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(RESEARCH ARTICLE)

A simplified model for predicting ventricular hypertrophy than traditional methods

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Abstract

Ventricular hypertrophy is the thickening of the muscles in the ventricular chambers of the heart which stiffens and thickens the cardiac walls giving rise to many complications like arrhythmia, high blood pressure, or even heart failure. One of the ways to diagnose ventricular hypertrophy is through an Echocardiogram which can be predicted by the positive large amplitude of Chest Leads [V4–V6] of an Electrocardiogram (ECG). But chest lead application is one of the complicated more parts of the ECG than limb lead. Here we have tried to predict ventricular hypertrophy with bipolar limb lead electrocardiogram [L-I, L-II & L-III] without any chest leads which can be easily designed to make an ECG prototype instead of any sophisticated instruments to increase its global accessibility even in remote areas for the prediction of ventricular hypertrophy even may be for other diagnosis in future. We acquired electrocardiogram data sets from the physio-net database, specifically collected data from both normal and hypertrophic patients in an institute. These data sets were obtained using the same recording device. The Lead-I of the RVH and normal patients were not satisfactorily distinguishable. However, in this work, it has been established that Lead-I can be used to predict for identification of LVH patients.

Keywords: Hypertrophy; LVH; ECG; Physio-net; RVH; MATLAB

1. Introduction

In remote areas where the availability of high-end instruments and doctors are not available, it becomes hard for people to be diagnosed with cardiac ailments like hypertrophy in their initial stages. Ventricular Hypertrophy is a heart condition where the muscles in the ventricular heart chamber thicken and stiffen the blood circulation resulting in improper pumping of the heart. Ventricular hypertrophy is usually caused due to many reasons namely: gene mutations, overload of pressure induced by arteriolar vasoconstriction, aortic stenosis, obstructive cardiomyopathy, or even chronic hypertension. Ventricular hypertrophy can lead to conditions like arrhythmia, ischemia, and heart failure. One of the usual ways to predict ventricular hypertrophy from an ECG signal is to use the QRS complex amplitude of V4 to V6 lead. The volume overload in the ventricles is depicted by the amplitude of the R wave and associated direction of the T wave [1].

The objective is to initially predict ventricular hypertrophy by bipolar limb lead system without any chest limbs. We took the ECG database of 48 patients of Left Ventricular Hypertrophy (LVH), 18 patients of Right Ventricular Hypertrophy (RVH), and 48 normal patients collected by the same device (CS-12) of the same hospital. We compared the ECG of both LVH and RVH patients and noted that the amplitude of Lead-I of RVH patients is not that much distinguishable with normal ECG whereas it is highly distinguishable with the LVH patient [1].

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2. Literature Review

The recognition of Ventricular Hypertrophy dates back to the pioneering work of Willem Einthoven which laid the foundation for ECG and revolutionized the diagnosis of cardiac diagnostics in the early 20th century [2]. The Framingham Heart Study, initiated in 1948, immensely benefitted the understanding of cardiac ailments, including Ventricular Hypertrophy [3].

2.1. Symptoms

The symptoms of Ventricular Hypertrophy are manifested differently for different patients based on the affected ventricle [4]. The symptoms usually start with subtle discomfort in the chest, shortness of breath, and palpitations and give rise to fatigue, fainting spells from dizziness, and severe chest pains as the condition worsens [5].

2.2. Diagnosis & Treatment

Initially, diagnosis of Ventricular Hypertrophy was using chest leads (V4-V6) which is still pivotal, but the advent of Echocardiography revolutionized the precision and reliability of diagnosis [6]. The major treatment modalities encompass lifestyle modifications (which include a heart-healthy diet, smoking cessation, stress reduction, and regular exercise), pharmacotherapy (involving medications like beta-blockers, calcium channel blockers, and ACE inhibitors to reduce cardiac workload and manage blood pressure) and in critical cases even surgical interventions (like septal myectomy / septal ablation) [7], [8].

2.3. Diagnostic Challenges

Ventricular Hypertrophy poses diagnostic challenges which often lead to false alarms due to several factors, involving anxiety-induced physiological retaliation. Accurate diagnosis is very necessary since many symptoms often overlap with those induced by anxiety. This may lead to misinterpretation and irrelevant concerns. Mostly symptoms like elevated heart rate, palpitations, shortness of breath, and chest tightness. Hence accurate measurement techniques are obligatory in diagnosing ventricular hypertrophy [9], [10].

3. Material and method

The research was conducted utilizing the PTB XL ECG database, consisting of over 21,000 ECG records of patients, derived from the Physio-Net repository [11]. To maintain uniformity with the database, a thorough study was done utilizing the Physio-Net website's resources and the PTB XL ECG dataset (version 1.0.3).

3.1. Data Selection

Upon downloading the extensive dataset, and filtering data entries possessing a sample rate of 100Hz for duration of 10 seconds. The database was precisely organized based on keywords, especially 'NORM' denoting normal patients; 'LVH' for Left Ventricular Hypertrophy, and 'RVH' for Right Ventricular Hypertrophy. Eventually, a deliberate selection process emerged, encircling 75 Normal patients, 48 with left ventricular hypertrophy, and 18 with right ventricular hypertrophy. Given the dataset's scarcity, the inclusion criteria were confined to individuals with just RVH and no additional concurrent co-morbidities.

3.2. Data Acquisition

The CS-12 ECG machine was used to collect all of the data according to the Physio-bank dataset, assuring uniformity in data collecting and consistency in the recording procedure. Within the header file, each patient record had complete details such as patient identification, age, height, illness categorization, and other pertinent information. The core dataset was made up of '.dat' files, which represented waveform database files containing raw data. These raw data files were rigorously processed in MATLAB to extract and refine relevant information for further research.

The mean QRS complex values were obtained from various leads for patients diagnosed with left and right ventricular hypertrophy, as well as for individuals with normal cardiac function. A representative chart illustrating these values is provided below.

Table 1 Sample of the data after processing in MATLAB

Leads/ Patient ID	Normal		LVH		RVH	
	31	**84**	**3842**	**14805**	**5306**	**18417**
AVF	1.002	0.575	0.331	0.557	0.531	0.219
AVL	0.195	0.244	1.142	0.974	0.221	0.393
AVR	0.141	0.378	0.229	0.259	0.515	0.344
I	0.546	0.614	1.411	1.468	0.326	0.491
II	1.251	0.797	0.889	1.173	0.555	0.321
III	0.752	0.459	0.289	0.365	0.588	0.257
V1	0.147	0.301	0.289	0.537	0.417	0.677
V2	0.516	0.443	0.789	0.511	0.58	0.33
V3	0.836	0.73	1.273	0.568	0.996	1.26
V4	1.137	1.042	2.015	1.489	1.496	1.902
V5	1.18	1.16	2.17	2.021	1.278	1.367
V6	1.157	0.955	1.86	1.856	0.987	0.901

3.3. Statistical Data Processing & Analysis

The MATLAB environment aided in the analysis of the waveform database records, extracting critical information for each patient ID, which included normal, LVH, and RVH patients. The processed results were imported insidean array in the workspace using MATLAB's null vector feature. The optimum amplitude of each lead within the 12-lead ECG was determined for each patient using a specially constructed MATLAB method, resulting in a full set of 12 amplitude data points per patient.

Following processing, additional classification was applied to the revised data, dividing the patient groups into LVH, RVH, and normal. Plotting the trend curves for each lead inside each patient group allowed for a comparative comparison. In order to identify unique patterns within each patient cohort, the analysis employed the average function to create a single lead value for each patient type (RVH, LVH, and normal). These lead values were then visualized in the form of trend curves. This thorough methodological approach made it easier to identify distinctive trends in lead levels among various patient groups, which eventually helped the research achieve its main goal of ventricular hypertrophy prediction.

4. Result and Discussion

The maximal ECG signal amplitudes were shown as a bar graph using 48 individuals from the LVH and normal cohorts, respectively. Between LVH and normal individuals, there was a discernible difference in the total amplitude, according to the graph. The total amplitude sum recorded by LVH patients was greater than that of normal people, measuring around 19.962 mV as opposed to 9.77 mV which gives a preliminary thought to precede the experiment for VH detection.

An analysis was conducted on graphs (Fig: 1) showing the average maximum values for all leads (AVF, AVL, AVR, lead-I, lead-II, lead-III, V1-V6) in patients with LVH and normal patients. The evaluation of amplitude variations between different leads from leg and chest sources was made possible by this comparison, which is crucial for forecasting ventricular hypertrophy. Notably, both kinds of leads showed discernible amplitude variations for individuals with LVH, indicating their possible use in VH prediction in daily life.

The graphical presentation (Fig:1) of positive QRS complex values, supports the present commercial methodologies to predict the Ventricular Hypertrophy from the positive large amplitude of chest Leads [V4–V6] of hypertrophy patients with respect to Normal patients. This graph also gives one another important significance for considering the Lead-I and Lead-II values for the initial prediction of Ventricular Hypertrophy, especially Lead-I.

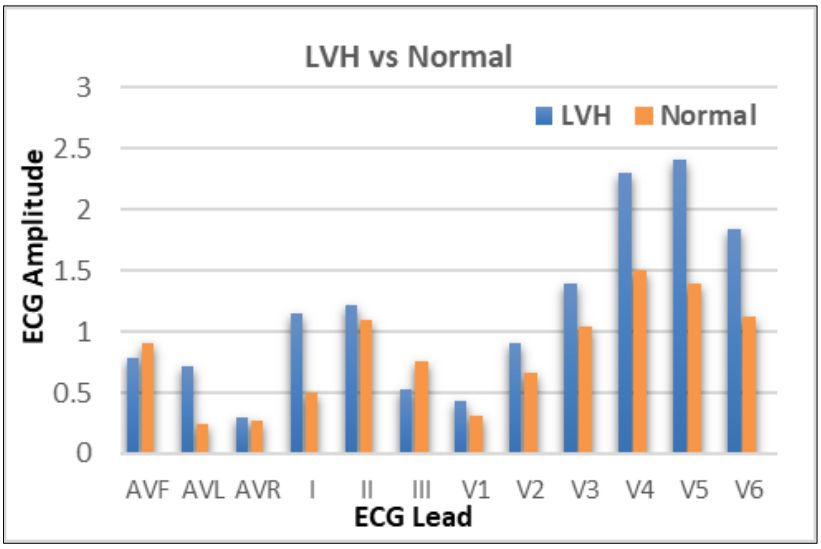

Figure 1 Comparison of average maximum lead values for LVH and Normal patients

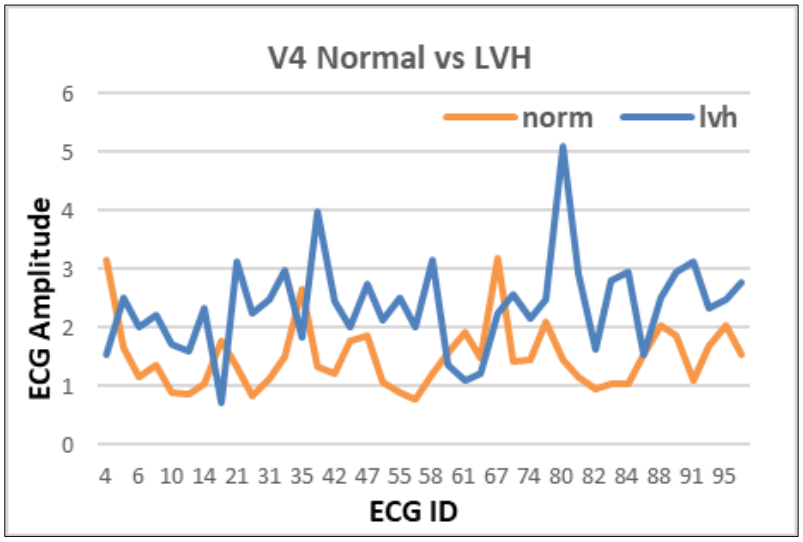

Figure 2 V4 Lead amplitude Analysis for LVH and Normal patients

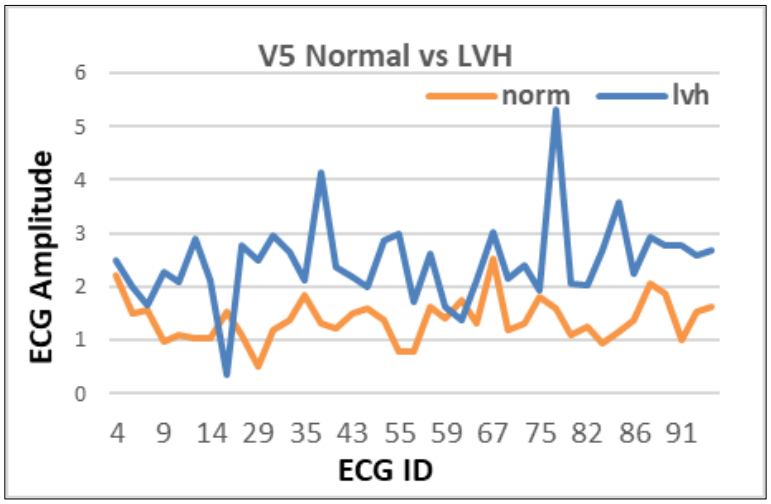

Figure 3 V5 Lead amplitude Analysis for LVH and Normal patients

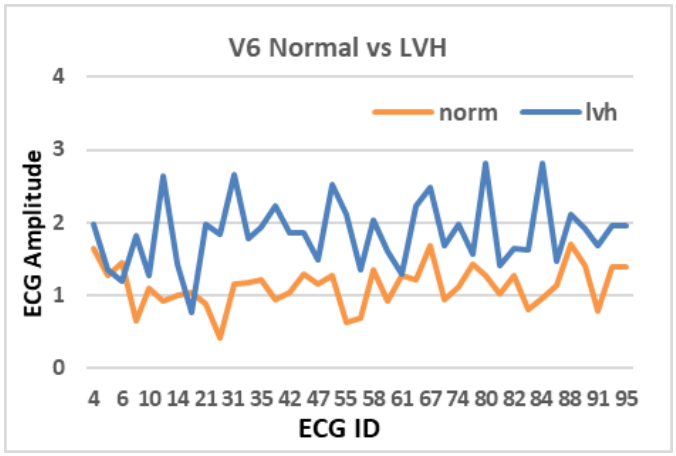

Figure 4 V6 Lead amplitude Analysis for LVH and Normal patients

Three-line graphs measuring the highest values of V4, V5, and V6 leads (Fig.2, Fig.3, and Fig. 4) for LVH and normal individuals were included in the experiment. For comparison, random samples from the database were chosen.

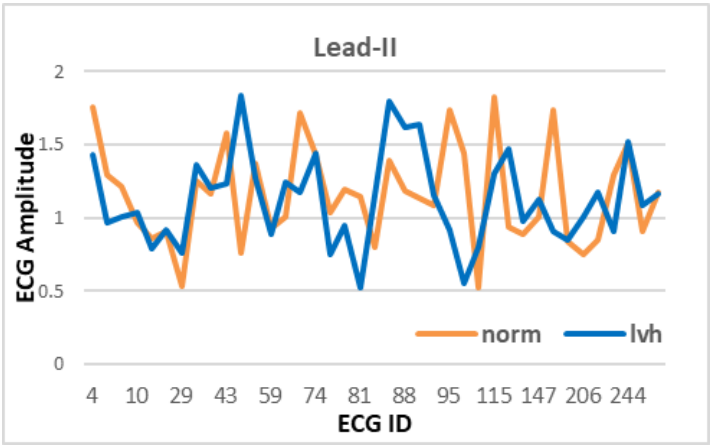

Figure 5 Lead-II amplitude Analysis for LVH and Normal patients

This revealed the accuracy of conventional amplitude distinguishing of chest lead for prediction of LVH. The findings cast likewise accurate prediction results of Lead-I as compared to chest lead in VH prediction. Analysis of Lead II line graphs (Fig: 5) in both LVH and normal patients reveals data points closely aligned, potentially intersecting in specific scenarios, rendering that LVH prediction is may not possible via Lead II. The minute proximity and occasional overlap in data points prohibit reliable hypertrophy prognoses using this Lead II.

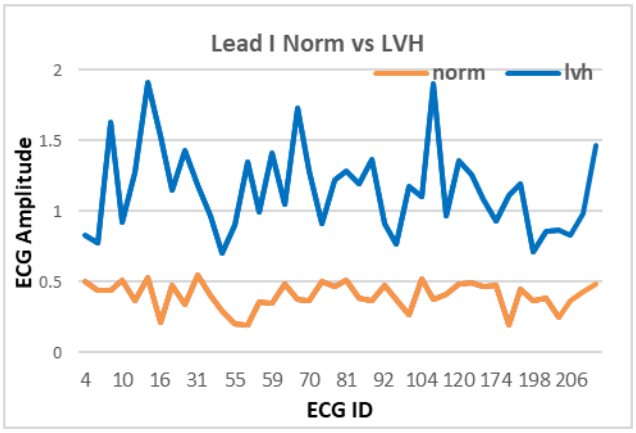

Figure 6 Lead-I amplitude comparison for LVH & Normal Patients

A detailed evaluation was conducted on Lead-I values exclusively for LVH and normal patients. This comparative analysis visualized Lead-I data for both patient types within a single frame, reaffirming the distinct amplitude differences and the potential diagnostic significance of Lead-I in predicting LVH (Fig: 6).

In clinical practice, the diagnosis of left ventricular hypertrophy (LVH) relies on ECG data from leads V4-V6 which is pretty accurate and rarely erroneous due to anxiety-related false alarms. Likewise, the waveform patterns in Lead I exhibit clear distinctions between LVH and normal patients, devoid of any overlap, thereby indicating the similar accuracy of Lead I with chest leads for accurate LVH diagnosis. Lead I assume crucial significance in clinical assessments, particularly in settings devoid of complex ECG systems, such as rural areas or where comprehensive chest lead systems are inaccessible. Through Lead I and the bipolar limb lead system, LVH prediction becomes feasible, offering a valuable method for diagnosing the potential presence of LVH in such environments.

Plotting two-line graphs highlighted how Lead-I maximum values for LVH patients differed from those for normal individuals. These plots, which showed non-intersecting lines and the constant amplitude behavior of Lead-I, were based on random samples of 42 patients each. This recurring pattern confirmed Lead-I's ability to accurately differentiate LVH patients from normal individuals, improving the precision of ventricular hypertrophy identification.

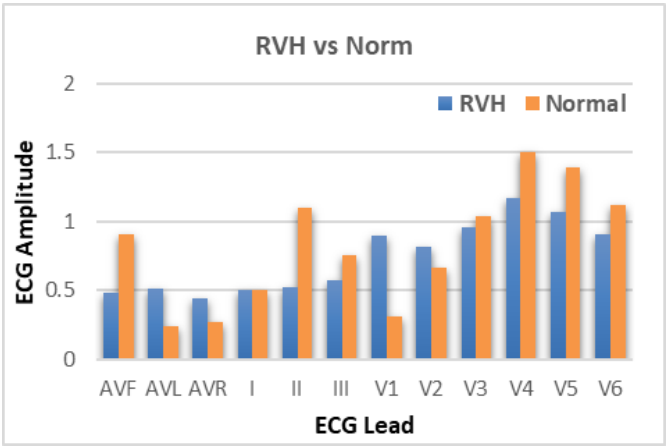

Figure 7 Comparison of lead amplitudes for RVH & Normal patients

Just for clinical investigation of both RVH and normal patients, a graph is created that evaluates the highest lead values over a range of leads. The study showed difficulties in distinguishing RVH from normal individuals, which were most noticeable in Lead-II. This suggests that further research is required to develop reliable prediction approaches for RVH.

Finally, the full study underlines the importance of Lead-I in accurately identifying LVH from normal individuals, indicating continuous amplitude differences critical for successful ventricular hypertrophy prediction by using a simple, cost-efficient, easily available Bipolar limb lead system, where there is inaccessibility of complex chest lead system from an ECG. However, RVH prediction remains difficult, needing more research efforts for definitive forecasts in this setting.

4.1. Future Prospects

The potential to detect ventricular hypertrophy (VH) through the novel use of a bipolar limb lead system without chest leads is enormous. The model can be integrated with the artificial neural network, for most optimum cases we could predict the presence of ventricular hypertrophy by analyzing new ECG data with the help of a confusion matrix of previously trained ECG data. We can integrate the model as wearable devices and IoT for continuous monitoring, validation studies, and clinical trials are being conducted, user-friendly prototypes are being designed, applications in telemedicine are being explored, ethical and regulatory considerations are being addressed, patient-centric health education is being promoted, and collaboration among multidisciplinary teams is being fostered. This study has the potential to revolutionize cardiac diagnostics by providing a more comprehensive, accessible, and preventative strategy for improving early diagnosis and management of heart problems.

5. Conclusion

The findings of the study on predicting ventricular hypertrophy (VH) utilizing a bipolar limb lead system without chest leads have far-reaching consequences in cardiac diagnosis for its simplicity. Left ventricular hypertrophy prediction is

mostly clinically focused on chest lead ECGs (V4-V6), which are pretty accurate but very rarely produce false predictions due to anxiety and various Lung-related complications. Lead I distinctly differentiate LVH and normal cases, with similar accuracy using a simple three Lead configuration. The method's ease of use and low cost might democratize VH diagnosis, especially in disadvantaged regions. This invention can promote distant healthcare and telemedicine by allowing practitioners to test for VH in areas where specialized resources are limited. The ability to diagnose VH early allows for preventative interventions, decreasing VH-related consequences. The optimization of healthcare resources, more studies, and technological breakthroughs in ECG signal processing are encouraged. The patient-centered approach is consistent with worldwide healthcare trends, giving people more control over their heart health. In summary, the implications of the study have the potential to transform cardiac diagnostics by promoting inclusion, efficiency, and patient empowerment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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