

Electrocardiographic Correlates of Subclinical Left Ventricular Systolic Dysfunction in Patients with Left Bundle Branch Block and Preserved Ejection Fraction: A Prospective Observational Study from North-Western India

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Abstract

Background: Patients with complete left bundle branch block (LBBB) and a normal left ventricular ejection fraction (LVEF) may nonetheless harbour subclinical left ventricular systolic dysfunction (LVSD) that is detectable only by two-dimensional speckle-tracking echocardiography (2DSTE). Whether routinely measured electrocardiographic (ECG) features can identify such patients, particularly in an Indian population, has not been established. **Material and Methods:** In this prospective, single-centre, observational cross-sectional study, 60 consecutive patients with complete LBBB and a normal LVEF ($\geq 52\%$ in men, $\geq 54\%$ in women) underwent standard 12-lead electrocardiography, conventional two-dimensional echocardiography and 2DSTE. Subclinical LVSD was defined a priori as left ventricular global longitudinal strain (LV GLS) greater than -20% despite a normal LVEF. Predefined ECG characteristics were compared between patients with and without subclinical LVSD, and their diagnostic performance was assessed by receiver operating characteristic (ROC) curve analysis and multivariable logistic regression. **Results:** Thirty patients (50.0%) had subclinical LVSD. QRS duration (160.5 ± 13.3 vs 150.8 ± 11.2 ms, $p = 0.003$), a QS pattern in lead V1 (76.7% vs 46.7%, $p = 0.017$), discordant LBBB (73.3% vs 33.3%, $p = 0.002$), R-wave peak time in V5–V6 (69.3 ± 4.5 vs 66.2 ± 5.9 ms, $p = 0.027$) and the QRS-T angle ($122.1 \pm 29.6^\circ$ vs $105.6 \pm 20.4^\circ$, $p = 0.021$) were each significantly associated with subclinical LVSD. QRS duration correlated with LV GLS ($r = +0.561$, $p < 0.001$) and gave an area under the ROC curve (AUC) of 0.708 (95% CI 0.575–0.841) at an optimal cut-off of 161 ms. On multivariable analysis, discordant LBBB (adjusted odds ratio [aOR] 6.76, 95% CI 1.82–25.10, $p = 0.004$) and QRS duration (aOR 1.080 per ms, 95% CI 1.024–1.139, $p = 0.005$) were independently associated with subclinical LVSD. A combined model incorporating QRS duration, QS pattern in V1 and discordant LBBB achieved an AUC of 0.833 (95% CI 0.726–0.941), with 83.3% sensitivity and 76.7% specificity, significantly outperforming QRS duration alone (DeLong $p = 0.039$). A simple three-item additive score based on these variables achieved comparable discrimination (AUC 0.815). **Conclusion:** In patients with LBBB and preserved ejection fraction, a combination of QRS duration, QS pattern in lead V1 and discordant LBBB — all visible on a standard printed electrocardiogram — identifies subclinical LVSD with good, though imperfect, accuracy. No single ECG parameter is sufficiently discriminatory to be used alone. These features may serve as a low-cost triage tool for selecting patients for referral for strain echocardiography in settings where deformation imaging is not routinely available, pending prospective outcome studies and independent validation.

Keywords: left bundle branch block, global longitudinal strain, speckle-tracking echocardiography, subclinical left ventricular dysfunction, electrocardiography, preserved ejection fraction.

Received: 01 September 2026

Revised: 18 September 2026

Accepted: 06 October 2026

Published: 13 October 2026

INTRODUCTION

Left bundle branch block (LBBB) develops when conduction through the left bundle fails and the left ventricle is instead activated by slow, cell-to-cell spread of the impulse originating on the right side of the septum. This produces the broad, notched QRS complex that defines the pattern on the surface electrocardiogram and results in markedly dyssynchronous contraction, with early septal and late lateral wall activation.^[1,2] The 2009 AHA/ACCF/HRS criteria remain the most widely used definition of complete LBBB, although the stricter criteria proposed by Strauss and colleagues, requiring a longer QRS duration and mid-QRS notching in at least two contiguous leads, select a narrower and more homogeneous population intended for

resynchronisation candidacy.^[3,4]

The prognostic significance of LBBB depends heavily on the

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DOI:
10.21276/amit.2026.v13.i3.1123

How to cite this article: Kumar A, Shekhawat DS, Gautam D, Kumar G, Panwar N, Meena DS. Electrocardiographic Correlates of Subclinical Left Ventricular Systolic Dysfunction in Patients with Left Bundle Branch Block and Preserved Ejection Fraction: A Prospective Observational Study from North-Western India. Acta Med Int. 2026;13(3):652-659.

myocardial context in which it is found. In unselected, largely healthy populations the finding behaves benignly.^[5,8,9] whereas in the Framingham cohort newly acquired LBBB carried a markedly adverse prognosis, with half of affected patients dying of cardiovascular disease within a decade.^[6-11] Between these extremes lies a large and clinically important group: patients with complete LBBB, no symptoms of heart failure, and a left ventricular ejection fraction (LVEF) within the normal range, often termed LBBBpEF (LBBB with preserved ejection fraction).^[12,13] Even in this group, dyssynchronous activation causes measurable mechanical consequences — including septal flash and impaired longitudinal shortening — well before the ejection fraction falls.^[14,15]

The ejection fraction is an insensitive measure of this process because it is dominated by circumferential and radial shortening and is relatively insensitive to the longitudinal shortening generated by subendocardial fibres, which are most vulnerable to early injury.^[17] Two-dimensional speckle-tracking echocardiography (2DSTE) overcomes this limitation by quantifying myocardial deformation directly. Left ventricular global longitudinal strain (LV GLS), the average peak systolic longitudinal strain across all myocardial segments, has a well-established normal value of approximately -19.7% ,^[18] outperforms the ejection fraction for predicting adverse cardiac events,^[19,23] and can be reduced even when the ejection fraction remains normal — a state termed subclinical left ventricular systolic dysfunction (LVSD).^[20,21] However, 2DSTE requires dedicated software, an experienced operator and good image quality, and remains available only at tertiary centres in much of India.

The electrocardiogram (ECG), by contrast, is inexpensive, ubiquitous and operator-independent at the point of acquisition. If specific ECG features already visible on the routine tracing of a patient with LBBB could identify those with reduced GLS, the ECG could convert an unselected referral practice for strain imaging into a targeted one. Prior work has suggested that such information is recoverable: QRS morphology carries prognostic information beyond duration alone.^[25] the relationship between QRS duration and ventricular anatomy differs in cardiomyopathy patients with LBBB compared with those without.^[26] and deep-learning models applied to standard or even photographed ECG tracings can detect systolic dysfunction with clinically useful accuracy.^[27,29] Most directly relevant, Li and colleagues related a defined panel of ECG characteristics to strain-defined subclinical LVSD in 111 Chinese patients with LBBBpEF.^[13]

However, the evidence base linking ECG characteristics to subclinical LVSD in LBBBpEF is limited essentially to that single, non-Indian cohort. Body habitus, blood pressure profile, diabetes burden and age at presentation differ appreciably in Indian patients and are each known to influence QRS characteristics and strain values, so cut-off values derived elsewhere cannot be assumed to transfer. No published Indian data address this question. We therefore designed a prospective study to compare a predefined panel

of ECG characteristics between patients with LBBB and preserved LVEF who did and did not have strain-defined subclinical LVSD, and to quantify the diagnostic performance of any discriminating ECG variables, in a tertiary-care Indian cohort.

MATERIALS AND METHODS

Study design and setting: This was a single-centre, prospective, observational, cross-sectional analytical study conducted in the Department of Cardiology, S.M.S. Medical College and Attached Group of Hospitals, Jaipur, Rajasthan, India, a tertiary referral centre, over a one-year period (June 2025 to June 2026). Each participant underwent a single set of study assessments — clinical evaluation, standard 12-lead ECG, conventional two-dimensional echocardiography and 2DSTE — completed on the same day wherever possible and always within seven days of enrolment. No study intervention was administered and clinical management was not altered by participation.

Participants: Consecutive patients aged ≥ 18 years presenting to the department with complete LBBB on a standard 12-lead ECG (2009 AHA/ACCF/HRS criteria³) and a normal LVEF on two-dimensional echocardiography ($\geq 52\%$ in men, $\geq 54\%$ in women).^[16] were screened. Patients were excluded for a subnormal LVEF; arrhythmias other than LBBB (including atrial fibrillation, pre-excitation, frequent ventricular ectopy, permanent pacing or advanced atrioventricular block); structural heart disease (significant valvular disease, congenital heart disease, hypertrophic, dilated or infiltrative cardiomyopathy, pericardial disease); acute coronary syndrome or prior ischaemic heart disease; systemic disease likely to affect myocardial function; an N-terminal pro-B-type natriuretic peptide (NT-proBNP) above 125 pg/mL; inadequate ECG or echocardiographic image quality (including ≥ 2 untrackable myocardial segments on any apical view); pregnancy; or refusal of consent. Written informed consent was obtained from every participant. Ethical clearance was obtained from the Institutional Ethics Committee and Research Review Board of S.M.S. Medical College, Jaipur, and the study was conducted in accordance with the Declaration of Helsinki and the Indian Council of Medical Research national ethical guidelines.

Sample size: The sample size was calculated to detect a difference in LV GLS between the two groups at 95% confidence and 80% power, using a pooled standard deviation of 1.47% and an expected between-group difference of 1.08%, both derived from Li and colleagues.^[13] This gave a requirement of 30 patients per group (60 in total). Because group allocation depended on the GLS value measured during the study assessment, consecutive recruitment continued until each group contained at least 30 patients; the resulting equal group sizes are therefore an artefact of the sampling plan and do not represent a prevalence estimate.

Electrocardiographic assessment: A supine 12-lead ECG (10 mm/mV, 25 mm/s) was recorded in every participant after ≥ 5 minutes of rest. All interval and morphological measurements were made manually with electronic calipers on the digitally acquired tracing by a single investigator, each as the mean of three consecutive complexes, and included heart rate, PR

interval, QRS duration and axis, QRS morphology (mid-QRS notching/slurring and number of leads involved), a QS pattern in lead V1 (absent R wave, or R-wave amplitude < 0.1 mV), R-wave peak time in V5–V6, T-wave concordance/discordance, discordant LBBB (ST-segment/T-wave direction opposite to the QRS in the lateral leads), QT and Bazett-corrected QTc intervals, the QRS-T angle (where measurable), left atrial abnormality, and whether the stricter Strauss criteria⁴ were additionally satisfied.

Echocardiography: Conventional two-dimensional echocardiography (GE Vivid S6, 3.5 MHz probe) was performed with the patient in the left lateral decubitus position, in accordance with American Society of Echocardiography/European Association of Cardiovascular Imaging recommendations,¹⁶ and included biplane Simpson LVEF, diastolic indices (E, A, e', E/e'), left atrial volume index, LV linear dimensions and mass index, LV geometry, interventricular mechanical delay, septal flash (presence and extent), tricuspid annular plane systolic excursion (TAPSE) and peak tricuspid regurgitation velocity. Speckle-tracking analysis was performed offline (QLAB, GE Vivid S6) on apical four-, two- and three-chamber views to derive an 18-segment LV GLS, together with the standard deviation (Ts-SD) and range (Ts-Diff) of time-to-peak segmental strain as indices of mechanical dispersion. Subclinical LVSD was defined a priori as LV GLS greater than -20% despite a normal LVEF, based on the meta-analytically derived normal value of -19.7%,^[18] and matching the threshold used by Li and colleagues.^[13]

Statistical analysis: Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) according to distribution (Shapiro-Wilk test) and compared using the unpaired t test or Mann-Whitney U test; categorical variables were compared using the chi-square or

Fisher's exact test. Associations between individual ECG parameters and the continuous LV GLS value were assessed by Pearson or Spearman correlation. ROC curve analysis was performed for each ECG parameter that differed significantly between groups, with the optimal cut-off identified by the Youden index and areas under the curve (AUC) compared by the DeLong method. Multivariable binary logistic regression, restricted to three predictors in view of the 30 available events (≥ 10 events per variable), was used to identify independent correlates of subclinical LVSD; model discrimination was assessed by AUC and calibration by the Hosmer-Lemeshow test. A two-sided $p < 0.05$ was considered significant. Analyses were performed on complete cases, with the number of observations stated for each analysis.

RESULTS

Participants: Sixty patients met all eligibility criteria and completed the full study protocol; speckle-tracking image quality was adequate in every patient and none withdrew after enrolment. Thirty patients (50.0%) had LV GLS greater than -20% (subclinical LVSD) and 30 (50.0%) had LV GLS of -20% or less, reflecting the pre-specified sampling plan rather than a prevalence estimate. The overall cohort had a mean age of 60.2 ± 10.5 years (range 36–80), 31 (51.7%) were men, and hypertension and diabetes were present in 46.7% and 35.0% respectively. The two groups were well matched for age, sex, body size, blood pressure, and the prevalence of diabetes, hypertension, smoking, alcohol use and family history of coronary disease (all $p > 0.10$; [Table 1]), and no laboratory parameter, including NT-proBNP, differed significantly between groups. LV GLS in the cohort as a whole was $-19.55 \pm 2.84\%$ (range -25.2% to -11.9%) with a continuous, unimodal distribution and no natural separation at the -20% threshold [Figure 1].

Table 1: Baseline demographic, clinical and key echocardiographic characteristics of the two groups

Variable	Subclinical LVSD (n=30)	No subclinical LVSD (n=30)	p value
Age (years)	60.7 $\pm$ 9.2	59.6 $\pm$ 11.8	0.680
Male sex, n (%)	15 (50.0)	16 (53.3)	0.796
Body mass index (kg/m ²)	23.87 $\pm$ 4.23	24.77 $\pm$ 4.03	0.402
Systolic BP (mmHg)	131.8 $\pm$ 15.5	128.9 $\pm$ 13.3	0.446
Diabetes mellitus, n (%)	8 (26.7)	13 (43.3)	0.176
Hypertension, n (%)	14 (46.7)	14 (46.7)	1.000
NT-proBNP (pg/mL)	58.6 $\pm$ 28.3	57.8 $\pm$ 25.9	0.908
LV ejection fraction (%)	59.86 $\pm$ 3.77	63.31 $\pm$ 5.32	0.005
LV mass index (g/m ²)	104.0 $\pm$ 22.5	91.0 $\pm$ 26.0	0.043
Average e' (cm/s)	7.51 $\pm$ 1.82	8.81 $\pm$ 1.73	0.006
Interventricular mechanical delay (ms)	48.0 $\pm$ 12.5	31.4 $\pm$ 12.7	<0.001
Eccentric LV hypertrophy, n (%)	10 (33.3)	2 (6.7)	0.034*
LV global longitudinal strain (%)	-17.80 (-18.60 to -16.47)	-21.75 (-22.90 to -20.42)	<0.001

Values are mean $\pm$ SD or median (IQR). *p value for the overall distribution of LV geometry across four categories (chi-square test). A full listing of demographic, laboratory and echocardiographic variables is available from the authors on request.

Electrocardiographic characteristics: Of 14 ECG variables examined, five differed significantly between groups [Table 2]. QRS duration was 9.7 ms longer in patients with subclinical LVSD (160.5 ± 13.3 vs 150.8 ± 11.2 ms, $p = 0.003$; [Figure 2]). A QS pattern in lead V1 (76.7% vs 46.7%, $p = 0.017$; odds ratio [OR] 3.76, 95% CI 1.24–11.39) and discordant LBBB (73.3% vs 33.3%, $p =$

0.002; OR 5.50, 95% CI 1.81–16.68) were both considerably more prevalent in patients with subclinical LVSD [Figure 3]. R-wave peak time in V5–V6 (69.3 ± 4.5 vs 66.2 ± 5.9 ms, $p = 0.027$) and the QRS-T angle ($122.1 \pm 29.6^\circ$ vs $105.6 \pm 20.4^\circ$, $p = 0.021$, measurable in 54/60 patients) were also significantly greater. Heart rate, PR interval, QRS axis, mid-QRS notching (present in 93.3% of

both groups), the number of notched leads, QT/QTc intervals, left atrial abnormality and satisfaction of the

stricter Strauss criteria (63.3% vs 56.7%, $p = 0.598$) did not differ significantly.

Table 2: Comparison of electrocardiographic characteristics between the two groups

ECG variable	Subclinical LVSD (n=30)	No subclinical LVSD (n=30)	p
Heart rate (bpm)	72.3 ± 10.2	74.1 ± 9.2	0.459
PR interval (ms)	164.5 ± 16.6	161.0 ± 21.6	0.484
QRS duration (ms)	160.5 ± 13.3	150.8 ± 11.2	0.003
QRS axis (°)	-7.6 ± 29.4	-12.9 ± 29.1	0.491
Mid-QRS notching, n (%)	28 (93.3)	28 (93.3)	1.000
QS pattern in V1, n (%)	23 (76.7)	14 (46.7)	0.017
R-wave peak time V5-V6 (ms)	69.3 ± 4.5	66.2 ± 5.9	0.027
Discordant LBBB, n (%)	22 (73.3)	10 (33.3)	0.002
QT interval (ms)	410.1 ± 45.3	398.5 ± 32.6	0.262
QTc interval, Bazett (ms)	446.3 ± 30.5	440.4 ± 22.4	0.400
QRS-T angle (°)	122.1 ± 29.6	105.6 ± 20.4	0.021
Left atrial abnormality, n (%)	10 (33.3)	8 (26.7)	0.573
Strauss criteria satisfied, n (%)	19 (63.3)	17 (56.7)	0.598

Values are mean ± SD or n (%). Bold rows denote $p < 0.05$. The QRS-T angle was measurable in 54/60 patients (27 per group).

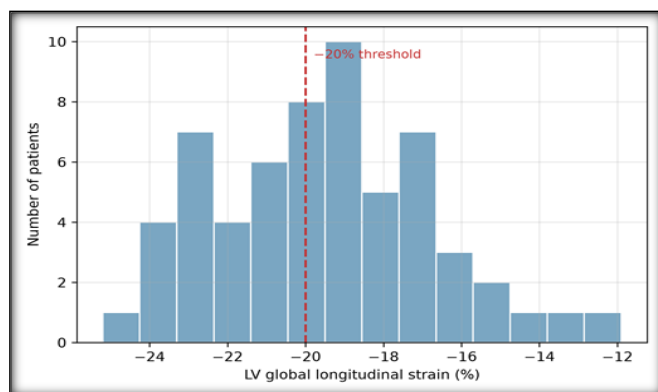


Figure 1: Distribution of left ventricular global longitudinal strain in the study cohort, showing a continuous, unimodal pattern without a natural break at the -20% threshold.

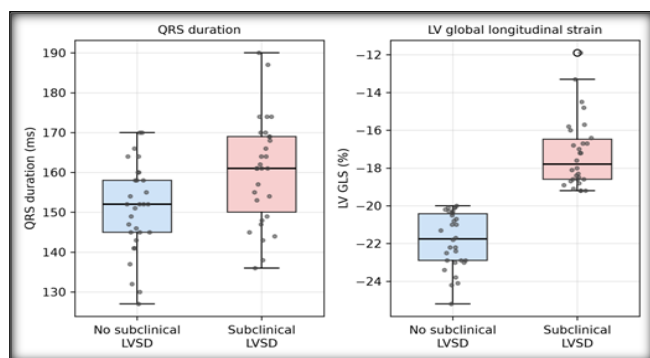


Figure 2: QRS duration and left ventricular global longitudinal strain by group.

Correlation with LV global longitudinal strain: QRS duration correlated moderately with LV GLS ($r = +0.561$, 95% CI +0.358 to +0.713, $p < 0.001$; [Figure 4]), such that each 10 ms increment in QRS duration was associated with an approximately 1.2 percentage-point deterioration in strain. R-wave peak time ($r = +0.295$, $p = 0.022$) and the uncorrected QT interval ($r = +0.294$, $p = 0.023$) showed weaker but significant correlations; the QTc interval, QRS-T angle, heart rate, PR interval, QRS axis and notching extent did not correlate significantly. Among non-

electrocardiographic variables, interventricular mechanical delay showed the strongest correlation of any parameter measured ($r = +0.644$, $p < 0.001$), followed by Ts-Diff ($r = +0.513$), Ts-SD ($r = +0.481$) and LV mass index ($r = +0.382$, $p = 0.003$), consistent with the electrocardiogram providing an indirect estimate of a mechanical dyssynchrony process that is measured directly by echocardiography.

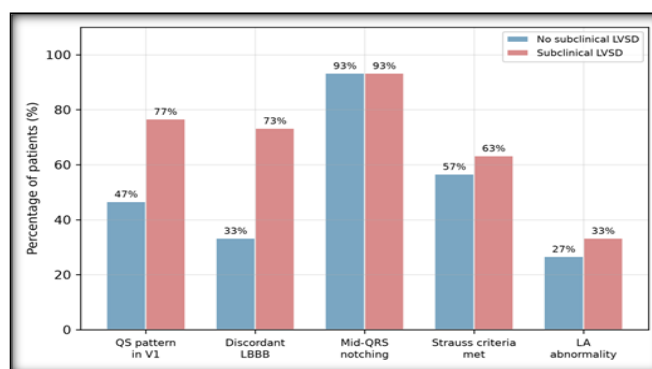


Figure 3: Prevalence of categorical electrocardiographic markers (QS pattern in V1, discordant LBBB, mid-QRS notching, Strauss criteria) by group.

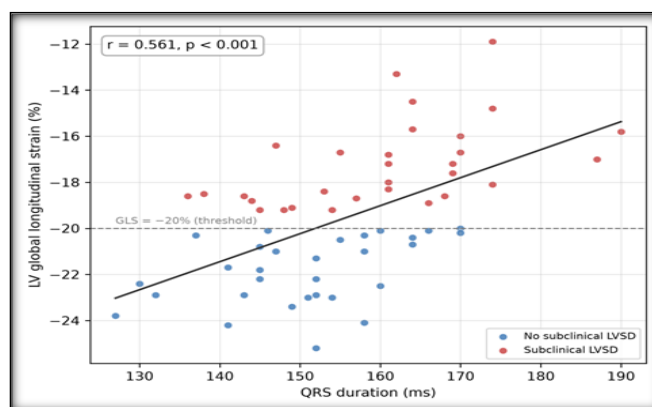


Figure 4: Relationship between QRS duration and left ventricular global longitudinal strain (Pearson $r = +0.561$, $p < 0.001$).

Diagnostic performance: QRS duration gave an AUC of 0.708 (95% CI 0.575–0.841, $p = 0.002$) for subclinical LVSD, with an optimal Youden cut-off of ≥ 161 ms (sensitivity 60.0%, specificity 83.3%, accuracy 71.7%). The QRS-T angle gave an AUC of 0.671 ($p = 0.022$); R-wave peak time, QTc interval, PR interval and notching extent were not significant discriminators [Table 3, Figure 5]. As binary tests, discordant LBBB achieved the best single-

marker accuracy (70.0%; sensitivity 73.3%, specificity 66.7%), while a QS pattern in V1 gave 65.0% accuracy. A combined model of QRS duration, QS pattern in V1 and discordant LBBB achieved an AUC of 0.833 (95% CI 0.726–0.941, $p < 0.001$), significantly better than QRS duration alone (DeLong $p = 0.039$), with sensitivity 83.3%, specificity 76.7%, positive predictive value 78.1% and negative predictive value 82.1%.

Table 3: Diagnostic performance of electrocardiographic parameters for subclinical LVSD

Parameter	AUC (95% CI)	Cut-off	Sn (%)	Sp (%)	Acc (%)
QRS duration (ms)	0.708 (0.575–0.841)	≥ 161	60.0	83.3	71.7
R-wave peak time, V5–V6 (ms)	0.635 (0.494–0.776)	≥ 66	86.7	36.7	61.7
QRS-T angle ($^{\circ}$)	0.671 (0.525–0.817)	≥ 125	48.1	85.2	66.7
QTc interval (ms)	0.557 (0.407–0.706)	≥ 485	20.0	100.0	60.0
QS pattern in V1 (binary)	—	present	76.7	53.3	65.0
Discordant LBBB (binary)	—	present	73.3	66.7	70.0
Combined model (QRS + QS-V1 + discordant LBBB)	0.833 (0.726–0.941)	—	83.3	76.7	80.0

AUC = area under the receiver operating characteristic curve; Sn = sensitivity; Sp = specificity; Acc = accuracy. The combined model discriminated significantly better than QRS duration alone (DeLong $p = 0.039$).

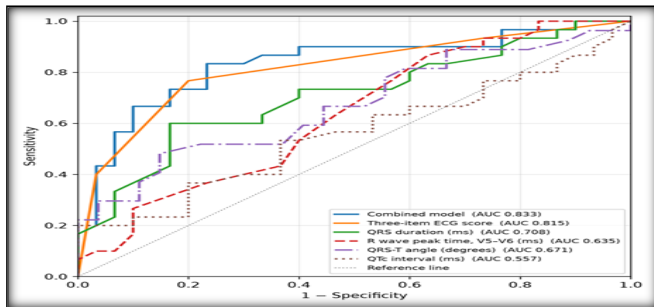


Figure 5: Receiver operating characteristic curves for electrocardiographic parameters and the combined model in the prediction of subclinical left ventricular systolic dysfunction.

Independent predictors and a simple bedside score: On univariable logistic regression, discordant LBBB (OR 5.50, $p = 0.003$), QRS duration per ms (OR 1.069, $p = 0.007$), QS pattern in V1 (OR 3.76, $p = 0.019$), QRS-T angle per degree (OR 1.027, $p = 0.027$) and R-wave peak time per ms (OR 1.125, $p = 0.034$) reached $p < 0.10$; no demographic or clinical variable did. In a multivariable model restricted to three predictors (30 events), discordant LBBB (aOR 6.76, 95% CI 1.82–25.10, $p = 0.004$) and QRS duration (aOR 1.080 per ms, 95% CI 1.024–1.139, $p = 0.005$) remained independently associated with subclinical LVSD; QS pattern in V1 did not retain independent significance (aOR 2.98, 95% CI 0.83–10.75, $p = 0.096$). Model discrimination was good (AUC 0.833) and calibration satisfactory (Hosmer-Lemeshow $\chi^2 = 5.04$, $p = 0.753$).

[Table 4] shows a simple additive score, awarding one point each for QRS duration ≥ 161 ms, a QS pattern in V1, and discordant LBBB (range 0–3). Of 13 patients scoring 3 points, 12 (92.3%) had subclinical LVSD, versus 2 of 10 (20.0%) scoring 0. The score achieved an AUC of 0.815 (95% CI 0.709–0.921, $p < 0.001$); a threshold of ≥ 2 points gave 76.7% sensitivity and 80.0% specificity (accuracy 78.3%), and ≥ 3 points gave 96.7% specificity at the cost of sensitivity (40.0%). As the score was derived and evaluated in the same cohort, these figures are optimistic and require independent validation.

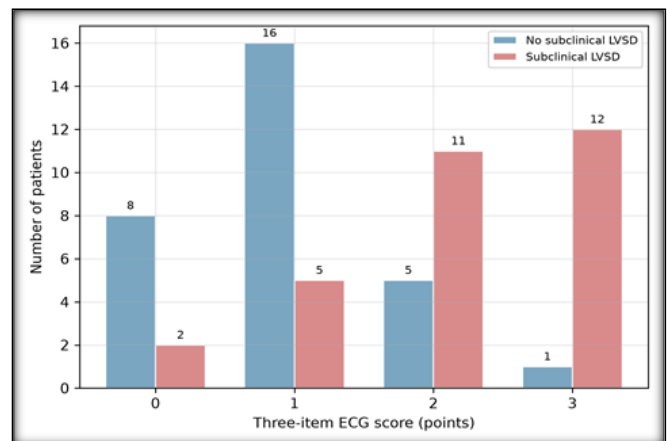


Figure 6: Distribution of the three-item electrocardiographic score by group.

Table 4: Multivariable predictors of subclinical LVSD and performance of a three-item electrocardiographic score

Multivariable predictor		Adjusted OR (95% CI)	p value
Discordant LBBB		6.759 (1.820–25.098)	0.004
QRS duration (per ms)		1.080 (1.024–1.139)	0.005
QS pattern in lead V1		2.978 (0.825–10.754)	0.096
Score (0–3 points)	Subclinical LVSD, n	No subclinical LVSD, n	% with subclinical LVSD
0	2	8	20.0
1	5	16	23.8

2	11	5	68.8
3	12	1	92.3

Model: $n=60$, 30 events; likelihood-ratio $p<0.001$; McFadden pseudo- $R^2=0.280$; AUC 0.833 (0.726–0.941). Score: one point each for QRS duration ≥ 161 ms, QS pattern in V1, and discordant LBBB; AUC 0.815 (0.709–0.921), $p<0.001$; derived and tested in the same cohort.

DISCUSSION

In this prospective study of 60 Indian patients with complete LBBB and preserved LVEF, five ECG characteristics — QRS duration, a QS pattern in lead V1, discordant LBBB, R-wave peak time in the lateral precordial leads, and the QRS-T angle — distinguished patients with strain-defined subclinical LVSD from those without. On multivariable analysis, only QRS duration and discordant LBBB remained independently associated with subclinical dysfunction. No single variable was sufficiently discriminatory to be used alone: QRS duration alone gave an AUC of 0.708, whereas combining it with the two morphological markers raised the AUC to 0.833 (sensitivity 83.3%, specificity 76.7%), a significant improvement (DeLong $p = 0.039$). The electrocardiogram in this population is therefore useful when interval and morphological information are combined, and of limited value when QRS duration is used alone.

The mechanistic explanation is straightforward. QRS duration in LBBB reflects the extent of slow, cell-to-cell conduction replacing normal Purkinje activation, and a longer QRS complex implies a longer interval between septal and lateral wall contraction — precisely the interval that generates wasted myocardial work, abnormal regional load and reduced longitudinal shortening. This chain of reasoning is supported by the observation that interventricular mechanical delay correlated more strongly with strain ($r = +0.644$) than QRS duration did ($r = +0.561$): the electrocardiogram appears to provide an indirect estimate of a mechanical delay that the echocardiogram measures directly. A QS pattern in V1 indicates complete failure of left-sided septal activation, and T-wave/ST discordance reflects an abnormal repolarisation sequence proportional to the degree of activation delay; both are, in effect, qualitative surrogates for the severity of the conduction defect that can be read from a printed tracing without measurement, which explains why they retained value in a model already containing QRS duration.

Two negative findings merit emphasis. Mid-QRS notching, present in 93.3% of both groups, was a defining feature of this LBBB cohort rather than a discriminating one, and the Strauss criteria — designed to select candidates for resynchronisation therapy — did not distinguish patients by strain status (63.3% vs 56.7%, $p = 0.598$). These findings clarify that stricter definitions intended to identify complete conduction block for device selection are not interchangeable with markers of myocardial consequence.

The present findings closely reproduce those of Li and colleagues, the only comparable published study, who reported longer QRS duration, a higher prevalence of QS patterns and more frequent discordant LBBB among 111 Chinese patients with subclinical LVSD.^[13] The direction of

every association was identical in this independent, ethnically and geographically distinct population, which is strong evidence that these associations are real rather than artefacts of local measurement practice. Quantitatively, however, the optimal QRS duration cut-off differed (161 ms here vs 153 ms in the Chinese cohort); applying the 153 ms threshold to the present data reproduced sensitivity almost exactly (73.3%) but specificity was 13 percentage points lower, most plausibly reflecting differences in body size, ventricular mass and age at presentation between the two populations. This finding directly supports the rationale for the present study: electrocardiographic thresholds derived in one population should not be transferred to another without local verification. Combined discriminatory performance was nonetheless similar across both cohorts (AUC 0.833 here vs 0.82 in Li et al.), suggesting that the ceiling for conventional ECG measurement in this setting lies near an AUC of 0.8.

The findings are also consistent with earlier work showing that markers of dyssynchronous contraction (septal flash, mechanical dispersion) predict reduced GLS in LBBB with preserved EF.^[14,15] and with the demonstration in heart failure with preserved ejection fraction that longitudinal systolic and early diastolic function are impaired together despite a normal ejection fraction.^[20,21] In the present cohort, patients with subclinical LVSD had a significantly lower average early diastolic mitral annular velocity (e') despite comparable E/A and E/ e' ratios, consistent with shared involvement of subendocardial longitudinal fibres in both systole and early diastole.

Clinical implications: These results support a defined and limited role for the ECG in this population: as a triage test to decide who should be referred for strain imaging, not as a substitute for it. A patient with complete LBBB and a normal LVEF whose ECG shows two or more of a QRS duration ≥ 160 ms, a QS pattern in V1, and discordant LBBB should be considered for referral for speckle-tracking echocardiography; a patient with none of these features has an approximately one-in-five probability of subclinical dysfunction and may reasonably be followed clinically. In settings without access to strain imaging — which describes most district-level cardiac services in India — the same features could guide referral to a tertiary centre. Because all three features are already visible on every ECG recorded in patients with LBBB, we suggest that ECG reports in this population routinely state QRS duration, the presence or absence of a QS pattern in V1, and T-wave concordance/discordance, at no additional cost.

Strengths and limitations: Strengths of this study include its prospective design with a pre-specified strain threshold, measurement by a single investigator using a single protocol and platform, well-matched comparison groups, and reporting of diagnostic performance with confidence intervals and formal AUC comparison. Several limitations should be considered. The study was conducted at a single tertiary referral centre, and

findings may not generalise to unselected or community populations. The sample size, calculated to detect a difference in mean GLS, was underpowered for precise estimation of an optimal ROC cut-off, and the wide confidence interval around the QRS duration AUC (0.575–0.841) reflects this. The cross-sectional design precludes any statement about whether patients with subclinical LVSD progress to overt heart failure. Coronary disease was excluded clinically rather than by angiography, intra-/inter-observer reproducibility was not formally assessed, and the three-item score was derived and evaluated in the same cohort and therefore requires external validation before clinical use. Finally, dichotomising a continuous strain variable at –20% necessarily degrades apparent test performance for patients near the threshold, who are, for practical purposes, physiologically similar regardless of group assignment.

Future directions: Prospective longitudinal follow-up of this and similar cohorts is needed to establish whether ECG-identified subclinical LVSD predicts progression to overt heart failure. Internal (bootstrap) and external validation of the three-item score, ideally in a multicentre Indian study, would clarify whether the optimal QRS threshold is stable across populations or must be derived locally. Larger studies would permit fuller multivariable models incorporating the QRS-T angle and R-wave peak time, and comparison with deep-learning ECG models could quantify how much additional information is recoverable beyond manual caliper measurement.^[27,29]

CONCLUSION

In patients with complete LBBB and a normal left ventricular ejection fraction, QRS duration, a QS pattern in lead V1, discordant LBBB, R-wave peak time and the QRS-T angle are each associated with strain-defined subclinical left ventricular systolic dysfunction, with QRS duration and discordant LBBB independently so. No single ECG parameter is accurate enough to be used alone, but a combination of three simple, routinely visible features identifies subclinical dysfunction with a sensitivity of 83.3% and a specificity of 76.7%. The electrocardiogram is therefore best regarded as a low-cost triage tool to prioritise referral for speckle-tracking echocardiography in this population, rather than a substitute for deformation imaging. Because the optimal cut-off identified here (161 ms) differs from that reported outside India (153 ms), thresholds should be locally verified before adoption, and prospective validation of the proposed score is required before clinical use.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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