemaker implantation. The present study was undertaken to evaluate changes in LV global longitudinal strain following RV pacing and to determine whether a decline in GLS at three months can identify early myocardial dysfunction despite preserved conventional LV systolic function.

The present study aims to evaluate the effect of permanent pacemaker implantation on left ventricular myocardial function using global longitudinal strain (GLS) and to determine the occurrence of subclinical LV dysfunction following right ventricular pacing. The primary objective is to determine the incidence of subclinical LV dysfunction at 3 months after pacemaker implantation. Secondary objectives include assessing changes in LV-GLS and conventional echocardiographic parameters, including LVEF and LV dimensions; evaluating the association of RV pacing burden and paced QRS duration with GLS deterioration; comparing myocardial deformation between RV apical and RV septal pacing; and identifying independent predictors of GLS deterioration following permanent pacemaker implantation.

MATERIALS AND METHODS

Study Design: Hospital-based, prospective observational study.

Study Place: Department of Cardiology, Institute of Post Graduate Medical Education and Research (IPGME&R) and SSKM Hospital, Kolkata, West Bengal, India.

Study Duration: 18 months

Study Population: Consecutive adult patients (≥ 18 years) undergoing permanent pacemaker implantation for symptomatic bradyarrhythmias.

Sample Size: 57 patients

Study variables:

- Age Distribution of the Study Population
- Baseline Characteristics of the Study Population (n = 57)
- Conventional Echocardiographic Parameters at Baseline and 3 Months
- Global Longitudinal Strain (GLS) at Baseline and 3 Months
- McNemar's Test Showing the Proportion of Patients Developing Subclinical LV Dysfunction at 3 Months
- Comparison of Patients with and Without Subclinical LV Dysfunction at 3 Months
- Pacing Characteristics and Their Association with GLS Decline at 3 Months. (GLS = GLS at 3 months – GLS at baseline. More negative values indicate greater deterioration in myocardial deformation.)
- ROC Analysis for Prediction of Subclinical LV Dysfunction

Inclusion Criteria

- Adults ≥ 18 years undergoing permanent pacemaker implantation for guideline-based indications.
- Baseline LVEF $\geq 50\%$.
- Willingness to provide written informed consent.
- Adequate echocardiographic image quality for speckle-tracking GLS assessment.

Exclusion Criteria

- Baseline LVEF $< 50\%$.
- Significant coronary artery disease or previous myocardial infarction.
- Moderate or severe valvular heart disease.
- Known cardiomyopathy.
- Myocarditis or pericardial disease.
- Previous cardiac resynchronization therapy or conduction system pacing.
- Poor echocardiographic window preventing accurate GLS assessment.
- Contraindication to permanent pacemaker implantation.
- Refusal to participate in the study.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 27.0 and GraphPad Prism version 5. Continuous variables were expressed as mean $\pm$ standard deviation (SD), while categorical variables were presented as frequencies and percentages. Independent (unpaired) t-test was used to compare continuous variables between two independent groups, while paired t-test was used for within-subject comparisons. Categorical variables were compared using the Pearson chi-square test or Fisher's exact test, as appropriate. A two-tailed p-value ≤ 0.05 was considered statistically significant.

RESULTS

Table 1: Age Distribution of the Study Population

Age Group (years)	Frequency	Percentage (%)
50–59	6	10.5

60–69	28	49.1
70–79	23	40.4

Table 2: Baseline Characteristics of the Study Population (n = 57)

Characteristic	Value
Age (years), mean $\pm$ SD	66.5 $\pm$ 6.2
Male sex, n (%)	35 (61.4%)
Female sex, n (%)	22 (38.6%)
Indication for Permanent Pacemaker Implantation	Complete Heart Block
	34 (59.6%)
	Sick Sinus Syndrome
	12 (21.1%)
	Bifascicular Heart Block
	6 (10.5%)
Pacemaker Mode	2:1 AV Block
	3 (5.3%)
	Trifascicular Heart Block
	2 (3.5%)
	DDDR
	34 (59.6%)
	VVIR
	23 (40.4%)
RV Lead Position	RV Apical (Apex)
	52 (91.2%)
	RV Septal
	5 (8.8%)
Comorbidities	Hypertension
	38 (66.7%)
	Diabetes Mellitus
	24 (42.1%)
	Smoking
	14 (24.6%)
	Dyslipidemia
	12 (21.1%)
	Chronic Kidney Disease
	5 (8.8%)
	Chronic Obstructive Pulmonary Disease
	3 (5.3%)

Table 3: Conventional Echocardiographic Parameters at Baseline and 3 Months

Parameter	Baseline (Mean $\pm$ SD)	3 Months (Mean $\pm$ SD)	Paired t-value	p-value
LVEF (%)	60.44 $\pm$ 2.19	60.42 $\pm$ 2.31	0.239	0.812
LVIDd (mm)	47.82 $\pm$ 2.49	47.76 $\pm$ 2.53	1.016	0.314
LVIDs (mm)	30.42 $\pm$ 2.45	30.46 $\pm$ 2.56	-0.59	0.558

Table 4: Global Longitudinal Strain (GLS) at Baseline and 3 Months

Parameter	Baseline Mean $\pm$ SD	3 Months Mean $\pm$ SD	Mean Difference (Δ)	Paired t-value	p-value
GLS (%)	-19.77 $\pm$ 1.04	-17.06 $\pm$ 1.89	2.71 $\pm$ 1.20	-17.04	<0.001

Table 5: McNemar's Test Showing the Proportion of Patients Developing Subclinical LV Dysfunction at 3 Months

Variable	Baseline n (%)	3 Months n (%)	McNemar χ^2	p-value
Subclinical LV Dysfunction (GLS > -16%)	0 (0%)	21/57 (36.8%)	19.05	<0.001

Table 6: Comparison of Patients With and Without Subclinical LV Dysfunction at 3 Months

Variable	GLS $\leq$ -16% (n = 36)	GLS > -16% (n = 21)	Test Statistic	p-value
Age (years)	65.8 $\pm$ 6.1	67.8 $\pm$ 6.4	t = -1.18	0.24
Male sex, n (%)	20 (55.6)	15 (71.4)	χ^2 = 1.40	0.24
Hypertension, n (%)	22 (61.1)	16 (76.2)	χ^2 = 1.35	0.25
Diabetes mellitus, n (%)	13 (36.1)	11 (52.4)	χ^2 = 1.45	0.23
Smoking, n (%)	8 (22.2)	6 (28.6)	χ^2 = 0.28	0.6
Dyslipidemia, n (%)	6 (16.7)	6 (28.6)	χ^2 = 1.16	0.28
CKD, n (%)	3 (8.3)	2 (9.5)	Fisher's exact	1
COPD, n (%)	2 (5.6)	1 (4.8)	Fisher's exact	1
RV pacing burden (%)	65.0 $\pm$ 24.3	94.6 $\pm$ 6.5	t = -6.90	<0.001
Paced QRS duration (ms)	152.0 $\pm$ 17.1	173.4 $\pm$ 7.4	t = -6.52	<0.001
RV apical pacing, n (%)	31 (86.1)	21 (100.0)	Fisher's exact	0.146
RV septal pacing, n (%)	5 (13.9)	0 (0.0)	—	—

Table 7: Pacing Characteristics and Their Association With GLS Decline at 3 Months. (GLS = GLS at 3 months – GLS at baseline. More negative values indicate greater deterioration in myocardial deformation.)

Variable	Category	n (%)	Mean Δ GLS (%) $\pm$ SD	t-value	p-value
RV Pacing Burden	<40%	9 (15.8)	-1.61 $\pm$ 0.53	6.42	<0.001
	$\geq$ 40%	48 (84.2)	-2.92 $\pm$ 1.22		
Paced QRS Duration	<150 ms	17 (29.8)	-1.45 $\pm$ 0.54	8.54	<0.001
	$\geq$ 150 ms	40 (70.2)	-3.25 $\pm$ 1.21		
RV Lead Position	RV Septal	5 (8.8)	-1.66 $\pm$ 0.11	-6.57	<0.001
	RV Apical	52 (91.2)	-2.81 $\pm$ 1.21		
Overall Pacing Characteristics	Mean RV pacing burden (%)	—	78.4 $\pm$ 16.2	—	—
	Mean paced QRS duration (ms)	—	158.6 $\pm$ 18.4	—	—

Table 8: ROC Analysis for Prediction of Subclinical LV Dysfunction

Predictor	AUC	Optimal Cutoff	Sensitivity	Specificity
RV Pacing Burden (%)	0.896	94%	76.20%	91.70%
Paced QRS Duration (ms)	0.845	160 ms	100.00%	52.80%

Correlation of Clinical and Pacing Variables With Δ GLS at 3 Months

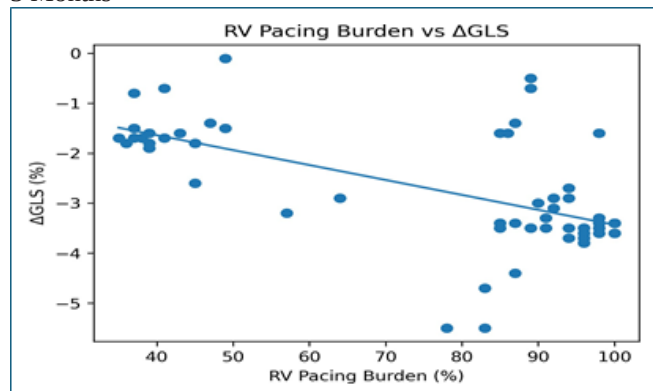


Figure 1: Scatter plot demonstrating the relationship between RV pacing burden and deterioration in global longitudinal strain (Δ GLS) at 3 months.

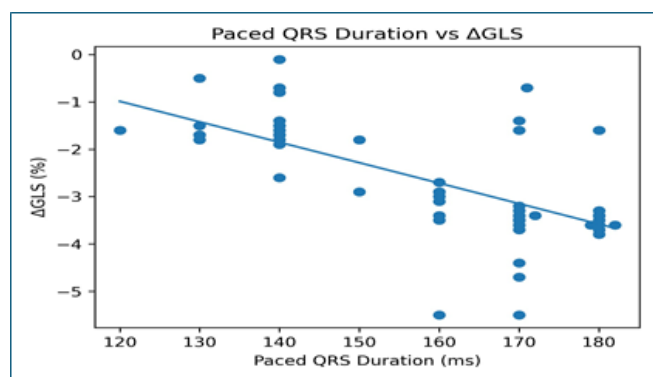


Figure 2: Scatter plot showing the association between paced QRS duration and deterioration in global longitudinal strain (Δ GLS).

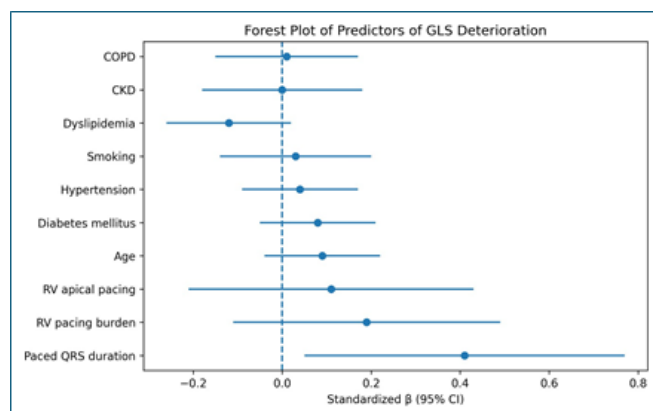


Figure 3: Multivariable Linear Regression Analysis for Predictors of GLS Deterioration

Among the study participants, the majority were in the 60–69 years age group, comprising 28 patients (49.1%). This was followed by the 70–79 years age group, which included 23 patients (40.4%), while 6 patients (10.5%) belonged to

the 50–59 years age group. [Table 1]

The mean age of the study participants was 66.5 ± 6.2 years. Of the total 57 patients, 35 (61.4%) were male and 22 (38.6%) were female, indicating a male predominance in the study population. Regarding the indications for permanent pacemaker implantation, complete heart block was the most common indication, observed in 34 patients (59.6%), followed by sick sinus syndrome in 12 patients (21.1%) and bifascicular heart block in 6 patients (10.5%). 2:1 AV block was present in 3 patients (5.3%), while trifascicular heart block was observed in 2 patients (3.5%). Thus, complete heart block was the predominant indication for pacemaker implantation. With respect to pacemaker mode, 34 patients (59.6%) received a DDDR pacemaker, whereas 23 patients (40.4%) received a VVIR pacemaker, showing that DDDR was the more frequently used pacing mode. Regarding right ventricular lead position, the lead was positioned at the RV apex in 52 patients (91.2%), while 5 patients (8.8%) had an RV septal lead position, demonstrating a marked predominance of apical lead placement. Among the assessed comorbidities, hypertension was the most common, present in 38 patients (66.7%), followed by diabetes mellitus in 24 patients (42.1%). Smoking was reported in 14 patients (24.6%), while dyslipidemia was present in 12 patients (21.1%). Chronic kidney disease and chronic obstructive pulmonary disease were observed in 5 patients (8.8%) and 3 patients (5.3%), respectively. [Table 2]

The mean LVEF at baseline was $60.44 \pm 2.19\%$, which remained almost unchanged at 3 months ($60.42 \pm 2.31\%$). The paired t-test showed no statistically significant difference between baseline and 3 months ($t = 0.239$, $p = 0.812$), indicating preserved and stable left ventricular systolic function during follow-up. The mean LVIDd was 47.82 ± 2.49 mm at baseline and 47.76 ± 2.53 mm at 3 months. The difference was not statistically significant ($t = 1.016$, $p = 0.314$), suggesting no meaningful change in left ventricular end-diastolic dimension over the 3-month follow-up period. Similarly, the mean LVIDs was 30.42 ± 2.45 mm at baseline and 30.46 ± 2.56 mm at 3 months. No statistically significant difference was observed ($t = -0.590$, $p = 0.558$), indicating that left ventricular end-systolic dimension remained stable during follow-up. [Table 3]

The mean GLS at baseline was $-19.77 \pm 1.04\%$, which changed to $-17.06 \pm 1.89\%$ at 3 months. The mean difference was $2.71 \pm 1.20\%$, with a paired t-value of -17.04 . The difference between baseline and 3-month GLS values was statistically highly significant ($p < 0.001$). [Table 4]

The comparison between patients with $GLS \leq -16\%$ ($n=36$) and $GLS > -16\%$ ($n=21$) showed that age ($p=0.24$), male sex ($p=0.24$), hypertension ($p=0.25$), diabetes mellitus ($p=0.23$), smoking ($p=0.60$), dyslipidemia ($p=0.28$), CKD ($p=1.00$), COPD ($p=1.00$), and RV apical pacing ($p=0.146$) were not statistically significantly different between the two groups (all $p > 0.05$). In contrast, RV pacing burden and paced QRS duration were significantly higher in the $GLS > -16\%$ group (both $p < 0.001$). Overall, the $GLS > -16\%$ group was significantly associated with greater RV pacing burden and longer paced

QRS duration, while the other demographic, clinical, and pacing characteristics showed no statistically significant differences. [Table 5]

The mean change in GLS (Δ GLS) was significantly associated with RV pacing burden, paced QRS duration, and RV lead position. Patients with RV pacing burden $\geq 40\%$ showed a greater change in GLS ($-2.92 \pm 1.22\%$) compared with those with pacing burden $<40\%$ ($-1.61 \pm 0.53\%$), with a statistically significant difference ($p < 0.001$). Similarly, patients with paced QRS duration ≥ 150 ms had a greater change in GLS ($-3.25 \pm 1.21\%$) than those with QRS duration <150 ms ($-1.45 \pm 0.54\%$), which was statistically significant ($p < 0.001$). Regarding RV lead position, RV apical pacing was associated with a greater change in GLS ($-2.81 \pm 1.21\%$) compared with RV septal pacing ($-1.66 \pm 0.11\%$), with a statistically significant difference ($p < 0.001$). [Table 6]

ROC analysis demonstrated that RV pacing burden had an AUC of 0.896, with an optimal cutoff of 94%, yielding a sensitivity of 76.2% and specificity of 91.7%. Paced QRS duration showed an AUC of 0.845, with an optimal cutoff of 160 ms, providing a sensitivity of 100.0% and specificity of 52.8%. [Table 7]

DISCUSSION

The present study showed that GLS detected early LV myocardial dysfunction despite preserved conventional echocardiographic parameters. LVEF remained stable (60.44% vs 60.42%, $p = 0.812$), whereas GLS significantly worsened from -19.77% to -17.06% ($p < 0.001$) after 3 months.

Huang et al,^[11] reported greater impairment of LV strain with RV apical pacing, supporting our finding of significant GLS deterioration following pacing. Kiehl et al,^[12] found that RV pacing burden was independently associated with pacing-induced cardiomyopathy; 12.3% of 823 patients developed cardiomyopathy, with RV pacing $\geq 20\%$ being an important predictor. In our study, RV pacing burden $\geq 40\%$ was associated with significantly greater GLS deterioration (-2.92% vs -1.61% , $p < 0.001$). Similarly, paced QRS duration ≥ 150 ms was associated with greater GLS deterioration (-3.25% vs -1.45% , $p < 0.001$). Chan NY et al,^[13] These findings are consistent with previous evidence identifying pacing burden and QRS prolongation as important determinants of pacing-related LV dysfunction. Chin et al,^[14] demonstrated that pre-implant GLS could identify patients at risk of pacing-induced cardiomyopathy, supporting the role of GLS as an early marker before conventional LVEF decline. Iqbal et al,^[15] studied 37 patients undergoing pacemaker implantation and found that GLS significantly deteriorated from $-20.30 \pm 3.38\%$ to $-16.93 \pm 3.47\%$ ($p < 0.001$). A pacing burden $>40\%$ was significantly associated with greater GLS deterioration ($p = 0.007$), supporting our finding that higher RV pacing burden is associated with subclinical LV dysfunction. Manocha et al,^[16] evaluated patients with permanent pacemakers and reported that frequent RV

pacing was associated with deterioration in LV-GLS and adverse clinical outcomes. Their findings further support the use of GLS as an early marker of pacing-related LV dysfunction before conventional LVEF decline becomes evident.

CONCLUSION

Permanent right ventricular pacing may cause early subclinical left ventricular dysfunction, even when conventional echocardiographic parameters remain preserved. Global longitudinal strain is a sensitive tool for detecting early myocardial dysfunction and appears particularly useful in patients with higher RV pacing burden, prolonged paced QRS duration, and apical pacing. Serial GLS assessment may therefore facilitate early identification and monitoring of patients at risk of pacing-induced ventricular dysfunction.

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Conflicts of interest

There are no conflicts of interest.

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