Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(3), 1203-1209 | ISSN:2251-6727

Diagnostic Accuracy of the Electrocardiography Criteria for Left Ventricular Hypertrophy in Comparison with Echocardiography in Hypertensives

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(Received: 16 March 2025 Revised: 20 April 2025 Accepted: 01 May2025)

KEYWORDS

Left Ventricular Hypertrophy, Hypertension, Electrocardiography, Echocardiography, Diagnostic Accuracy, Concentric LVH, Eccentric LVH.

ABSTRACT:

Background: Electrocardiography (ECG) and echocardiography (ECHO) are routinely employed to detect LVH. ECG, although widely accessible and non-invasive, demonstrates variable sensitivity and specificity. Echocardiography remains the diagnostic gold standard due to its superior capability in visualizing cardiac structure and quantifying left ventricular mass with higher accuracy.

Objective: To assess the diagnostic performance of various ECG criteria in detecting LVH among hypertensive individuals and to compare these findings with echocardiographic results, thereby determining the reliability of ECG in relation to ECHO.

Methods: A cross-sectional study was conducted at Aarupadai Veedu Medical College and Hospital between June 2022 and June 2024, involving 170 patients diagnosed with hypertension. Inclusion was limited to hypertensive patients with echocardiographically confirmed LVH, while individuals with valvular heart disease, hypertrophic obstructive cardiomyopathy, anemia, or thyrotoxicosis were excluded.

Results: The majority of participants (45.3%) were within the 51–60-year age group. Among the ECG criteria assessed, Sokolow-Lyon (35.2%) and Cornell Voltage (32.3%) were most frequently indicative of LVH. Echocardiographic analysis revealed concentric LVH in 67.1% of patients and eccentric LVH in 32.9%. ECG failed to detect several cases confirmed by ECHO, underscoring the limitations of ECG in isolation. No statistically significant associations were observed between LVH findings and other clinical variables.

Conclusion: LVH is commonly observed in hypertensive patients, especially in those aged 51–60 years, with concentric LVH being more prevalent. Although ECG serves as a useful initial screening tool, its limited sensitivity necessitates the use of echocardiography for definitive diagnosis. Integrating ECG with ECHO enhances diagnostic precision and facilitates better clinical management of hypertensive patients at risk of LVH.

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JCHR (2025) 15(3), 1203-1209 | ISSN:2251-6727

Introduction

Left Ventricular Hypertrophy (LVH) refers to the pathological thickening of the left ventricular wall and is a frequent consequence of long-standing hypertension. It substantially increases the risk of adverse cardiovascular outcomes, including heart failure, myocardial infarction, and sudden cardiac death. Timely and precise identification of LVH is vital in the clinical management of hypertensive individuals to prevent such complications. LVH represents an adaptive response of the myocardium to increased arterial pressure and serves as an early manifestation of hypertensive heart disease. It occurs in approximately 15–20% of patients with hypertension and functions as an independent predictor of cardiovascular outcomes, regardless of other risk factors.[1] The presence of LVH has been shown to elevate the risk of cardiovascular disease by five to ten times in individuals with hypertension.[2] Consequently, its early and accurate detection is essential for guiding treatment strategies in hypertensive patients.[3]

Electrocardiography (ECG) and echocardiography are commonly employed diagnostic tools for the detection of LVH. ECG, a widely accessible, low-cost, and non-invasive test, records the heart's electrical activity and is endorsed in international clinical guidelines as a primary screening tool for LVH.[4] Multiple ECG criteria, including the Sokolow-Lyon index and Cornell voltage, have been established to identify LVH. Nevertheless, ECG's diagnostic sensitivity and specificity can vary significantly depending on factors such as body composition, sex, and other comorbidities.[5]

Identifying the precise etiology of LVH presents a clinical challenge. Traditionally, LVH has been classified based on the relative wall thickness (RWT), calculated as the ratio of left ventricular wall thickness to chamber diameter. According to this criterion, LVH is categorized as concentric when RWT is elevated and eccentric when it is not. Despite its frequent use, this method has notable limitations, particularly its failure to account for left ventricular dilation, an important element of geometric remodeling. A more refined classification system has recently been proposed using cardiac magnetic resonance (CMR) imaging, which incorporates both left ventricular end-diastolic volume (EDV) and the concentricity index as a measure of wall thickness. This system subdivides eccentric hypertrophy into dilated and indeterminate forms based on LV volume, and concentric hypertrophy into thick and thick-dilated subtypes. The four-tiered classification of LVH, which incorporates both wall thickness and EDV, allows for improved risk stratification. It has been demonstrated that patients with dilated or thick-dilated forms of LVH have a heightened risk of heart failure and cardiovascular death.[6]

Hypertension (HTN), a major modifiable risk factor for cardiovascular morbidity and mortality, often coexists with other conditions such as chronic kidney disease (CKD), obesity, hyperlipidemia, diabetes mellitus (DM), and tobacco use. Among the target organs affected by HTN, the left ventricle (LV) is the most frequently involved.[7] Hypertension-induced LV remodeling is typically associated with three geometric patterns: concentric remodeling (CR), concentric LVH (cLVH), and eccentric LVH (eLVH).[8] Echocardiography, in contrast to ECG, offers a comprehensive evaluation of cardiac morphology and function. As the gold standard in LVH detection, it allows direct measurement of left ventricular wall thickness and chamber geometry. However, it requires specialized equipment and trained operators, making it more resource-dependent than ECG.[9]

The present study is undertaken to assess the diagnostic accuracy of different ECG criteria in the detection of LVH among hypertensive patients and to compare these findings with echocardiographic evaluations.

Materials and Methods

The present study was designed as a cross-sectional investigation and was conducted over a two-year period from June 2022 to June 2024 at Aarupadai Veedu Medical College and Hospital, within the Departments of General Medicine and Cardiology. The study population consisted of hypertensive patients attending both outpatient and inpatient services of these departments. Prior to participation, written informed consent was obtained from all individuals. Ethical clearance was granted by the Institutional Human Ethics Committee of Aarupadai Veedu Medical College and Hospital, Kirumampakkam, Puducherry, under the approval number IHEC No.AV/IHEC/2022/081. Patients included in the study were required to have a confirmed diagnosis of left ventricular hypertrophy (LVH) by echocardiography (ECHO). Exclusion criteria encompassed the presence of

Journal of Chemical Health Risks

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JCHR (2025) 15(3), 1203-1209 | ISSN:2251-6727

valvular heart disease, hypertrophic obstructive cardiomyopathy (HOCM), anemia, or thyrotoxicosis.

The sample consisted of 170 patients, determined based on a similar study conducted by Bayram et al. in 2021,[10] and participants were selected using consecutive sampling. Data collection involved obtaining detailed demographic profiles, clinical history, and physical examination findings, followed by electrocardiography (ECG) and echocardiography for all participants. For patients diagnosed with LVH via ECHO, various ECG criteria for LVH were subsequently evaluated. Data were systematically recorded using a predesigned proforma.[11]

The data were entered and processed using Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, Version 26.0 (Armonk, NY: IBM Corp. Released 2019). Tests for normality, including the Kolmogorov-Smirnov and Shapiro-Wilk tests, indicated that the dataset did not follow a normal distribution. Accordingly, non-parametric tests were employed for statistical analysis. Descriptive statistics were used to summarize frequencies, percentages, means, and standard deviations of study variables. Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the diagnostic performance of various ECG criteria in detecting LVH. A significance level of 5% ($\alpha = 0.05$) was adopted, and a p-value less than 0.05 was considered statistically significant.

Results

The study population predominantly comprised individuals aged 51–60 years (45.3%), followed by those aged 41–50 years (25.9%). A smaller proportion belonged to the age groups 31–40 years (11.8%), over 60 years (13.5%), and ≤30 years (3.5%). Males constituted a slight majority at 51.8%, with females accounting for 48.2% of the participants. Among the ECG criteria applied, the most frequently observed findings were Sokolow-Lyon (35.2%) and Cornell Voltage (32.3%), while Romhilt-Estes (12.3%), Peguero-Lo Presti (8.8%), and normal ECG (11.1%) were less common. Echocardiographic assessment revealed that 67.1% of patients had concentric LVH, whereas 32.9% had eccentric LVH.

The mean age of the study participants was 51.11 ± 9.45 years, with a range from 26 to 67 years. The average height was 1.70 ± 0.07 meters, and the mean weight was 79.83 ± 8.78 kilograms, resulting in a mean Body Mass Index (BMI) of 27.60 ± 2.62. The duration of hypertension among participants ranged from 2 to 22 years, with a mean of 8.57 ± 4.90 years. The average systolic blood pressure (SBP) was 134.84 ± 11.13 mmHg, and the average diastolic blood pressure (DBP) was 84.83 ± 5.99 mmHg. The mean pulse rate was 74.65 ± 3.92 beats per minute, while the mean oxygen saturation (SpO_2) was 96.77 ± 1.52%. The average body temperature was 36.87 ± 0.22°C, and the mean respiratory rate (RR) was 16.02 ± 1.42 breaths per minute.

Spearman's correlation analysis revealed no statistically significant associations between ECG findings and the clinical or physiological parameters assessed. The correlation values between ECG and variables such as height ($r = 0.072$), weight ($r = 0.110$), BMI ($r = 0.058$), duration of hypertension ($r = 0.003$), systolic blood pressure ($r = 0.000$), diastolic blood pressure ($r = 0.002$), pulse rate ($r = 0.006$), SpO_2 ($r = -0.011$), temperature ($r = 0.065$), and respiratory rate ($r = -0.024$) were all weak and statistically non-significant, with p-values greater than 0.05 in each case.

Spearman's correlation analysis showed no statistically significant relationship between echocardiographic findings and the evaluated clinical parameters. The correlation between ECHO and ECG findings was weak and non-significant ($r = -0.018$, $p = 0.818$). Similarly, no significant associations were observed between ECHO and height ($r = -0.031$), weight ($r = -0.017$), BMI ($r = 0.054$), duration of hypertension ($r = -0.126$), systolic blood pressure ($r = -0.128$), diastolic blood pressure ($r = -0.101$), pulse rate ($r = -0.090$), SpO_2 ($r = -0.029$), temperature ($r = -0.067$), or respiratory rate ($r = 0.065$), with all p-values exceeding 0.05.

Discussion

The present study aimed to determine the prevalence and characteristics of left ventricular hypertrophy (LVH) in hypertensive individuals, utilizing both electrocardiography (ECG) and echocardiography (ECHO) as diagnostic modalities. It also examined potential correlations between ECG findings and various clinical parameters. The study population exhibited a broad age distribution, with the highest proportion of participants aged between 51 and 60 years (45.3%). This finding is consistent with that of Pedersen et al. (2020),

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who reported that hypertensive complications predominantly affect middle-aged to older adults.[12] The gender distribution was nearly equal, with 51.8% males and 48.2% females, allowing generalizability of results across both sexes. Notably, the study by Pedersen et al. (2020) included only male participants, but similarly reported a slightly higher male representation.[12]

The mean age was 51.11 ± 9.45 years, and the mean body mass index (BMI) was 27.60 ± 2.62, indicating a predominantly overweight cohort. In contrast, Pedersen et al. (2020) observed a lower average BMI in their study population.[12] Mean systolic and diastolic blood pressures were 134.84 ± 11.13 mmHg and 84.83 ± 5.99 mmHg, respectively, suggesting relatively well-controlled hypertension. These values were higher than those reported by Pedersen et al. (2020), who found lower average systolic and diastolic pressures among their study participants.[12]

Among the ECG criteria evaluated, Sokolow-Lyon (35.2%) and Cornell Voltage (32.3%) were most commonly observed. However, 11.1% of participants demonstrated normal ECG readings despite having echocardiographic evidence of LVH, highlighting the limitations of ECG as a standalone diagnostic tool. Echocardiographic evaluation showed a predominance of concentric LVH (67.1%) over eccentric LVH (32.9%), which is consistent with the expected remodeling pattern associated with chronic hypertension, where the myocardium thickens concentrically in response to increased afterload.

No statistically significant correlations were found between ECG findings and clinical parameters such as height, weight, BMI, duration of hypertension, blood pressure, pulse rate, oxygen saturation (SpO_2), temperature, or respiratory rate. Similarly, ECHO findings did not demonstrate significant associations with these variables, suggesting that neither ECG nor ECHO findings were strongly influenced by these specific clinical factors in the detection of LVH.[13]

The results align with existing literature highlighting the limited sensitivity of ECG for LVH detection when compared to echocardiography.[14] Ngabea et al. (2023) found that although ECG criteria like Cornell Voltage, Sokolow-Lyon, and Massoleini demonstrated diagnostic value, echocardiography remained more reliable for identifying LVH in hypertensive patients.[15] Kharel et al. (2024) similarly reported that the Cornell Voltage duration criterion exhibited superior sensitivity and area under the curve (AUC) compared to other ECG criteria.[16] Wang et al. (2020) reported that among Chinese hypertensive patients, ECG criteria had high specificity but low sensitivity, and that combining multiple ECG criteria improved diagnostic yield without sacrificing specificity.[17] Conversely, Kothendaraman et al. (2023) found that ECG criteria were inconsistent and generally unreliable in detecting LVH among high-risk Indian adults.[18] Notably, Tavares et al. (2021) demonstrated that the Peguero-Lo Presti criterion offered better diagnostic performance in elderly hypertensive populations, with higher sensitivity and specificity than conventional ECG criteria, underlining the importance of accurate LVH detection in this age group for effective cardiovascular risk management.[19,20]

Conclusion

The present study underscores the prevalence and characteristics of left ventricular hypertrophy (LVH) among hypertensive individuals, utilizing both electrocardiography (ECG) and echocardiography (ECHO) for evaluation. The findings indicate that LVH is most frequently observed in the 51–60-year age group, with concentric hypertrophy being more prevalent than eccentric. Although ECG was able to detect LVH in a significant number of cases, it failed to identify some, highlighting the superior diagnostic accuracy of echocardiography. These results are consistent with existing evidence supporting ECHO as a more reliable modality for LVH detection, particularly in older adults. The integration of both ECG and ECHO can improve diagnostic precision and aid in the effective management of hypertension and its cardiac complications.

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Table 1: Characteristics of the study participants (categorial variables)

		Frequency	**Percentage**
Age group	≤30 yrs	6	3.5
	31 – 40 yrs	20	11.8
	41 – 50 yrs	44	25.9
	51 – 60 yrs	77	45.3
	>60 yrs	23	13.5
Gender	Male	88	51.8
	Female	82	48.2
ECG findings	Cornell Voltage	55	32.3
	Sokolow Lyon	60	35.2
	Normal ECG	19	11.1
	Peguero Lo Presti	15	8.8
	Romhilt Estes	21	12.3
ECHO findings	Concentric LVH	114	67.1
	Eccentric LVH	56	32.9

Table 2: Characteristics of the study participants (continuous variables)

	Minimum	**Maximum**	**Mean ± SD**
Age	26.00	67.00	51.11 ± 9.45
Height in meters	1.53	1.88	1.70 ± 0.07
Weight in kilograms	54.00	104.00	79.83 ± 8.78
BMI	20.40	36.10	27.60 ± 2.62
Hypertension in yrs	2.00	22.00	8.57 ± 4.90
SBP	108.00	158.00	134.84 ± 11.13
DBP	70.00	99.00	84.83 ± 5.99
Pulse Rate	66.00	85.00	74.65 ± 3.92
SPO2	92.00	99.00	96.77 ± 1.52

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Temp	36.40	37.60	36.87 ± 0.22
RR	14.00	19.00	16.02 ± 1.42

Table 3: Correlation between ECG and other clinical findings

	Spearman's Correlation value	**P value**
ECG vs Height	0.072	0.350
ECG vs Weight	0.110	0.153
ECG vs BMI	0.058	0.455
ECG vs Hypertension	0.003	0.969
ECG vs SBP	0.000	0.999
ECG vs DBP	0.002	0.975
ECG vs Pulse Rate	0.006	0.937
ECG vs SpO2	-0.011	0.886
ECG vs Temp	0.065	0.397
ECG vs RR	-0.024	0.759

Table 4: Correlation between ECHO and other clinical findings

	Spearman's Correlation value	**P value**
ECHO vs ECG	-0.018	0.818
ECHO vs Height	-0.031	0.687
ECHO vs Weight	-0.017	0.826
ECHO vs BMI	0.054	0.482
ECHO vs Hypertension	-0.126	0.102
ECHO vs SBP	-0.128	0.095
ECHO vs DBP	-0.101	0.192
ECHO vs Pulse Rate	-0.090	0.244
ECHO vs SpO2	-0.029	0.711
ECHO vs Temp	-0.067	0.387
ECHO vs RR	0.065	0.397