Pacific Journal of Medical and Health Sciences
ISSN: 2456-7450 | Vol.4, No.2, 2022, pp-53-61

PJMHS
PACIFIC JOURNAL OF MEDICAL AND HEALTH SCIENCES

Review

Electrocardiographic Diagnosis of Left Ventricular Hypertrophy – A Strong Predictor of Cardiovascular Morbidity and Mortality

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ABSTRACT

Left ventricular hypertrophy (LVH) is defined as an increase in the left ventricular mass. It is a physiologic response to the increased wall stress from volume or pressure overload. When the stress is prolonged, the changes become pathological. It can also be associated with genetic and infiltrative disorders and a risk factor for sudden death. Various methods are available to assess the LVH. The present review will restrict to electrocardiographic criteria for evaluation of LVH.

KEYWORDS: LVH, HOCM, Sudden death

INTRODUCTION

Left ventricle (LV) is the main pump of the heart as compared to right ventricle (RV). The RV works like a conduit, allowing the blood to pass on to pulmonary circulation. At this juncture it is to be stressed that interventricular septum is part of LV and not just a partition between the two ventricles[1]. (Fig.1)

Enlargement of heart due to ventricular hypertrophy is not a sign of healthy heart. It always reflects some underlying serious disease and that may lead to heart failure or sudden death. It may increase the risk of developing dementic and cognitive impairment. LVH results either due to pressure overload such as hypertension, aortic stenosis and hypertrophic cardiomyopathy or due to volume overload like mitral regurgitation (MR), aortic regurgitation (AR) and patent ductus arteriosis (PDA)[2,3] . It can also be seen in amyloidosis and in people who are predisposed genetically to hypertrophic obstructive cardiomyopathy (HOCM). In the later condition there is usually a family history of sudden death[4].

Left ventricular hypertrophy (LVH) is defined as an increase in the left ventricular mass (LVM) in response to a disease state, due to either increase in cavity size or left ventricular wall thickness or both. Morphologically, LVH may be characterized by increased wall thickness (concentric LVH), increased chamber volume (eccentric LVH).

There are several factors which can influence the incidence of LVH in adults. Obesity is one and race or ethnicity is other. LVH is more common in hypertensive African-Americans (50%) than in whites (33%), and the adjusted risk of having LVH, whether indexed by height 2.7 or by body surface area (BSA)[5,6]. Diabetes mellitus (DM) have

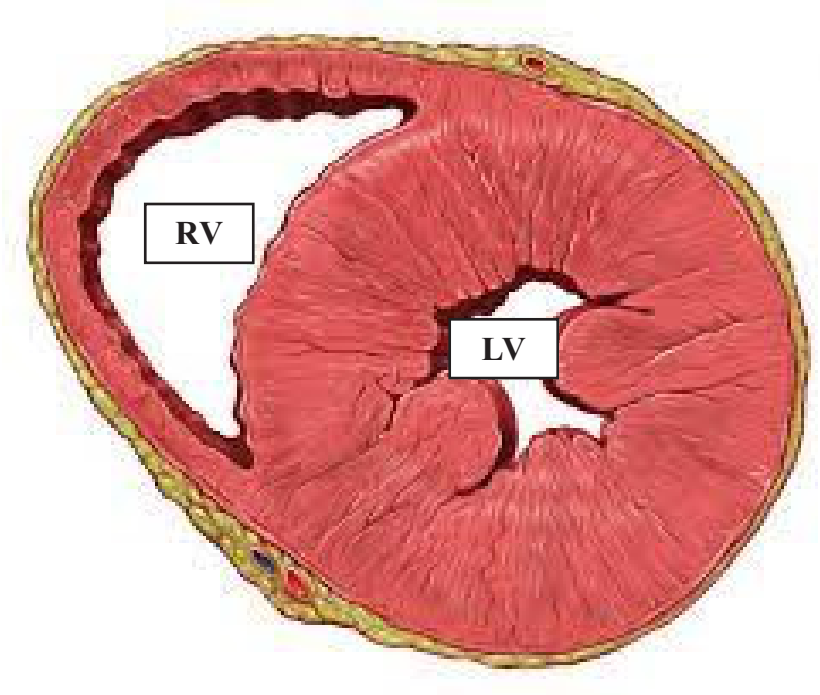


Figure 1: Left ventricular hypertrophy
RV: Right ventricle; LV: Left ventricle

higher LV mass, independent of hypertension. In fact age and ethnicity strongly influence the diagnosis of LVH.

Left ventricular hypertrophy can be suspected clinically by observing the displacement of apex beat which goes down and out in position as well as it becomes forceful in character as assessed by palpation[3]. Radiology may be helpful. Electrocardiography (ECG) is simple, economic and non-invasive method to assess LVH.

Echocardiography (ECHO) is very helpful for the diagnosis of LVH because it can visually measure every parameter of cardiac structure. In ECHO inter-ventricular septum, LV internal diameter and posterior wall thickness are measured and left ventricular mass can be calculated using American Society of Echocardiography recommended formula[7]. It is highly sensitive and specific that makes ECHO a gold standard for the detection of LVH. However, many conditions have restricted its application in routine clinical practice and therefore more convenient and economic ECG can be utilized as non-invasive method for detecting LVH.

The present paper will restrict its boundaries on ECG criteria for diagnosis of LVH as the investigation is available at all the levels of health care system. It is non-invasive, simple, and cost effective and has reasonably high sensitivity and specificity. Moreover, ECG evidence of LVH is a major non-invasive marker of increased risk of cardiovascular morbidity and mortality including sudden cardiac death[4].

The clue to the diagnosis of LVH in ECG is increase in voltage of QRS complex when the tracing has been recorded after proper standardization (10 mm), prolongation of VAT and repolarisation abnormalities[8]. Different criteria described by various investigators, time to time are based on the voltage in different leads. The most well-known electrocardiographic criteria are the Cornell voltage, the Cornell product, the Sokolow-Lyon voltage criteria and the Romhilt-Estes point score system[9,10]. Left ventricular strain (LVS), however, is diagnosed by repolarising changes (ST segment depression and T wave inversion) even without voltage criteria of LVH. Volume over load (AR, PDA) on LV can be suspected by the presence of tall T waves (> 10 mm) in lateral leads (V5 V6)[8]. Common electrocardiographic criteria for the diagnosis of left ventricular hypertrophy are described in table 1.

DIFFERENT LVH CRITERIA

Sokolow- lyon voltage criteria[11]

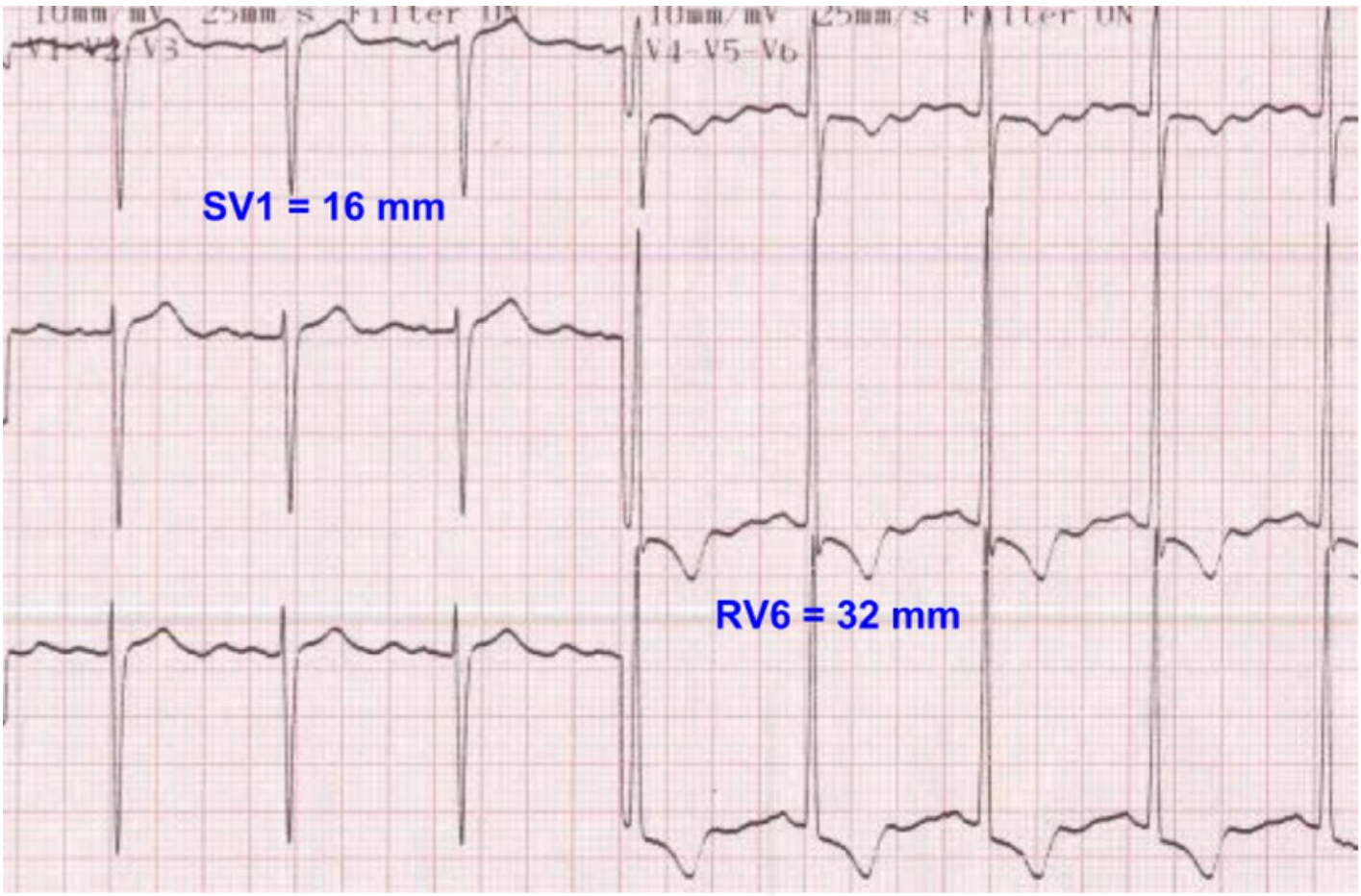
Sokolow-Lyon criteria is based on the fact that R wave in left oriented leads(V5 & V6) and S wave in right oriented leads (V1 & V2)represent left ventricular activity, as the left ventricular activation proceeds in a direction away from the right oriented leads and towards the left oriented leads. In Sokolow -Lyon criteria, V5 and V6 are taken as left oriented leads and V1 as right oriented lead. It is one of the most popular criteria for checking left ventricular hypertrophy in the ECG.

S wave in V1 + R wave in lead V5 or V6 > 3.5 mV (35 mm on standard ECG) OR
R wave in V5 or V6 > 2.6 mV (26 mm on standard ECG)

Romhilt- Estes point score[12,13]

Romhilt- Estes point score system was developed before any imaging technologies were available for the proper assessment of LVH. This score system assigned points for the presence of each of six ECG features. If a given ECG reached a total of 5 points or more, it was considered positive for Left ventricular hypertrophy, and 4 points were considered as probable LVH. Three points or less were taken as no sign of LVH.

For predicting LVH this point score system proved to be specific for predicting left ventricular hypertrophy but the sensitivity was low. This sensitivity was in the range of 60% in the original series. This sixty percent sensitivity was similar to other ECG criteria for LVH such as the Sokolow-Lyon index or the Cornell voltage criteria.



Sokolow Lyon criteria for LVH

Romhilt-Estes score		Points
Voltage criteria: (any of)		
R or S in limb leads ≥20 mm S wave in V1 or V2 ≥30 mm R wave in V5 or V6 ≥30 mm	☐	3
ST-T abnormalities		
ST-T vector opposite to QRS without digitalis	○	3
ST-T vector opposite to QRS with digitalis	○	1
Normal ST-T vector	○	0
P wave abnormalities		
Negative terminal P mode in V1 ≥1 mm in depth or 40 ms in duration	☐	3
Others		
Left-axis deviation (QRS of -30° or more)	☐	2
Delayed intrinsicoid deflection in V5 or V6 (>0.05 s)	☐	1
QRS duration ≥0.09 s	☐	1

- **3 points or less:** no signs of left ventricular hypertrophy.
- **4 points:** probable left ventricular hypertrophy.
- **5 or more points:** positive for left ventricular hypertrophy

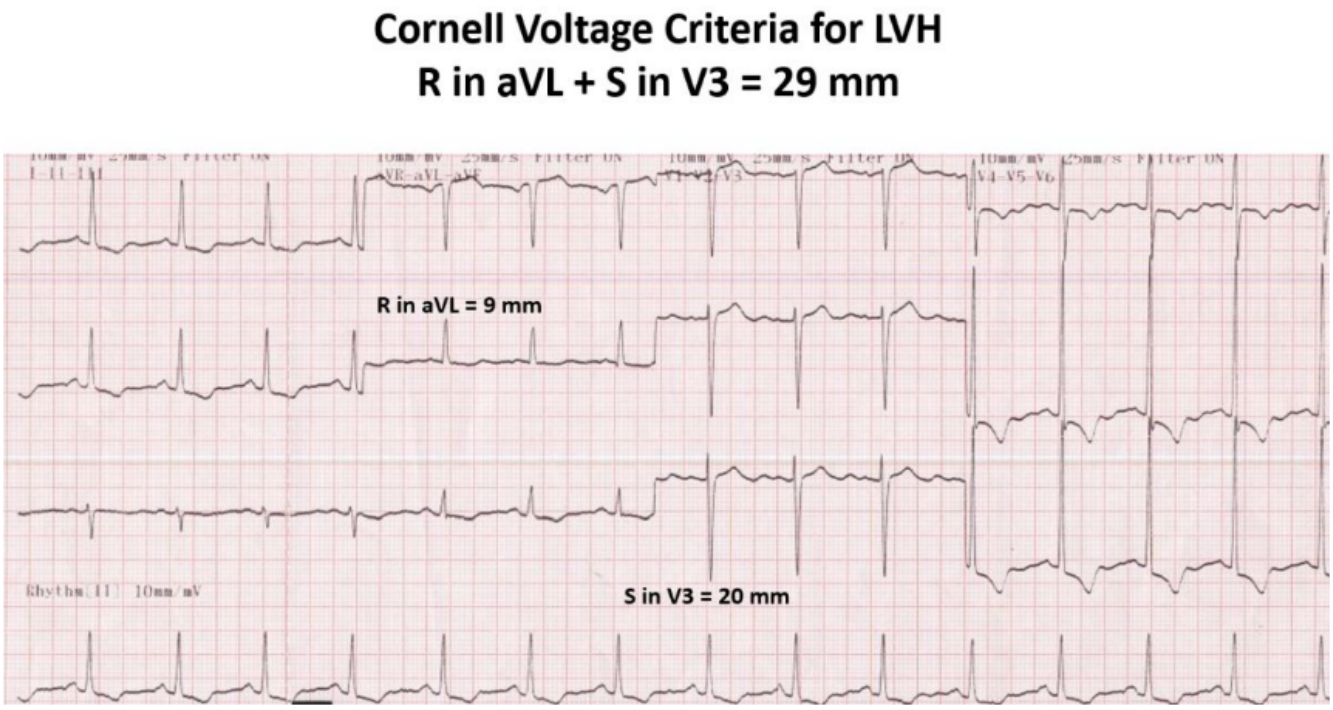
Cornell voltage criteria[14]

According to this criteria, the depth of S wave in V3 is added to the height of R wave in a VL. If the sum comes out to be 20 mm or more in females and 28 mm or more in males the left ventricular hypertrophy is considered.

Left ventricular mass index (LVMI) can be calculated from Cornell voltage as follows:

1.LVMI = 14.5 × Cornell voltage + 78.9 for males

2.LVMI = 21.5 × Cornell voltage + 61.5 for females



ECG showing Cornell Voltage Criteria for LVH

Cornell Product[14]

Cornell product is {(Cornell voltage + 0.6 mV for females) × QRS duration}

Left ventricular mass index can be calculated from Cornell product as follows :

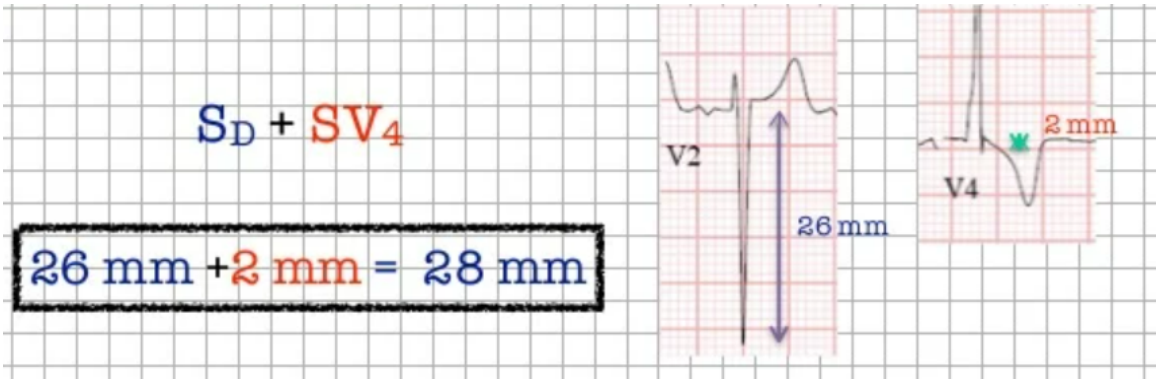
$$LVMI = 0.15 \times \text{Cornell product} + 68.8.$$

Peguero Lo- Presti Criteria[15,16]

In order to improve the sensitivity of diagnosis of LVH in ECG while maintaining the high specificity as compared to older well established criterion such as Cornell voltage and Sokolow Lyo; the new ECG criteria were proposed by Peguero Lo – Presti.

New ECG criteria for LVH has been proposed by Peguero Lo-Presti to improve the sensitivity of ECG while maintaining the The Peguero Lo-Presti criteria was calculated by adding deepest S wave in any lead to the S amplitude in V4 (SD + SV4). Cut off values of SD + SV4 $\geqslant$ 2.3 mV for female subjects and $\geqslant$2.8 mV for male subjects were considered positive for LVH based on the recent study by Peguero JG et al. In cases in which the deepest S wave was found in lead V4, the S wave amplitude was doubled to obtain the value SD + SV_4.

Peguero Lo- Presti criteria has higher sensitivity and specificity for diagnosing LVH in the ECG compared to Sokolow-Lyon and Cornell voltage criteria considering LV mass index by 2D Echocardiography as reference standard.



Framingham criteria[17]

- **R in avL > 11 mm**
- **R in V_4-V_6 >25mm**
- **S in V_1-V_3 > 25mm**
- **S in V_1 or V_2 + R in V_5 or V > 35 mm**
- **R in I + S III > 25mm**

Perugia Criterion[18]

The Perugia criterion was defined by the presence of a typical strain pattern or a modified Cornell voltage (sum of the S wave in V3 plus the R wave in aVL ⩾ 2.0 mV in women and ⩾2.4 mV in men).

Table 1: Electrocardiographic criteria for diagnosis of LVH

Sokolow-Lyon voltage[11]	SV1+RV5or V6⩾3.5mV
Romhilt-Estes score[12,13]	⩾5(LVH); ⩾4(probable LVH)
Cornell voltage[14]	SV3+R aVL>2.8mV (men), >2.0mV (women)
Cornell product[14]	(SV3+R Avl ,with 0.6mV added in women) x QRS
Pegeuro lo presti[15,16]	Deepest S wave in any lead plus S wave in lead V4 ⩾2.3 mV in female and ⩾2.8 mV in male
Framingham Criterion[17]	LV strain + ⩾1 voltage criterion (R aVL>1.1mV, R1+SIII⩾2.5mV, SV1/V2 ⩾R V5/V6 ⩾3.5mV , SV1/V2⩾2.5mV, R V5/V6⩾2.5mV)
Perugia Criterion[18]	SV3+R aVL>2.4mV(men), >2.0 mV (women), and or LV strain,and/or Romhilt-Estes score⩾5
Lewis voltage[19]	R1+ RIII – S1+RIII ⩾ 1.7mV
Gubner - Ungerleider Voltage[19]	R1+SIII ⩾ 2.5 mV

SUMMARY

The diagnosis of LVH is important in view of its interpretation for the assessment of the diagnosis of the disease, its severity and as a marker of increase risk of cardiovascular morbidity and mortality. Electrocardiographically it is possible to assess left LV enlargement (LVE), LVS, and LVS esp. in context with clinical findings. It is usually not possible to memorise the different criteria by their names but LVH can be diagnosed or suspected by taking into consideration of R and S voltage, VAT, and ST, T changes[1,4,8,20].

1.R in avL > 13 mm (Horijontal Heart)

2. R in avF > 20 mm (Vertical Heart)

3. R in V_5 or V_6 > 25 mm

4. R or S in any limb lead > 20 mm (2 mV)

5. R in V_5orV_6 > 30 mm (3 mV)

6. S in V_1, V_2 or V_3 > 30 mm (3 mV)

7. S in V_1 + R in V_5 or V_6 > 35 mm (**Sokolow-Lyon voltage**)

8. R in I + S in III > 25 mm (**Gubner- Ungerleider Voltage**)

9. R in avL + S in V_3 > 20 mm in women , > 28 mm in men (Cornell voltage)

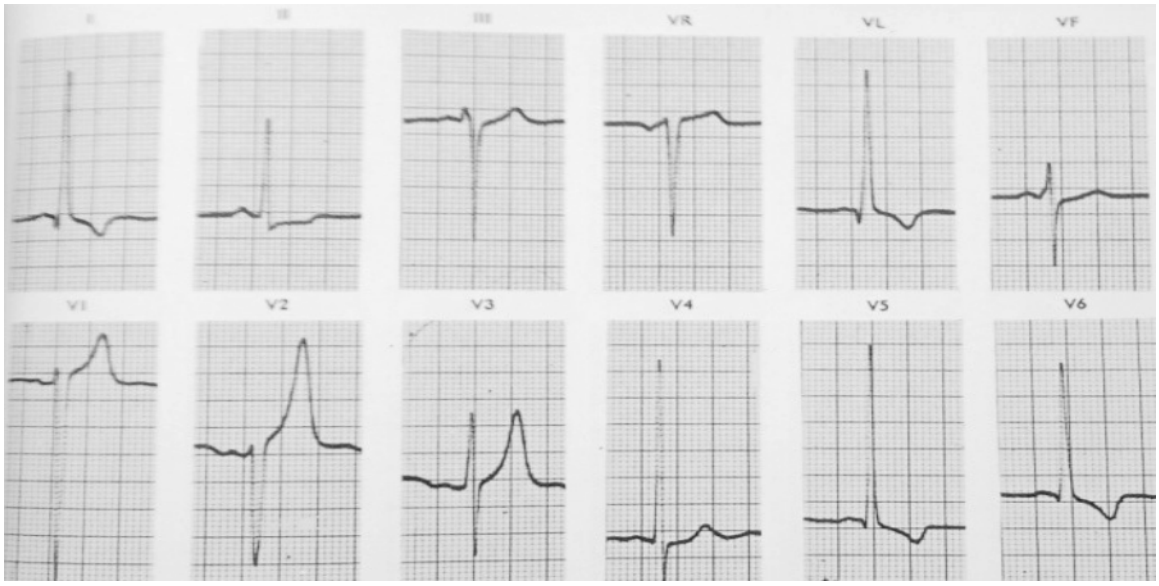
10. S in V_2 + R in V_6 > 45 mm (LVH in LBBB , 86% sensitivity)

11. VAT > 0.05 sec. in V_5 or V_6 (> 0.05 – 0.08 sec.)

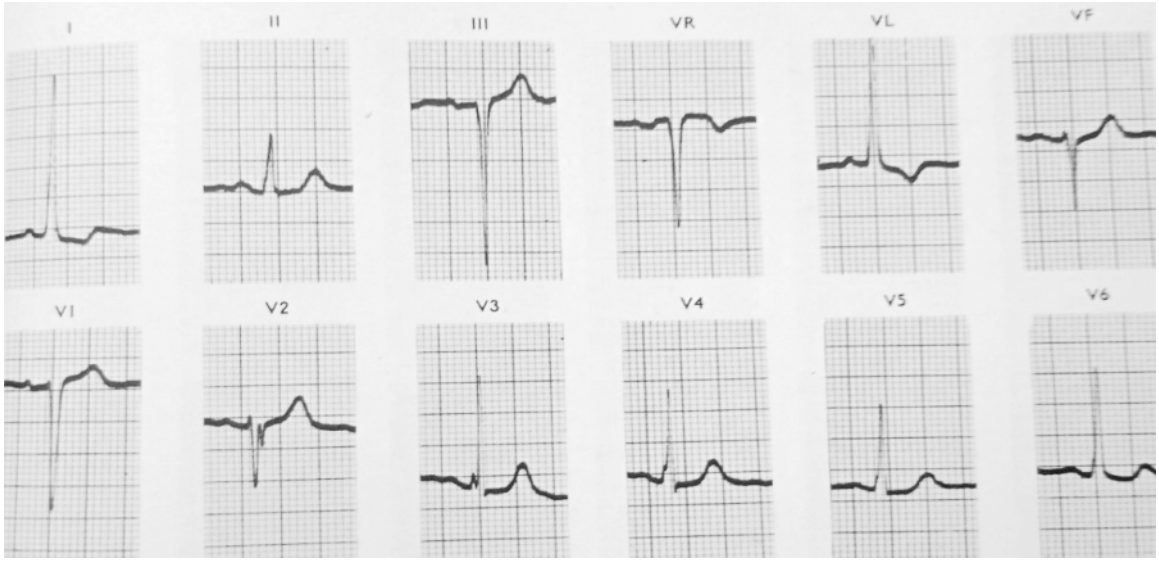
12. QRS prolongation over 0.1 sec. in V5-V6

13. ST segment depression, T wave in version in V_5-V_6

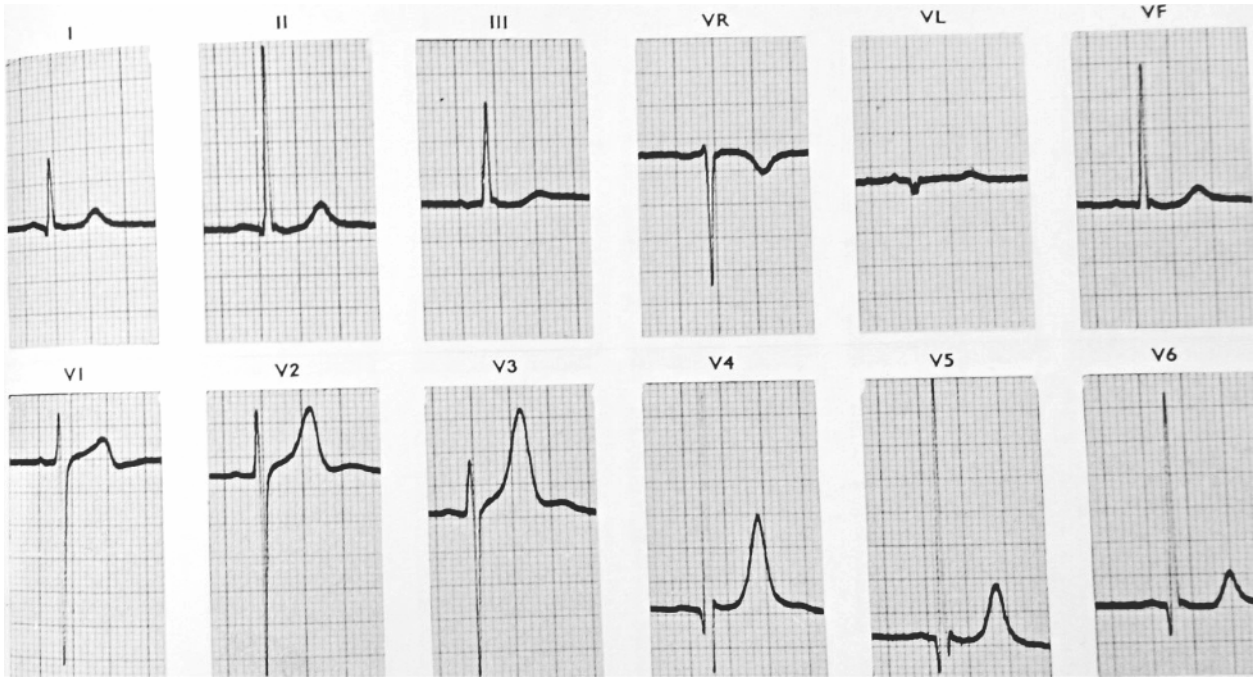
[Minimum criteria- 1,3,7 VAT- Ventricular activation time]



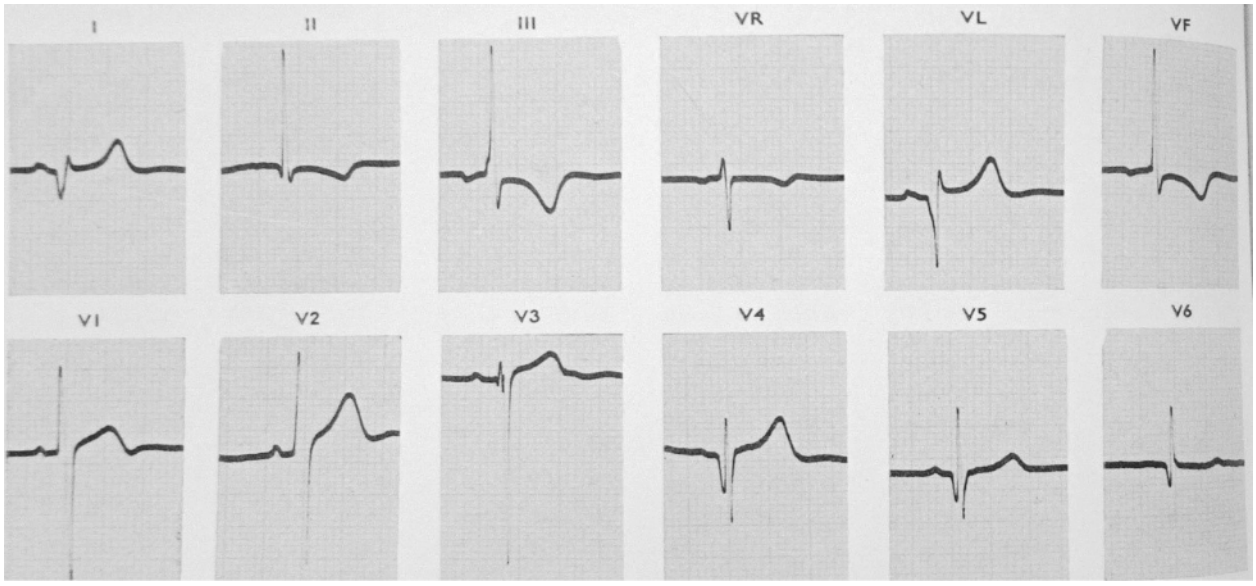
ECG 1. Showing most of the citeria of LVH (Classical pattern)



ECG 2. LVH seen in limb leads only



ECG 3. LVH with tall T waves ("volume overload" or "diastolic overload")



ECG 4. LVH and pathological Q waves (Hypertrophic cardiomyopathy)

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