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Left Ventricular Hypertrophy in Hypertension-Correlation between Electrocardiography and Echocardiography

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Abstract
Hypertension is a prevalent public health issue, often asymptomatic, and frequently associated with left ventricular hypertrophy (LVH). LVH, a response to increased wall stress, is commonly seen in hypertensive individuals and significantly raises the risk of cardiovascular diseases, morbidity and mortality. Various diagnostic methods for LVH, including electrocardiography (ECG) and echocardiography (ECHO), differ in accessibility and accuracy. This study aims to explore the reliability of ECG compared to ECHO in diagnosing LVH among hypertensive patients. The specific objectives are to estimate the efficiency of clinical evaluation and ECG in diagnosing LVH, to compare the reliability of ECG with ECHO and to assess the validity of ECG in diagnosing LVH in these patients. The study was conducted from November 2010 to March 2012 at K.V.G Medical College Hospital, involving 100 patients with essential hypertension. Using a cross-sectional design and simple random sampling, detailed clinical histories, clinical examinations and relevant investigations were performed. ECG and ECHO were used to assess the presence of LVH. The sensitivity, specificity and agreement of three ECG criteria (Sokolow-Lyon index, Romhilt and Estes score and total QRS voltage criteria) were compared against ECHO findings. The prevalence of LVH increased with the duration of hypertension, with an overall prevalence of 60%. Clinical evaluation for LVH had a sensitivity of 30% and specificity of 100%. The Sokolow-Lyon index showed a sensitivity of 40% and specificity of 90%, the Romhilt and Estes score had a sensitivity of 41.2% and specificity of 80%, and the total QRS voltage criteria showed the highest sensitivity (60%) and specificity (92.5%). The total QRS voltage criteria demonstrated the highest accuracy and agreement with ECHO. Echocardiography is the most reliable method for diagnosing LVH. While ECG can serve as an initial screening tool, especially in resource-limited settings, the total QRS voltage criteria showed the highest reliability among the ECG methods. Regular screening and improved access to ECHO are recommended for comprehensive management of hypertensive patients.

INTRODUCTION

Hypertension is a prevalent public health issue, with many patients remaining asymptomatic. Left Ventricular Hypertrophy (LVH) is a heart condition that adapts to increased wall stress and is commonly observed in hypertensive individuals. The prevalence of LVH escalates with age, the severity of hypertension, and the duration of the condition, suggesting prolonged periods of uncontrolled hypertension[1]. Hypertension combined with LVH significantly raises the risk of cardiovascular diseases, morbidity and mortality. Patients with LVH are more susceptible to various cardiovascular diseases, including coronary artery disease, congestive cardiac failure, stroke, ventricular arrhythmias and sudden cardiac death[2,3]. Multiple diagnostic methods for LVH exist, such as electrocardiography (ECG), roentgenography and echocardiography (ECHO). Although ECHO is superior to ECG, it is more expensive and less accessible in rural areas[4,5]. This study aims to explore the reliability of ECG compared to ECHO in diagnosing LVH in hypertensive patients. The objectives are to estimate the efficiency of clinical evaluation and ECG in diagnosing LVH in hypertensive patients, to compare the reliability of ECG with ECHO and to assess the validity of ECG in diagnosing LVH in these patients.

MATERIALS AND METHODS

The study was conducted on patients attending the outpatient department or cardiology clinic and those admitted to the medicine wards of K.V.G Medical College Hospital in Sullia from November 2010-March 2012. A total of 100 patients were included in this cross-sectional study, selected using simple random sampling. Data collection involved detailed clinical histories, clinical examinations and relevant investigations to assess the prevalence and characteristics of left ventricular hypertrophy (LVH) among patients with essential hypertension.

Inclusion criteria for the study were all cases of essential hypertension, regardless of the duration of hypertension or the type of treatment received. Exclusion criteria included secondary hypertension, ischemic heart disease/myocardial infarction, ischemic cardiomyopathy, congenital heart disease and valvular heart disease.

Patients were systematically assigned case numbers, and their demographic details such as name, age, sex, occupation and socio-economic status were recorded. Comprehensive information regarding their current complaints, duration of hypertension, medications used and personal habits like smoking, tobacco use and alcohol consumption were meticulously documented. Additionally, family histories of hypertension and ischemic heart disease were noted. The data collection followed a structured proforma to ensure consistency and completeness.

The clinical examination was thorough, encompassing general examinations including measurements of height, weight, body mass index (BMI) and observations of pallor, clubbing, edema, pulse and jugular venous pressure (JVP). Blood pressure (BP) measurements were taken with the patient seated quietly, with back support for five minutes. Patients were advised to avoid caffeine for the preceding hour, refrain from smoking and not engage in exercise 30 minutes before BP measurement. BP readings were taken from both arms, with the arm supported at heart level. Each BP measurement was based on the mean of two or more readings taken at each of two or more visits following an initial screening. The cardiovascular examination focused on assessing the pulse, the position and character of the apical impulse and auscultatory findings, particularly for the A2 sound. Other system examinations included a fundus examination.

Laboratory investigations included blood tests for hemoglobin percentage (Hbg%), total counts (TC), differential counts (DC), blood urea, serum creatinine, and random blood sugar (RBS). Urine analyses for albumin, sugar and microscopy were performed. Imaging studies included chest X-rays and electrocardiograms (ECG). Echocardiograms (2D ECHO) with color Doppler and continuous wave Doppler were also conducted.

For the electrocardiographic assessment, a standard 12-lead ECG was obtained for all patients. Specific variables noted included the electrical axis, voltage of R, S, or Q waves in all leads, duration of QRS complexes, intrinsicoid deflection in V5 and V6 and ST-T changes. The P terminal force in V1 was also recorded[6]. Three main electrocardiographic criteria were employed: the Sokolow-Lyon index, the Romhilt and Estes score and total QRS voltage criteria. The Sokolow-Lyon index considered significant if the sum of S in V1 and R in V5 or V6 was greater than 35 mm. The Romhilt and Estes score, which includes variables such as R or S in limb leads, S in V1, V2, V3, R in V4, V5, V6, any ST shift without digitalis effect, typical strain ST-T with digitalis, left axis deviation of -15 degrees or more, QRS interval of 0.09 seconds or more, intrinsicoid deflection in V5 or V6 greater than 0.04 seconds, and P terminal force greater than 0.04 seconds, was used to score left ventricular hypertrophy with a total score of 13 points (a score of 5 or more indicating LVH and 4 indicating probable LVH)[7]. The total QRS voltage was calculated by adding the QRS amplitude in each lead in the 12-lead ECG, with a total QRS voltage of 174 mm considered normal and any value of 175 mm or more indicating significant LVH[8].

Echocardiographic studies involved combined M-mode and two-dimensional echocardiography using 2D ECHO with color Doppler and continuous wave Doppler. Multiple tomographic planes were utilized,

including parasternal views of the left ventricle in both long and short axes, apical four-chamber and long-axis views, and subcostal four-chamber and short-axis views. M-mode measurements were taken using the leading-edge to leading-edge technique as recommended by the American Society of Echocardiography, averaging measurements from three good quality cardiac cycles[9]. The left ventricular posterior wall and septum were measured at the time of atrial depolarization before the onset of the notch. The left ventricular internal dimension was measured at the level of the chordae tendineae. An average septal thickness of 1.1 cm was considered normal, with any value above this threshold taken as evidence of LVH[10].

Statistical Methods: Data was analyzed using SPSS 17 version software (IBM SPSS Statistics, Somers NY, USA). Categorical data was represented in the form of Frequencies and proportions. Chi-square test was used as test of significance for qualitative data. Continuous data was represented as mean and standard deviation. Validity of Screening test [ECG Criterias] was determined by sensitivity, specificity in comparison with ECHO findings. Kappa Statistics: Agreement between two or more methods or instruments and was assessed by using Kappa statistics. P<0.05 was considered as statistically significant after assuming all the rules of statistical tests.

RESULTS AND DISCUSSIONS

The study involved 100 patients with essential hypertension, distributed across various age groups and gender, to assess the prevalence and characteristics of left ventricular hypertrophy (LVH). The age distribution was as follows: 24% were aged 40-49 years, 19% were aged 50-59 years, 34% were aged 60-69 years, 17% were aged 70-79 years and 6% were aged 80 years or older. The gender distribution showed that 59% were males and 41% were females. Smoking history was present in 50% of the participants, while 47% had a family history of hypertension. The duration of hypertension varied among the participants, with 27% having hypertension for 0-5 years, 35% for 6-10 years, 22% for 11-15 years, 10% for 16-20 years and 6% for >20 years [Table 1].

The prevalence of LVH with respect to the duration of hypertension was notable. Among patients with hypertension for 0-5 years, 7.4% had LVH. For those with hypertension for 6-10 years, 65.7% had LVH. The prevalence increased significantly for patients with hypertension for 11-15 years, with 95.4% having LVH. For those with 16-20 years of hypertension, 80% had LVH, and all patients with hypertension for more than 20 years had LVH, leading to an overall prevalence of 60% for LVH among the hypertensive patients [Table 2].

The clinical evaluation for LVH showed a sensitivity of 30% and a specificity of 100%, with a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 48.78%. The accuracy of clinical evaluation was 58%, with a Kappa measure of agreement of 0.25, indicating fair agreement. Out of the 100 patients, 18 were clinically diagnosed with LVH, all of whom were confirmed by echocardiography ($p < 0.001$). However, 42 patients who were clinically negative for LVH had positive findings on echocardiography, while 40 patients were negative by both methods.

The ECG-based diagnostic criteria for LVH showed varied performance compared to echocardiography. Using the Sokolow-Lyon index, 28 patients were diagnosed with LVH, of which 24 were confirmed by echocardiography. This criterion had a sensitivity of 40%, specificity of 90%, PPV of 85.7%, NPV of 50%, accuracy of 60% and a Kappa measure of agreement of 0.27. The Romhilt and Estes criteria diagnosed LVH in 36 patients, with 28 confirmed by echocardiography. This method had a sensitivity of 41.17%, specificity of 80%, PPV of 77.78%, NPV of 53.3%, accuracy of 60%, and a Kappa measure of agreement of 0.24. The total QRS voltage criteria identified LVH in 39 patients, with 36 confirmed by echocardiography, showing a sensitivity of 60%, specificity of 92.5%, PPV of 92.3%, NPV of 60.6%, accuracy of 73% and a Kappa measure of agreement of 0.49.

This study sought to compare the efficacy of three electro cardiographic (ECG) criteria-Sokolow-Lyon index, Romhilt and Estes score and total QRS voltage criteria-in diagnosing left ventricular hypertrophy (LVH) among hypertensive patients, using echocardiography (ECHO) as the diagnostic standard. Our findings indicate variable sensitivity and specificity among the ECG criteria, underscoring the complexity of accurately diagnosing LVH with non-invasive methods.

Sokolow-Lyon Criteria: The Sokolow-Lyon index, established in 1949, remains one of the most commonly used and straightforward methods for detecting LVH via ECG. In this study, the Sokolow-Lyon index demonstrated a sensitivity of 40% and a specificity of 90%, with a positive predictive value (PPV) of 85.7% and a negative predictive value (NPV) of 50%. The overall accuracy was 60% and the Kappa measure of agreement with ECHO was 0.27, indicating poor agreement. When compared to previous studies, our results align closely with those reported by Murphy *et al.* (1985), who found a sensitivity of 60% and a specificity of 80%[1]. Reichek and Devereux (1981) reported a lower sensitivity of 21% but a higher specificity of 95%[2]. Other studies, such as those by Denarie *et al.* (1998) and Norman *et al.* (1995), found sensitivities of 20% and 30%, respectively and specificities of 90% and 86%[3,4]. These variations

Table 1: 100 patients with essential hypertension, distributed across various age groups and gender, to assess the prevalence and characteristics of left ventricular hypertrophy (LVH)

		Frequency (n =100)	Percentage
Age	40-49	24	24%
	50-59	19	19%
	60-69	34	34%
	70-79	17	17%
	≥80	06	06%
Gender	Males	59	59%
	Females	41	41%
H/o Smoking	Present	50	50%
Family H/O hypertension	Present	47	47%
Duration of Hypertension (years)	0-5	27	27%
	6-10	35	35%
	11-15	22	22%
	16-20	10	10%
	>20	6	6%

Table 2: Prevalence of LVH With Respect To Duration of Hypertension

Duration of Hypertension (years)	Number of patients with HTN	Number of patients having LVH among Hypertensive in 2D echo
0-5	27	2 (7.4%)
6-10	35	23 (65.7%)
11-15	22	21(95.4%)
16-20	10	8 (80%)
>20	6	6 (100%)
Total	100	60 (60%)

Table 3: Association between Clinical Detection of LVH and ECHO Diagnosis

	ECHO			
Clinical evaluation	Positive	Negative	Total	p-value
Positive	18	0	18	<0.001*
Negative	42	40	82	
Total	60	40	100	

Table 4: LVH diagnosis by ECG Criteria's and ECHO Findings

		ECHO		
		Positive	Negative	Total
ECG [Sokolow-Lyon Index]	Positive	24	4	28
	Negative	36	36	72
ECG [Romhilt And Estes Criteria]	Positive	28	8	36
	Negative	32	32	64
Total Qrs Voltage Criteria	Positive	36	3	39
	Negative	24	37	61

highlight the inconsistent performance of the Sokolow-Lyon index across different populations and study designs. Several factors contribute to the limitations of the Sokolow-Lyon index. For instance, the criteria may be affected by patient characteristics such as chest wall thickness, which tends to be higher in women, reducing precordial QRS voltage[5]. Additionally, conditions like left anterior hemiblock can result in abnormally high voltage in leads I and aVL, while regional wall motion abnormalities and intraventricular conduction delays, such as left bundle branch block, can also influence voltage measurements[6,7].

Romhilt and Estes Point Score System: The Romhilt and Estes point score system, introduced in 1968, involves a more complex scoring method based on various ECG parameters. In our study, this criteria showed a sensitivity of 41.2% and a specificity of 80%, with a PPV of 77.78% and an NPV of 53.3%. The overall accuracy was 60% and the Kappa measure of agreement was 0.24, indicating poor agreement with ECHO. Comparing our findings to earlier studies, Reichek and Devereux (1981) reported a sensitivity of 50% and specificity of 95%[2]. Murphy *et al.* (1985) found a sensitivity of 60% and specificity of 90%[1]. Devereux and Casale (1985) reported similar findings with a sensitivity of 48% and specificity of 85%[8]. More recent studies, such as those by Denarie *et al.* (1998) and Waqas Hameed *et al.* (2005), reported sensitivities of 20% and 35%, respectively, and specificities of 90% in both studies[3,9]. The variability in these results again underscores the challenges in using ECG criteria to diagnose LVH consistently. The Romhilt and Estes criteria's performance can be influenced by similar factors affecting the Sokolow-Lyon index. Additionally, its complexity in data acquisition and scoring may introduce variability depending on the examiner's experience and precision[10].

Total QRS Voltage Criteria: The total QRS voltage criteria, developed by Roberts *et al.,* uses the sum of QRS voltages across all 12 ECG leads, with a total voltage greater than 175 mm indicative of LVH. In this study, this criteria showed the highest sensitivity at 60% and specificity at 92.5%, with a PPV of 92.3% and an NPV of 60.6%. The overall accuracy was 73% and the Kappa measure of agreement was 0.49, indicating

fair agreement with ECHO. Previous studies have shown varying results. William C. Roberts (1992) reported a sensitivity of 71% and specificity of 90%[11]. Roman MJ (1995) reported a sensitivity of 50%[12]. Christian Jaggy *et al.* (2000) found a sensitivity of 42% and specificity of 78%[13]. Tarooqwaseem *et al.* (2003) reported a sensitivity of 34%[14]. Our study's results demonstrate higher sensitivity and specificity, indicating the potential utility of this criteria in specific populations. The higher sensitivity and specificity of the total QRS voltage criteria in our study may be attributed to its comprehensive approach in assessing the overall electrical activity of the heart, rather than focusing on specific leads. However, it is still subject to limitations such as variations in chest wall thickness and other anatomical and physiological factors affecting QRS voltage[15].

The overall performance of the ECG criteria in diagnosing LVH highlights the inherent limitations of ECG as a standalone diagnostic tool. While the Sokolow-Lyon index and Romhilt and Estes criteria provide quick and accessible methods, their low sensitivity and variable specificity limit their reliability. The total QRS voltage criteria, although more comprehensive, still falls short of the diagnostic accuracy provided by ECHO. Echocardiography remains the gold standard for diagnosing LVH due to its ability to provide detailed structural and functional information about the heart. However, its higher cost and limited accessibility, particularly in rural areas, necessitate the continued use of ECG in initial screenings. Our findings suggest that the total QRS voltage criteria could serve as a more reliable ECG-based method in such settings, provided that patients with suspected LVH are referred for confirmatory ECHO when possible.

CONCLUSION

The study underscores the significant prevalence of left ventricular hypertrophy (LVH) among patients with essential hypertension, with the prevalence increasing with the duration of hypertension. Echocardiography (ECHO) proved to be the most reliable method for diagnosing LVH, while clinical evaluation and electrocardiographic (ECG) criteria showed varied sensitivities and specificities. Among the ECG criteria, the total QRS voltage criteria demonstrated the highest accuracy and agreement with ECHO findings. This highlights the importance of using ECHO for definitive diagnosis, although ECG can still serve as a useful initial screening tool in resource-limited settings.

Limitations: The cross-sectional design does not allow for assessment of causality or changes over time. The sample size, while adequate for initial findings, may limit the generalizability of the results to broader populations. Additionally, the reliance on single-center data may not reflect regional or national variations. The exclusion of patients with secondary hypertension and other cardiovascular conditions may also limit the applicability of findings to the general hypertensive population. Lastly, the study's dependence on ECHO as the gold standard, despite its higher cost and limited availability in rural areas, highlights an accessibility issue for comprehensive hypertension management.

Recommendations: Firstly, regular screening for LVH should be integrated into the management plan for all hypertensive patients, with a preference for ECHO where available. For areas with limited access to ECHO, the total QRS voltage criteria on ECG can serve as a reasonably accurate screening tool, though it should be supplemented with ECHO for confirmation when possible. Health policies should focus on improving access to ECHO, particularly in rural and underserved areas, to ensure accurate diagnosis and management of LVH. Further studies with larger, more diverse populations and longitudinal designs are recommended to validate these findings and explore the long-term implications of LVH in hypertensive patients. Enhanced training for healthcare providers in the use of ECG and ECHO for diagnosing LVH can also improve early detection and management, ultimately reducing cardiovascular morbidity and mortality associated with hypertension.

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