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**Research Article**

# Comparative Study of Electrocardiographic and Echocardiographic Evidence of Left Ventricular Hypertrophy in Post COVID Hypertensive patients

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**Abstract**
**Background:** COVID-19 has harmed cardiovascular health, especially hypertensives. Left ventricular hypertrophy (LVH) by chronic hypertension raises cardiovascular risk.
**Aim:** To compare ECG LVH criteria for diagnosing LVH in post-COVID hypertensive patients using ECHO as the gold standard.
**Materials and Methods:** This 12-month observational comparison was done in NIMS Jaipur's General Medicine Department. Written informed consent was obtained from all 80 purposive sampled participants. Left ventricular hypertrophy (LVH) was diagnosed using the Sokolow-Lyon Index and Cornell Voltage Criteria on ECG and ECHO. Age, sex, residence, family history of hypertension, and duration of hypertension for known patients were obtained using a pre-designed questionnaire. Echocardiography verified LVH after ECG.
**Materials:** Our study comprised 80 hypertensives, 52.5% of whom were men. The average age was 56.36 ± 12.35 years, and the average duration of hypertension was 4.57 ± 4.75 years. The average pulse rate was 78 ± 9.46 beats/minute, with systolic and diastolic blood pressures of 135 ± 17.46 and 86 ± 11.43 mmHg, respectively 7.5% had newly diagnosed hypertension, 42.4% family history. Using Sokolow-Lyon criteria, ECG sensitivity and specificity for LVH diagnosis were 46.6% and 98.6%, with a PPV of 96.4% and an NPV of 70.5%. Cornell Voltage criterion yielded 40.1% sensitivity, 94.9% specificity, 86.0% PPV, and 67.3% NPV. Using both ECG criteria increased sensitivity to 53.0%, specificity to 94.9%, PPV to 87.9%, and NPV to 76.0%.
**Conclusion:** Cornell Voltage criteria had 40.1% ECG sensitivity for left ventricular hypertrophy (LVH) and Sokolow-Lyon criteria 46.6%. Using both criterion increases sensitivity to 53.0%. High specificity (>95%) for both criteria. Due to its low sensitivity, ECG cannot screen post-COVID hypertensives for LVH.

**Keywords:** COVID-19, LVH, ECG, ECHO

## INTRODUCTION

### Background

The COVID-19 pandemic, caused by SARS-CoV-2, presents significant challenges to global healthcare systems [1]. As of October 21, 2021, there have been over 240 million confirmed cases and 5 million deaths worldwide [2]. Recent reports indicate that hypertension is linked to an increased risk of SARS-CoV-2 infection and poorer COVID-19 outcomes [3-6]. Observational studies show that hypertension often coexists with other cardiovascular risk factors and older age. The elderly and individuals with comorbidities, such as diabetes, cardiovascular diseases, obesity, and chronic pulmonary conditions, face higher hospitalization rates and mortality from COVID-19 [7-9].

The role of first-line hypertension treatments, such as ACE inhibitors (ACEIs) and angiotensin receptor blockers (ARBs), is controversial in the context of COVID-19 [10-12]. Preclinical studies suggest that these Renin-Angiotensin System (RAS) antagonists may upregulate ACE2, the primary receptor that allows SARS-CoV-2 to enter cells [13, 14].

Left ventricular hypertrophy (LVH) is the thickening of the wall of left ventricle resulting in an increase in left ventricular mass. Left ventricular hypertrophy is a powerful independent risk factor for cardiovascular morbidity and mortality [15]. The increase in left ventricular mass represents a common final pathway toward the adverse effects on the cardiovascular system and higher vulnerability to complications [16].

Left ventricular hypertrophy may occur as a result of two basic hemodynamic abnormalities: Systolic overload and diastolic overload. Systolic overload is also known as pressure overload and occurs with conditions like aortic stenosis, systemic hypertension, hypertrophic cardiomyopathy, and coarctation of aorta. Diastolic overload is due to overfilling of left ventricle in diastole so that the left ventricle compromise occurs during diastole. Left ventricular diastolic overload is also known as volume overload, and occurs with mitral incompetence, aortic incompetence, and also with moderate left to right shunt [16].

The electrocardiogram (ECG) is a widely available and cost-effective tool for evaluating left ventricular hypertrophy (LVH), though its efficacy is often questioned compared to more specific methods like echocardiography and MRI. Two-dimensional echocardiography is considered the gold standard for LVH assessment [17]. Early detection of LVH via ECG can significantly guide treatment options [18]. While ECG criteria for LVH have high specificity (>90%), their sensitivity is lower (20-60%) [19]. Antihypertensive treatments can help regress LVH and prevent its progression, but the lower sensitivity of ECG compared to other imaging modalities limits its effectiveness in diagnosing LVH [20]. So far there is still limited data in our setting that compare and correlate the ECG criteria with ECHO to find LVH.

**Aim**

To compare different ECG LVH criteria and find out their sensitivity and specificity to diagnose LVH in post COVID hypertensive people taking ECHO as a gold standard method.

## MATERIALS AND METHODS

This observational comparative study was conducted for 12 months in the department of General Medicine, NIMS Jaipur.

The sample size, determined through purposive sampling, consisted of 80 participants. Written informed consent was obtained from all subjects before their participation. The presence or absence of left ventricular hypertrophy (LVH) was assessed using ECG and echocardiography (ECHO).

Participants included in the study were those aged 18 and older who met the case definition for systemic hypertension and provided written informed consent. Individuals with known hypertension already undergoing antihypertensive treatment were also included. Exclusion criteria encompassed conditions that can cause LVH, such as aortic stenosis, hypertrophic obstructive cardiomyopathy, and myocardial infarction, as well as congenital heart diseases like ventricular septal defect, patent ductus arteriosus, and coarctation of the aorta. Additionally, subjects with left bundle branch block (LBBB) on ECG were excluded.

Systemic hypertension was defined according to the Joint National Committee (JNC) 7 criteria [6] as a systolic blood pressure of ≥140 mmHg and a diastolic blood pressure of ≥90 mmHg. A twelve-lead ECG was performed on the subjects at a paper speed of 25 mm/sec with a calibration of 10 mm. LVH was diagnosed using either the Sokolow-Lyon Index or Cornell Voltage Criteria, defined as follows:

**1. Sokolow-Lyon Index [7]**

Sum of S wave in V1 and R wave in V5 or V6 ≥ 3.5 mV (35 mm)

And / or

R wave in aVL ≥1.1 mV (11mm)

**2. Cornell Voltage Criteria [8]**

For Male: Sum of S wave in V3 plus R wave in aVL > 2.8 mV (28mm)

For Female: Sum of S wave in V3 plus R wave in aVL> 2.0 mV (20mm)

After obtaining ECG subjects meeting the inclusion criteria underwent M-Mode, 2-Dimensional (2D), colour flow and Pulsed Wave Doppler transthoracic Echocardiography by Phillips IE 33 echocardiography machine. Echocardiogram was obtained at rest in the lateral decubitus or supine position using parasternal and apical views. Left Ventricular septal wall thickness or Posterior wall thickness was measured at the end diastole immediately below mitral valve leaflets tip along parasternal long or short axis. Septal wall thickness or Posterior wall thickness > 10 mm in Male and > 9 mm in female was considered as LVH on Echocardiography [9].

Data collection was conducted using a pre-designed questionnaire. The demographic profiles of study participants, including age, sex, address, family history of hypertension, and duration of hypertension (for known cases), were recorded. ECG findings indicating LVH, based on the Sokolow-Lyon Index and Cornell Voltage Criteria, were documented. Following this, echocardiography was performed to determine the presence or absence of LVH.

Data were imported into Excel 2010 and analysed using SPSS 22. Baseline characteristics were frequency, percentage, proportions, mean, and standard deviation.

Calculated sensitivity, specificity, positive predictive value, and negative predictive value for LVH diagnosis with ECG and echocardiography.

## RESULTS

In our study, a total of 80 hypertensive participants were enrolled. Approximately half of the study population (52.5%) were male. As shown in Table 1, the mean age of the participants was 56.36 ± 12.35 years. The mean duration of hypertension in the study population was 4.57 ± 4.75 years. The mean pulse rate was 78 ± 9.46 beats per minute. Similarly, the mean systolic and diastolic blood pressures of the participants were 135 ± 17.46 mmHg and 86 ± 11.43 mmHg, respectively. About 42.4% of the participants had a family history of hypertension, and 7.5% were found to have hypertension for the first time.

Table 1: Baseline Characteristics of the study Population (n=80)

| **Characteristic** | | **n (%)** |
|---|---|---|
| Age in years (mean ± SD*) | | 56.36 ± 12.35 |
| Gender | Male | 42 (52.5) |
| | Female | 38 (47.5) |
| Age of male Population in years (mean ± SD) | | 57.73 ± 12.54 |
| Age of female population in years(mean ± SD) | | 58.94 ± 11.36 |
| Duration of Hypertension in years(mean ± SD) | | 4.57 ± 4.75 |
| Family history of hypertension | | 34 (42.5) |
| Newly Diagnosed Hypertension | | 6 (7.5) |
| Pulse in rate per minute(mean ± SD) | | 78 ± 9.46 |
| Systolic BP in mmHg** (mean ± SD) | | 135 ± 17.46 |
| Diastolic BP in mmHg (mean ± SD) | | 86 ± 11.43 |
| Duration of Hypertension in years | < 5 | 44 (55) |
| | 5-10 | 23 (28.75) |
| | 10-15 | 9 (11.25) |
| | >15 | 4 (5) |

Out of 80 participants, 17 (21.25%) were found to have left ventricular hypertrophy on ECG according to the Sokolow-Lyon criteria, and 16 (20%) had left ventricular hypertrophy based on the Cornell Voltage criteria. When combining both the Sokolow-Lyon and Cornell Voltage criteria, 21 (26.25%) were identified as having left ventricular hypertrophy on ECG (either by Sokolow-Lyon or Cornell Voltage criteria). Additionally, echocardiography revealed that 35 (43.75%) of the study population had left ventricular hypertrophy, as shown in Table 2.

Table 2: Left Ventricular hypertrophy detected by Electrocardiography and Echocardiography (n= 80)

| **Diagnostic criteria** | **Left Ventricular Hypertrophy** | |
|---|---|---|
| | **Yes, n (%)** | **No, n (%)** |
| LVH on ECG by Sokolow-Lyon criteria | 17 (21.25) | 63 (78.75) |
| LVH on ECG by Cornell Voltage Criteria | 16 (20) | 64 (80) |
| ECG LVH on combining both Sokolow-Lyon and Cornell Voltage Criteria | 21(26.25) | 59 (53.75) |
| Echocardiographic LVH | 35 (43.75) | 45 (56.25) |

Using echocardiography as the gold standard, the sensitivity and specificity of different ECG criteria were calculated. As shown in Table 3, the sensitivity of ECG to detect left ventricular hypertrophy (LVH) by the Sokolow-Lyon criteria was 46.6%, while the specificity was 98.6%. The Positive Predictive Value (PPV) and Negative Predictive Value (NPV) for the Sokolow-Lyon criteria were 96.4% and 70.5%, respectively. Similarly, the sensitivity and specificity of ECG using the Cornell Voltage criteria to detect LVH were 40.1% and 94.9%, respectively, with a PPV of 86.0% and an NPV of 67.3%. When combining both ECG criteria, the sensitivity increased to 53.0%, with a specificity of 94.9%. The PPV and NPV of the combined ECG criteria were 87.9% and 76.0%, respectively.

Table 3: Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) of Diagnostic Criteria to diagnose LVH

| Diagnostic Criteria | Sensitivity | Specificity | PPV | NPV |
|---|---|---|---|---|
| Sokolow-Lyon Criteria | 46.6% | 98.6% | 96.4% | 70.5% |
| Cornell Voltage Criteria | 40.1% | 94.9% | 86.0% | 67.3% |
| Combining Sokolow-Lyon and Cornell Voltage Criteria | 53.0% | 94.9% | 87.9% | 76.0% |

## DISCUSSION

The involvement of the heart in COVID-19 is often caused by multiple factors, including a systemic inflammatory response caused by a cytokine storm, a mismatch between oxygen supply and demand due to hypoxia, the formation of blood clots in small or large blood vessels following inflammation and dysfunction of the inner lining of blood vessels, and direct damage to the heart muscle caused by the virus. These mechanisms have been proposed as explanations for the cardiac effects of COVID-19 [21]. Furthermore, COVID-19 recovered patients have shown signs of subclinical left ventricular dysfunction as a result of ongoing cardiac inflammation, including peri-myocarditis and early myocardial fibrosis [22, 23].

In addition to the criteria described earlier, the studies also employed additional methods to diagnose left ventricular hypertrophy (LVH), such as Minnesota codes and Romhilt-Estes [24]. However, we utilised the Sokolow-Lyon, Cornell voltage, and combined methods. Population-based research conducted in Thailand shown a reduced prevalence (6%) of left ventricular hypertrophy (LVH). However, the study only utilised the Sokolow-Lyon and Cornell voltage criterion [25].

There is a belief that left ventricular mass increases as a person gets older, leading to an increase in electrically-inactive fibrous tissue. Due to conduction problems, the accuracy of diagnosing left ventricular hypertrophy (LVH) via ECG is reduced in older individuals. ECG diagnostics exhibit limited sensitivity, resulting in the underestimate of left ventricular hypertrophy (LVH) [26]. The purpose of this study was to examine four key electrocardiographic criteria for left ventricular hypertrophy (LVH), using 3D echocardiography as the diagnostic standard.

Electrocardiogram Left Ventricular Hypertrophy

The Sokolow Lyon CR is a straightforward, long-standing, and expedient technique for diagnosing left ventricular hypertrophy (LVH). The current study shown that the presence of multiple co-morbidities resulted in the best sensitivity for identifying left ventricular hypertrophy (LVH). The Kappa measure of agreement yielded a value of 0.018, indicating a low level of agreement between ECHO and ECG in diagnosing LVH. The sensitivity of this criteria was 38%, indicating its ability to accurately identify positive cases. The specificity was 92%, indicating its ability to accurately identify negative cases. Singh et al and Martin et al reported comparable values for the Kappa coefficient and sensitivity, along with a specificity of 75% [27, 28]. Reichek et al discovered that the sensitivity was poor, at 21%, but the specificity was great, at 95% [29]. The studies conducted by Murphy et al and Jaggy et al found a high level of sensitivity, around 60%, and a specificity ranging from 75% to 80% [30, 31].

We also noted that the Cornell voltage criteria exhibited a high level of sensitivity in diagnosing left ventricular hypertrophy (LVH) in individuals with chronic kidney disease (CKD). The sensitivity of the method Echo is 40.1%, meaning it accurately detects 40.1% of the

cases with the condition. The specificity of the technique is 94.9%, indicating that it correctly identifies 94.9% of the cases without the condition. These statistics demonstrate a statistically significant relationship between the Echo and ECG procedures. Lv et al. discovered comparable outcomes, noting a more robust correlation between Echo-LVH and Cornell-related criteria [32].

The investigations conducted by Okin et al [33], Domingos et al [34], and Dada et al [35] reported sensitivities of 22%, 12%, and 22% correspondingly for the Cornell criteria in diagnosing LVH. The Cornell criteria was used in investigations conducted by Okin et al [33], Domingos et al [34], and Dada et al [35] to identify left ventricular hypertrophy (LVH) with specificities of 87%, 100%, and 80% respectively.

The sensitivity of the Sokolow criteria in diagnosing left ventricular hypertrophy (LVH) was found to be 46.6% in our investigation. This is greater than the sensitivity reported in the initial studies conducted by Sokolow and Lyon [36] and Casale et al [37], who reported sensitivities of 32% and 33% respectively for the Sokolow criterion. The specificity of the Sokolow criteria in our investigation was 98.6%, which aligns with the findings of Sokolow and Lyon [36] and Casale et al [37], who reported specificities of 100% and 93% respectively. These findings suggest that the Sokolow criteria is more effective in detecting left ventricular hypertrophy (LVH). By combining the Sokolow criterion and Cornell voltage criteria, a sensitivity of 53% was obtained, surpassing the sensitivity of either criterion alone.

## CONCLUSION

Electrocardiography is a less sensitive diagnostic method for identifying left ventricular hypertrophy in individuals with hypertension. The sensitivity of electrocardiography (ECG) in detecting left ventricular hypertrophy using the Cornell Voltage criterion is 40.1%, whereas the Sokolow-Lyon criteria yield a sensitivity of 46.6%. By integrating both criteria, the sensitivity of ECG increased to 53.0%. The specificity of both criterion is more than 95%. ECG's limited sensitivity precludes it from being regarded a suitable screening technique for detecting left ventricular hypertrophy (LVH) in individuals with post-COVID hypertension. Echocardiography remains the preferred method for detecting left ventricular hypertrophy (LVH) in individuals with hypertension.

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