Original Article

Left Ventricular Hypertrophy on Electrocardiography and Chronic Kidney Disease: A Case–Control Pilot Study

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Abstract

Background: **Chronic kidney disease (CKD) is a condition characterized by abnormalities in kidney structure or function lasting more than 3 months. CKD is known to increase the risk of cardiovascular events, which may be predicted by electrocardiography (ECG) abnormalities, such as left ventricular hypertrophy (LVH). ECG is widely used in under-resourced health care settings due to its practicality and accessibility.**

Objective: **This study aimed to analyze the relationship between LVH and CKD using ECG.**

Methods: **This analytical observational study used a case–control design. The case group included patients diagnosed with CKD, while the control group consisted of patients presenting with signs and symptoms suggestive of CKD but without a confirmed diagnosis. Each group included 35 participants. Simple random sampling was used for the case group, and stratified random sampling for the control group. ECG examinations were performed, and measurements were taken using calipers in millimeters (mm). The Sokolow–Lyon criteria were applied to identify LVH. Data were analyzed using an independent *t*-test, with statistical significance set at $p < 0.05$.**

Results: **The Sokolow–Lyon score was significantly higher in the case group than in the control group ($p = 0.03$).**

Conclusion: **There is a significant association between LVH, as identified on ECG, and CKD. These findings may assist health professionals in resource-limited settings, where access to ECG is restricted.**

Keywords: **Chronic Renal Insufficiency; Cardiovascular Diseases; Left Ventricular Hypertrophy; Electrocardiography.**

Introduction

Chronic kidney disease (CKD) is a condition characterized by persistent abnormalities in kidney structure or function lasting more than 3 months. Several pathophysiological processes in CKD contribute to a progressive decline in renal function, often leading to kidney failure.[1]

In the United States, the number of patients with progressive CKD requiring renal replacement therapy has increased over the past two decades.[2] According to data from Riskesdas (2018), the prevalence of CKD in Indonesia was 0.38% of the total population, affecting approximately 713,783 individuals.[3] The risk of cardiovascular disease in patients with CKD increases by 15%. Several studies have shown that more patients with CKD die from left ventricular enlargement and congestive heart failure than from coronary heart disease (CHD).[4-6]

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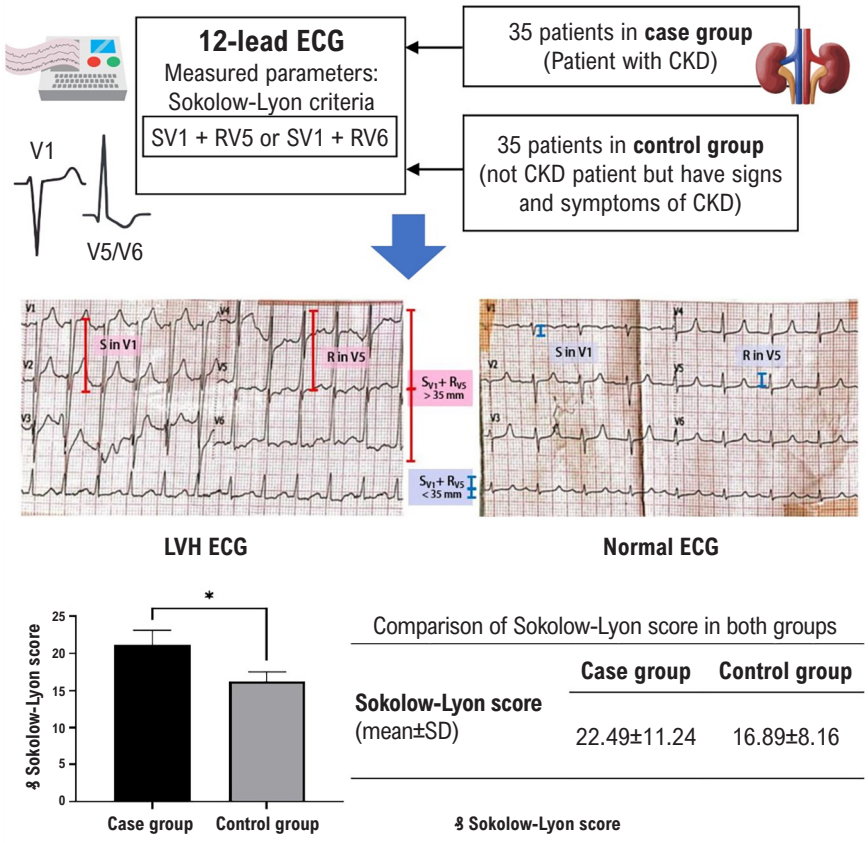
Research by Said (2014) on the relationship between CKD and cardiovascular risk demonstrated that electrocardiography (ECG) abnormalities are common in patients with CKD and may predict future cardiovascular events, including left ventricular hypertrophy (LVH).[7,8] Other studies have reported wide variations in the prevalence of ECG abnormalities, including prolongation of the Q wave and QRS complexes, which reflect ventricular electrical activity.[9]

Previous research by Taddei et al. on hypertension, LVH, and CKD reported a high prevalence of LVH among patients with CKD, regardless of the initial severity of the disease. This finding is largely attributed to the multifactorial pathogenesis of LVH in individuals with CKD.[10] Abnormal arterial stiffness and systolic hypertension increase afterload pressure by opposing left ventricular ejection, thereby contributing to the development of LVH. Moreover, older patients with CKD often present with ECG abnormalities — particularly ventricular hypertrophy — which are associated with a significantly higher risk of mortality compared to older individuals without CKD. This is especially evident in those aged 40 years or older, who face an elevated risk of developing CHD.[11,12]

LVH can be detected using various modalities, including ECG and echocardiography. Echocardiography is widely regarded as the gold standard for diagnosing LVH due to its superior accuracy in assessing left ventricular

Central Illustration: Left Ventricular Hypertrophy on Electrocardiography and Chronic Kidney Disease: A Case–Control Pilot Study



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Left Ventricular Hypertrophy on Electrocardiography and Chronic Kidney Disease: A Case–Control Pilot Study. CKD: Chronic kidney disease; ECG: electrocardiography; LVH: left ventricular hypertrophy.

mass.[13] However, in resource-limited settings, the use of echocardiography may be restricted by its higher cost, the need for specialized equipment, and the requirement for trained personnel.[14] ECG presents a more practical and accessible alternative. It is less expensive, easier to perform, and can serve as an initial screening tool for LVH, particularly in under-resourced health care environments.[13]

To date, no studies in Indonesia have investigated the detection of LVH by ECG in patients with CKD. Therefore, this pilot study aims to explore the relationship between CKD and LVH as diagnosed by ECG.

Methods

Study design

This observational study used a case–control design and was conducted in 2023.

Study population

The study population consisted of patients who underwent ECG examinations. Simple random sampling was used to select participants for the case group, while stratified random sampling was applied for the control group. The sample size was calculated with a 5% margin of error and a 95% confidence level, resulting in a total of 70 patients, equally divided into case and control groups.

For the case group, inclusion criteria were patients aged 40 years or older, diagnosed with CKD, and with recorded ECG results. Exclusion criteria included a prior diagnosis of heart disease, such as hypertensive heart disease, ischemic heart disease, or congestive heart failure.

For the control group, inclusion criteria were patients aged 40 years or older, with recorded ECG results, not diagnosed with CKD, and presenting risk factors for CKD, such as shortness of breath, anemia, hypertension, and/or diabetes mellitus. Exclusion criteria were the same as for the case group — patients with a prior diagnosis of hypertensive heart disease, ischemic heart disease, or congestive heart failure.

ECG data collection and analysis

Data from 12-lead ECGs recorded in hospital medical records were collected and documented. LVH was assessed using the Sokolow–Lyon criteria, and CKD was identified based on the Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease (RIFLE) classification.

ECGs were evaluated by clinical physicians experienced in ECG. Standard 12-lead resting ECGs were analyzed using the Sokolow–Lyon method, which involves measuring ECG voltage by calculating the sum of the S wave in lead V1 (SV1) and the largest R wave in lead V5 or V6 [max(RV5 or RV6)]. LVH was diagnosed when the total amplitude of SV1 + RV5 or SV1 + RV6 was equal to or greater than 3.5 mV.

Statistical analysis

All statistical analyses were performed using SPSS Statistics for Windows, version 25.0 (SPSS Inc., Chicago, Ill., USA). Baseline characteristics were summarized using descriptive statistics and compared between the case and control groups. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Normality of data was assessed using the Kolmogorov–Smirnov test. Comparisons of continuous variables between groups were conducted using independent *t*-tests, and categorical variables were compared using chi-square tests. Statistical significance was set at $p < 0.05$.

Results

The mean age of respondents was 58.31 ± 7.73 years in the case group and 60.03 ± 8.14 years in the control group. An independent *t*-test revealed no statistically significant difference in age between the two groups (Table 1).

In terms of sex distribution, the case group consisted primarily of women (51.4%), while the control group was predominantly male (57.1%). A chi-square test indicated no significant difference in sex distribution between the groups. Additional sociodemographic data are presented in Table 1, and a summary of the study's key findings is illustrated in Central Illustration.

As shown in Figure 1 and Table 2, analysis using the Sokolow–Lyon criteria demonstrated that the case group had a significantly higher score compared to the control group ($p = 0.03$). This finding indicates a statistically significant association between the Sokolow–Lyon score and CKD.

Table 1 – Respondent characteristics by age and sex

Variable	Case group	Control group	p-value
Age (mean ± SD)	58.31 ± 7.73	60.03 ± 8.14	0.377*
Sex (%)			0.632#
Male	48.6%	57.1%	
Female	51.4%	42.9%	

**Unpaired t-test; #Chi-square test; SD: standard deviation.*

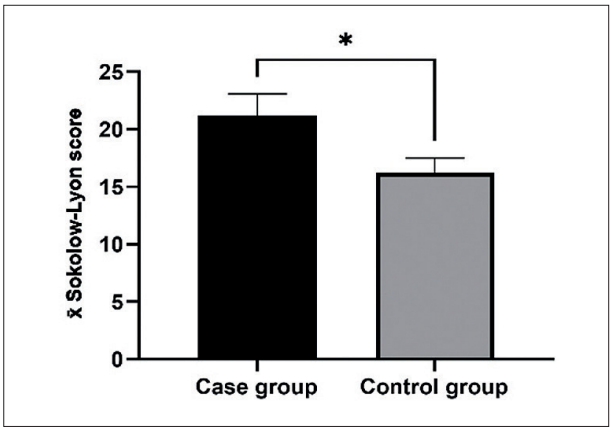

Figure 1 – *Comparison of Sokolow–Lyon scores between the two groups. *Significant difference (p < 0.05); unpaired t-test.*

Table 2 – Comparison of Sokolow–Lyon scores between groups

Variable	Case group	Control group	p-value
Sokolow–Lyon Score (mean ± SD)	22.49 ± 11.24	16.89 ± 8.16	0.03*

**p < 0.05; statistically significant; unpaired t-test*

Discussion

The mean age of participants with CKD in this study was 58.31 years. Similar findings were reported by Delima et al. (2017), who observed a higher likelihood of CKD in individuals over the age of 52.[15] This aligns with previous theories suggesting that, beginning at age 40, the number of functioning nephrons decreases by approximately 10% every 10 years.[16] As individuals age, kidney function progressively declines, resulting in reduced glomerular excretory capacity. When this decline occurs extensively, it can lead to a range of clinical symptoms and ultimately the development of CKD.[17] One contributing factor is the physiological mechanism of oxidative stress, which is commonly observed in aging. The combined effects of oxidative stress and inflammation during the aging process increase glomerular permeability, thereby elevating the risk of CKD.[6]

According to research by Abdelhafiz et al. (2010), two main theories explain the association between aging and increased risk of CKD: vascular changes and renal structural alterations. With advancing age, the arterial tunica intima tends to harden and develop endothelial dysfunction. In the tunica media, there is proliferation of smooth muscle cells, a reduction in elastin content, and progressive medial fibrosis.[18] These vascular changes contribute to increased intima-media thickness, vascular wall calcification, and stiffness of the aorta and large arteries.[19] Thickening of the tunica intima is considered an early marker of atherosclerosis, which is a known predictor of cardiovascular disease.[18] The rising prevalence of cardiovascular conditions with advancing age is closely linked to the increased prevalence of CKD.[20]

With regard to renal changes, aging is associated with both structural and functional alterations in the kidneys. Previous research by Tauchi et al. demonstrated a significant reduction in kidney mass in autopsies of individuals aged 40 years and older.[21] This decline in renal mass, along with the progression of glomerulosclerosis observed with aging, supports the theory that increasing age is related to a decrease in glomerular filtration rate.[22]

Regarding the analysis of sex, the results showed that women were more affected by CKD than men. This finding is consistent with previous research by Sundari et al. (2014), which also reported a higher prevalence of CKD in women.[23] According to the National Kidney Foundation, women may be more susceptible to CKD due to the shorter anatomical structure of the female urinary tract compared to males.[24,25] In women of reproductive age, CKD is often linked to disruptions in the hypothalamic–pituitary–ovarian axis, leading to hormonal imbalances and irregular menstrual cycles.[26] Additionally, postmenopausal women have an increased risk of developing CKD. Interestingly, a longer reproductive lifespan has been associated with a lower risk of CKD, suggesting that prolonged estrogen exposure during reproductive years may offer cumulative protective effects against the disease.[27]

This study also demonstrated varying Sokolow–Lyon scores, with a higher average score observed in participants with CKD (22.49 mm). These findings are consistent with a review by Cerasola et al. (2011), which reported a higher prevalence of LVH among individuals with CKD.[28] Similarly, a study by Han et al. (2020) showed the prevalence of LVH in patients with CKD is notably high, affecting between 29% and 74% of individuals, depending on the severity of renal impairment.[29] Furthermore, previous research by Losi et al. (2010) indicated that patients with CKD are prone to developing diastolic dysfunction — a type of left ventricular functional impairment — that results in fluid accumulation within the left ventricular space, ultimately contributing to the development of LVH.[30]

Bivariate analysis revealed a significant difference in Sokolow–Lyon scores between the CKD and non-CKD groups, with the CKD group exhibiting a significantly higher mean score. These findings are consistent with recent research conducted in Ghana, which demonstrated that ECG using the Sokolow–Lyon criteria effectively identified a high prevalence of LVH among patients with CKD.[14] The Sokolow–Lyon criteria are known for their high specificity, reported to range from 93% to 100% across various studies.[31,32] Ogunlade and Akintomide (2013) reported a sensitivity of 58.6% and a specificity of 60.66% for the Sokolow–Lyon criteria, surpassing the Cornell voltage criteria, which had a sensitivity of 51.72%.[33] However, other studies such as Ahn et al. (2015) reported much lower sensitivity, with rates as low as 3.3%.[34] In CKD populations, factors such as obesity and comorbid conditions may further reduce the sensitivity of the Sokolow–Lyon criteria, as noted by Snelder et al. (2020).[35] Therefore, while the Sokolow–Lyon criteria are valuable for detecting LVH, it is recommended that they be used in conjunction with other diagnostic tools, such as the Cornell voltage criteria, in order to improve overall diagnostic accuracy.[36]

These findings indicate a significant difference in the S and R wave amplitudes measured using the Sokolow–Lyon criteria between the two groups, which suggests a strong association between LVH on ECG and CKD. This relationship may be explained by the inflammatory and vascular calcification processes commonly observed in individuals with CKD. These pathological changes can lead to increased afterload and/or preload, ultimately resulting in LVH.[37,38] Figure 2 displays the proposed mechanisms contributing to the development of LVH in patients with CKD.

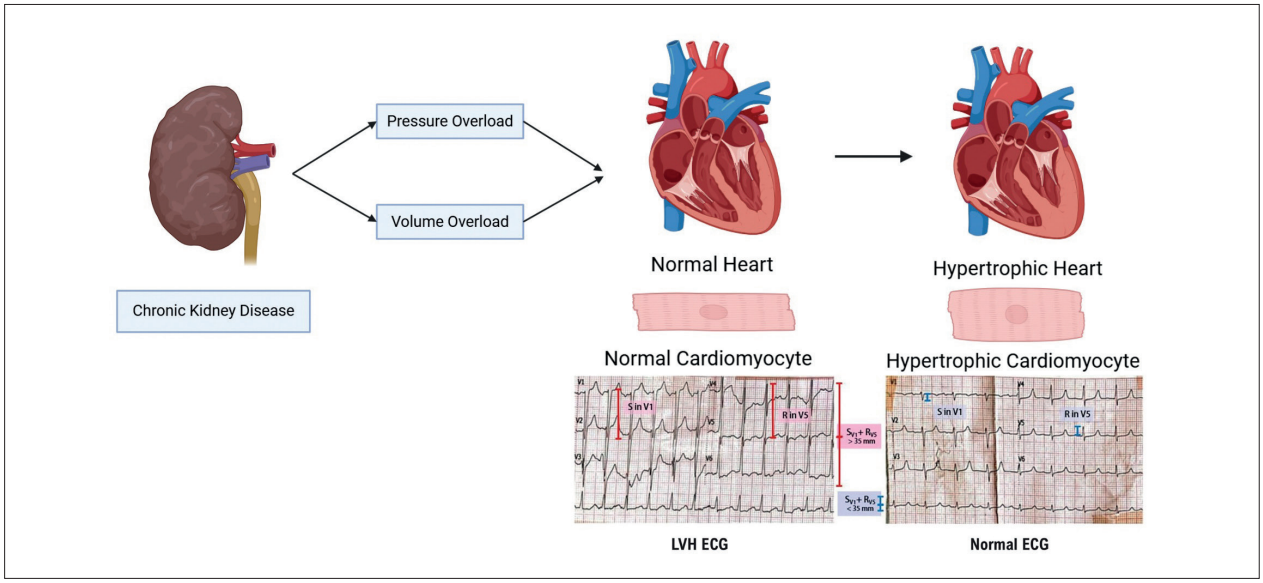

Figure 2 – *CKD causes LVH through various mechanisms. LVH in patients with CKD develops through two main pathways: pressure overload and volume overload. Both mechanisms lead to cardiomyocyte enlargement resulting in cardiac hypertrophy — particularly of the left ventricle — which can be identified using the Sokolow–Lyon criteria on an ECG. ECG: electrocardiography; LVH: left ventricular hypertrophy.*

This study has several limitations that should be acknowledged. First, there were constraints in collecting supporting data on key variables such as renal function and glomerular filtration rate. Ideally, the assessment of LVH should be compared against well-supported, established gold-standard methods.

Additionally, the case–control design may have affected the robustness of our findings since it limits the ability to establish causality. Future studies should aim to incorporate gold-standard diagnostic tools, such as echocardiography, and address methodological gaps to improve the validity and clinical relevance of results. Moreover, the relatively small sample size may limit the generalizability of our findings to broader populations. These limitations underscore the need for further research to validate our results and to better understand the complex interplay between renal function and cardiac health.

Conclusion

In conclusion, our findings demonstrate a significant association between LVH as assessed by the Sokolow–Lyon score on ECG and CKD. This suggests a potential relationship between cardiac structural changes and CKD. We propose that the Sokolow–Lyon score may serve as a reliable tool for detecting LVH in patients with CKD, particularly in resource-limited settings where access to echocardiography is restricted.

Future studies should consider additional factors that may influence the Sokolow–Lyon score, such as the duration of hemodialysis and the stage of CKD. The incorporation of alternative diagnostic criteria (e.g., the Cornell voltage criteria) could enhance the accuracy of LVH detection and help differentiate true LVH from other ECG abnormalities.

To strengthen the validity and generalizability of findings, future research should also consider alternative study designs, such as prospective cohort studies, larger sample sizes, and multi-center settings. These approaches would allow for more comprehensive and representative conclusions regarding the relationship between CKD and LVH.

Author Contributions

Conception and design of the research: Hajar N; acquisition of data, analysis and interpretation of the data and statistical analysis: Hajar N, Joveazhari NN; writing of the manuscript: Hajar N, Joveazhari NN, Chasani S, Wahab Z, Adhyatma GP, Fahdalhaq ZA, Wicaksono BA, Balqis IA; critical revision of the manuscript for intellectual content: Hajar N, Chasani S, Adhyatma GP, Balqis IA.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This study was approved by the Health Research Ethics Committee of Faculty of Medicine Universitas Muhammadiyah Semarang, under the protocol number No. 095/EC/KEPK-FK/UNIMUS/2022.

Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

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