Original Research Paper

International Physiology
Vol. 5 No. 2, July - December 2017
DOI: https://dx.doi.org/10.21088/ip.2347.1506.5217.9

A Study of Correlation between ECG and Echocardiography Findings in Left Ventricular Hypertrophy Secondary to Systemic Hypertension

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Abstract

Context: In clinical practice, left ventricular hypertrophy is best detected by echocardiography because its sensitivity exceeds that of the electrocardiography at the usual level of specificity. However, the greater availability, lower cost and relative simplicity of operation, the ECG continue to support its much wider use as a diagnostic instrument for this purpose. *Aims:* To study the correlation between ECG and Echocardiography findings in left ventricular hypertrophy secondary to systemic hypertension. *Settings and Design:* A hospital based cross sectional diagnostic evaluation study. Department of Physiology, Lt. BRKM Government Medical College. *Methods and Material:* The present study was conducted for a period of two years among 60 randomly selected patients from medical inpatient wards of this tertiary centre. Echocardiography was taken as gold standard to evaluation the performance of ECG. *Statistical Analysis:* Sensitivity, specificity, positive predictive value and negative predictive value were calculated for ECG to study its effectiveness. *Results:* Cornell voltage criteria (RavL + SV_3) has given significantly better sensitivity of 44% (p=0.042) compared to Sokolow-Lyon voltage criteria (SLV=SV_1+RV_6) which gave 26% sensitivity. Although Sokolow-Lyon voltage criteria have shown specificity of 100% compared to 90% of Cornell voltage criteria, difference was statistically not significant (p > 0.05). Cornell voltage criteria had a better correlation with LVM and LVMI compared to Sokolow-Lyon voltage criteria. *Conclusion:* Cornell voltage criteria are better than Sokolow-Lyon voltage criteria. It can be easily applicable in clinical practice in cases where echocardiography is not available.

Keywords: Clinical Practice; Echocardiography; ECG; Sensitivity.

Introduction

Hypertension is vastly an asymptomatic chronic disorder [1]. It is the commonest cardiovascular disorder, posing a major public health challenge to population in socio-economic and epidemiological transition. It is one of the major risk factors for cardiovascular mortality, which accounts for 20-50% of all deaths. There is also a direct relation between cardiovascular risk and blood pressure: the higher the blood pressure, the higher the risk of both stroke and coronary events [2].

Currently hypertension is staged as normal, pre-hypertension or hypertension based on the average of two or more readings taken at two or more visits. Isolated systolic hypertension is defined as a systolic blood pressure of 140 mmHg or more and a diastolic blood pressure of less than 90 mmHg [3].

Hypertension is typically associated with concentric hypertrophy of the ventricles. Grossman in 1975 proposed that the hypertrophic response was evoked by increased wall stress, the result of an increased intra-ventricular pressure. The pressure overload causes myocytes to grow wider and to thicken and according to the Laplace law, the increased wall thickness and even normalize the increased wall stress [4].

According to Devereux et al the increase in left ventricular mass represents a common final pathology towards the adverse effect on the cardiovascular system and higher vulnerability to complication [4].

ECG changes result from abnormal thickening of the left ventricular free wall or ventricular septum, left ventricular chamber dilatation or increased left ventricular wall tension. Echocardiography provides direct information concerning left ventricular wall

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Received on: July 17, 2017 **Accepted on:** August 17, 2017

thickness and chamber size [5-7]. In clinical practice, left ventricular hypertrophy is best detected by echocardiography because its sensitivity exceeds that of the electrocardiography at the usual level of specificity. However, the greater availability, lower cost and relative simplicity of operation, the ECG continue to support its much wider use as a diagnostic instrument for this purpose [8].

Hence present study was carried out to study the correlation between ECG and Echocardiography findings in left ventricular hypertrophy secondary to systemic hypertension.

Material and Methods

The present hospital based cross sectional diagnostic evaluation study was conducted for a period of two years at Department of Physiology, Lt. B. R. K. M. Government Medical College, Jagdalpur, Chhattisgarh, India for a period of two years among 60 randomly selected patients from medical inpatient wards of this tertiary centre. Echocardiography was taken as gold standard to evaluation the performance of ECG. Before the start of the study, Institutional Ethics Committee Permission was taken. Also the individual patient consent was taken.

The study was conducted at Department of Physiology from June 2015 to November 2016. The patients admitted in the General Medicine Wards during the study period were listed and a total of 60 eligible patients were selected randomly who showed the echocardiography evidence of left ventricular hypertrophy. The patients showing any evidence of multiple diseases or its complications, not willing patients and patients not able to participate in the study were excluded after careful discussion about the patient.

All patients underwent blood pressure measurement, 12 lead ECG and echocardiography. The idea was to evaluate the diagnostic efficacy of ECG and hence echocardiography was taken as gold standard for comparing the findings of ECG against echocardiography.

Blood pressure was classified using JNC VII criteria of classification [3].

ECG Criteria for Left Ventricular Hypertrophy

The electrocardiograph is a sophisticated galvanometer, a sensitive electromagnet, which can detect and record changes in electromagnetic potential. Cardiac hypertrophy result in changes at the cellular, tissue and volume conductor levels, all of which contribute to the electrocardiographic changes characteristics of left ventricular hypertrophy [9]. There are 12 standard electrocardiographic leads which may be physiologically divided into two groups [9].

1. The frontal plane leads – It includes leads I, II and III and leads AVR, AVL and AVF.
2. The horizontal plane leads – It includes leads V_1 to V_6.

Principle

The S wave of a right oriented lead and the R wave of a left oriented lead represent, in effect, the resultant and dominant right to left QRS vector of ventricular depolarization. These deflections constitute an indirect representation of free left wall activation. This is due to domination of free left ventricular wall activation over free right ventricular wall activation. So hypertrophy of the free wall of the left ventricle will be expressed by an increase in the depth of the S wave in the leads V_1 and V_2 and an increase in the height if the R wave in leads V_5 and V_6. [9]

Sokolow – Lyon Index: [10] $SV1 + (RV_5 \text{ or } RV_6) > 3.5$ mV

Or

RavL > 1.1 mV

Cornell Voltage Criteria: [1,11]

$SV_3 + RavL \geq 2.8$ mV (males)

$SV_3 + RavL \geq 2.0$ mV (females)

Echocardiographic Criteria for Left Ventricular Hypertrophy

Principle

Left ventricular dimensions usually are measured from two dimensional guided M mode echocardiograms of the left ventricle at the papillary muscle level, using the parasternal short axis view. Left ventricle dimensions measured from this view consists of thickness of the left ventricle posterior wall (PWT), thickness of inter-ventricular septum (IVST), left ventricular internal diastolic diameter (LVID) and left ventricular internal systolic diameter (LVIS). The values of IVST, LVID and PWT are used for Teichholz formula.

There is another formula known as relative wall thickness (RWT) which differentiates concentric LVH (due to hypertension) from eccentric LVH (due to overload) [12].

A. Cubed (Teichholz) Formula [12]

LV mass (g) = $\{(IVST + LVID + PWT)^3 - LVID^3\} X 1.05$.

Left ventricular hypertrophy is said to be present if LV mass is ≥ 163 gm in females or ≥ 224 gm in males [13].

Left ventricular mass index (LVMI) = LV mass / BSA.

Left ventricular hypertrophy is said to be present if LVMI is ≥ 96 gm in females or ≥ 116 gm in males [13].

B. Relative wall thickness (RWT) = PWT + IVST / LVID

RWT ≥ 0.45 indicates concentric hypertrophy [14].

Normal values of echocardiographic parameters for left ventricle are as follows [13].

PWT = 0.6 to 1 cm, IVST = 0.6 to 1 cm, LVID = 4.2 cm to 5.3 cm

Statistical Analysis

Sensitivity, specificity, positive predictive value and negative predictive value were calculated for ECG to study its effectiveness.

Results

Table 1 shows the characteristics of the patients. The various characteristics like mean values of age, weight, height, BMI, SBP, DBP were studied and compared between males and females. It was found that weight and height was significantly more in males than females. DBP was more in females and this difference was slightly significant. But age, BMI and SBP were similar among the males and females.

Table 2 shows echocardiographic findings among the study subjects. All parameters like PWT, IVST, LVID, LV mass and RWT were found to be similar among males and females. Only one parameter i.e. LVMI was significantly more among females compared to males. ($p < 0.05$).

Table 3 shows the diagnostic accuracy of Sokolow-Lyon voltage criteria. Overall it gave only 26% of sensitivity but had 100% specificity.

The overall positive predictive value was 100% which means that the patients diagnosed using these criteria surely have left ventricular hypertrophy. The sensitivity ranged from 11.11% for regular treatment to 34.08% for irregular treatment. But the specificity remained at 100% for all parameters.

Table 4 shows that there was poor correlation of Sokolow-Lyon criteria with that of LVM (0.202) and that of LVMI (0.189). Both were statistically not significant also ($p > 0.05$). Thus these criteria did not correlate well with echocardiography findings. There was slight variation in correlation in terms of gender, BMI, treatment history and duration of hypertension. But again this was not found to be statistically significant.

Table 5 shows the diagnostic accuracy of Cornell voltage criteria. Overall it gave a better sensitivity of 44% and the specificity was also 90%. This was also found to be statistically significant ($p < 0.05$). There was slight variation in sensitivity on the basis of gender, BMI, treatment history and duration of hypertension, but they were not found to be statistically significant.

Overall positive predictive value was 95.65% which means that the patients diagnosed using these criteria surely have left ventricular hypertrophy.

Table 6 shows that there was very good correlation of Cornell criteria with echocardiographic findings like LVM (0.55) and LVMI (0.45). Both were statistically significant ($p < 0.05$). Thus these criteria correlated well with echocardiography findings.

Table 1: Characteristics of the patients

Characteristic	Male		Female		T test	P value	Interpretation
	Mean	SD	Mean	SD			
Age (years)	62.68	10.75	60.27	11.8	1.1695	0.2446	Not significant
Weight (kg)	69.21	4.17	63.11	2.8	9.4071	0.0001	Significant
Height (cm)	166.71	2.67	157.05	2.85	19.1605	0.0001	Significant
BMI (kg/m^2)	24.94	1.45	24.65	1.38	1.1222	0.2641	Not significant
SBP (mmHg)	167.0	21.39	160.33	17.27	1.8793	0.0627	Not significant
DBP (mmHg)	86.5	15.34	91.44	10.37	2.0666	0.0410	Significant

BMI = Body Mass Index, SBP= Systolic Blood Pressure, DBP = Diastolic Blood Pressure

Table 2: Echocardiographic findings among the study subjects

Echocardiographic findings	Male		Female		T test	P value	Interpretation
	Mean	SD	Mean	SD			
PWT (cm)	1.33	0.16	1.29	0.29	0.8937	0.3733	Not significant
IVST (cm)	1.33	0.26	1.28	0.32	0.9393	0.3495	Not Significant
LVID (cm)	4.49	0.35	4.5	0.13	0.2075	0.8360	Not Significant
LV mass (gm)	293.6	78.35	285.37	110.82	0.4695	0.6394	Not significant
LVMI (gm/m²)	142.99	29.9	168.05	63.67	2.7596	0.0067	Significant
RWT	0.59	0.15	0.57	0.13	0.7805	0.4367	Not Significant

Table 3: Diagnostic accuracy of Sokolow-Lyon voltage criteria on the basis of gender, BMI, treatment history and duration of hypertension

Determinants	Sensitivity	Specificity	Positive predictive value	Negative predictive value	P value
Total	26	100	100	21.28	0.099
Male	28.12	100	100	28.12	0.166
Female	22.22	100	100	6.67	0.99
BMI > 25	19.05	100	100	32	0.55
BMI < 25	31.03	100	100	9.09	0.99
Irregular treatment	34.38	100	100	12.5	0.53
Regular treatment	11.11	100	100	30.43	0.99
Hypertensive of > 5 years	30	100	100	16	0.55
Hypertensive of < 5 years	20	100	100	27.27	0.54

Table 4: Correlation between Sokolow-Lyon voltage criteria and LVM & LVMI on the basis of gender, BMI, treatment history and duration of hypertension

Determinants	Correlation coefficient (r) with LVM			Correlation coefficient (r) with LVMI		
	r	p value	95% C.I.	r	p value	95% C.I.
Total	0.202	0.507	-0.392 to 0.671	0.189	0.535	-0.403 to 0.670
Male	0.218	0.571	-0.521 to 0.77	0.205	0.596	-0.531 to 0.765
Female	0.633	0.367	-0.837 to 0.991	0.844	0.156	-0.620 to 0.996
BMI > 25	0.028	0.971	0.958 to 0.963	0.009	0.990	-0.96 to 0.96
BMI > 25	0.390	0.298	-0.369 to 0.837	0.466	0.205	-0.286 to 0.863
Irregular treatment	0.292	0.382	-0.372 to 0.759	0.256	0.447	-0.406 to 0.741
Regular treatment	0.121	0.423	-0.267 to 0.238	0.112	0.512	-0.282 to 0.212
Hypertensive > 5 years	0.268	0.484	-0.481 to 0.795	0.274	0.474	-0.476 to 0.793
Hypertensive < 5 years	0.25	0.74	-0.076 to 0.935	0.240	0.659	-0.980 to 0.922

Table 5: Diagnostic accuracy of Cornell voltage criteria on the basis of gender, BMI, treatment history and duration of hypertension

Determinants	Sensitivity	Specificity	Positive predictive value	Negative predictive value	P value
Total	44	90	95.65	24.32	0.042
Male	40.63	88.89	92.86	29.63	0.13
Female	50	100	100	10	0.99
BMI > 25	28.57	87.5	85.71	31.82	0.634
BMI < 25	55.17	100	100	13.33	0.225
Irregular treatment	53.13	66.67	94.44	11.76	0.602
Regular treatment	27.78	100	100	35	0.27
Hypertensive of > 5 years	53.33	100	100	22.22	0.105
Hypertensive of < 5 years	30	100	100	30	0.28

Table 6: Correlation between Cornell voltage criteria and LVM & LVMI on the basis of gender, BMI, treatment history and duration of hypertension

Determinants	Correlation coefficient (r) with LVM			Correlation coefficient (r) with LVMI		
	r	p value	95% C.I.	r	p value	95% C.I.
Total	0.55	0.007	0.171 to 0.790	0.45	0.033	0.04 to 0.735
Male	0.433	0.138	0.154 to 0.794	0.5	0.075	-0.057 to 0.828
Female	0.309	0.0418	-0.446 to 0.807	0.483	0/186	-0.265 to 0.918
BMI > 25	0.416	0.411	-0.596 to 0.917	0.054	0.918	-0.792 to 0.829

BMI < 25	0.563	0.023	0.092 to 0.828	0.497	0.049	0.002 to 0.796
Irregular treatment	0.587	0.013	0.148 to 0.832	0.512	0.035	0.042 to 0.797
Regular treatment	0.922	0.025	0.215 to 0.995	0.994	0.004	0.922 to 0.999
Hypertensive > 5 years	0.425	0.1	-0.089 to 0.760	0.396	0.128	-0.123 to 0.745
Hypertensive < 5 years	0.863	0.026	0.171 to 0.984	0.615	0.193	-0.391 to 0.951

Discussion

In the present study, 60 hypertensive patients were studied. They were examined by taking their presenting complaints, past history of hypertension and treatment history. The routine investigations were done. 12 lead ECG and echocardiography was done and findings were noted.

An attempt was made to correlate the routine 12 lead ECG findings in cases of left ventricular hypertrophy, with that of echocardiographic findings, taking echocardiographic measurements as guidelines for left ventricular hypertrophy.

Although there are various criteria of ECG for the diagnosis of left ventricular hypertrophy, the voltage criteria are commonly used and had been selected for comparison with the echocardiographic measurements in the present study.

According to Sokolow-Lyon voltage criteria, it was found that overall the sensitivity of the ECG was 26% and specificity was 100%. The sensitivity was more in males compared to females. It was also observed that as obesity increased, the sensitivity decreased. Sensitivity was also affected by the regularity of the treatment. Sensitivity was also more among those with duration of hypertension of more than five years. The correlation coefficient of these criteria with LVM was 0.202 and with LVMI was 0.189.

Casale PN et al reported similar findings with sensitivity of 22% and specificity of 100% with Sokolow-Lyon voltage criteria [11]. Holt JH Jr et al found a sensitivity of 29% and a specificity of 100%. They also noted a correlation coefficient with LVM of 0.46 [15].

Reichek N et al found that the sensitivity was 21% but the specificity was little less of 95%. The correlation with LVM was poor [16]. Prakash O et al noted more sensitivity of 34% but a lesser specificity of 88%. Their correlation with LVMI was 0.076 [17]. Levy D et al observed an overall sensitivity of only 6.9% but the specificity was 98.8% [18].

As per Cornell voltage criteria we found that overall sensitivity was 44% and the specificity was 90%. The correlation with LVM was 0.55 and with that of LVMI was 0.45. The sensitivity was more in case of females compared to males. As the obesity increased, the sensitivity decreased. Patients having history of irregular treatment, showed a higher sensitivity than those on regular treatment. As the duration of hypertension increased, sensitivity also increased.

Similar findings were reported by various studies. Casale PN et al found a sensitivity of 42% and a specificity of 96% using Cornell voltage criteria [11]. Sobolev AV et al observed that the amplitude parameters of ECG provide the sensitivity of 58.8% and a specificity of 94.6% [19].

Pannarale G et al reported that the sensitivity and specificity of Cornell voltage criteria was 54.5% and 82% respectively [20]. Schillaci G et al observed that the sensitivity of electrocardiographic criteria of left ventricular hypertrophy varied between 9% and 33% and the specificity was generally more than or equal to 90%. The Cornell voltage criteria showed the closest association with echocardiographic left ventricular mass. (r = 0.48) [21].

Overall we observed that the Cornell voltage criteria ($RavL + SV_3$) has given better sensitivity of 44% ($p = 0.042$) compared to Sokolow-Lyon voltage criteria ($SLV = SV_1 + RV_6$) which had given the 26% sensitivity. This difference was statistically found to be significant ($p < 0.05$). Although the Sokolow-Lyon voltage criteria has shown absolute specificity of 100% compared to 90% as given by Cornell voltage criteria, but the difference was not found to be statistically significant ($p > 0.05$). Cornell voltage criteria had a better correlation with LVM and LVMI compared to Sokolow-Lyon voltage criteria. Similar findings were reported by Casale PN et al [11].

Conclusion

The Cornell voltage criteria showed better sensitivity and more correlation with echocardiographic findings than Sokolow-Lyon voltage criteria of ECG. So it can be concluded that Cornell voltage criteria of ECG improves the sensitivity of the ECG for detection of Left Ventricular Hypertrophy and it can be easily applicable in clinical practice to diagnose Left ventricular hypertrophy in case, where echocardiography is not available.

Key Messages

Where echocardiography is not available, Cornell voltage criteria should be used.

References

1. Gaziano TA, Gaziano MJ. Global burden of cardiovascular disease. In: Bonow RO, Mann DL, Zipes DP, Libby P, editors. Braunwald's Heart Disease. A textbook of cardiovascular medicine, 9th ed. Philadelphia: Elsevier; 2012.p.1-20.
2. World Health Organization. Hypertension Control. WHO Tech Rep Ser, 862;1996.
3. Chobanian AV, Bakris GL, Black HR et al. The seventh report of the Joint National Committee on prevention, detection, evaluation and treatment of high blood pressure: The JNC 7 Report. J Am Med Assoc 2003;289:2560.
4. Opie LH, Commerford PJ, Gersh BJ et al. Controversies in ventricular remodeling. Lancet 2006;367:356.
5. Rodriguer MI, Sodi PD. The mechanism of complete and incomplete bundle branch block. Am Heart J 1952;44:715.
6. Piccolo E, Raviele A, Delise P et al. The role of left ventricular hypertrophy: an echocardiographic study in man. Circulation 1979;59:1044.
7. King SB, Mansour KA, Hatcher CR et al. Coronary artery spasm producing Prinzmetal's angina and myocardial infarction in the absence of coronary atherosclerosis. Surgical treatment. Ann Thor Surg 1973;16:337.
8. Devereux RB, Koren MJ, de Simone G et al. Methods for detection of left ventricular hypertrophy: application to hypertensive heart disease. Eur Heart J 1992;14S:8-15.
9. Narsimhan C, Francis J, editors. Leo Schamroth An Introduction to Electrocardiography, 8th ed. New Delhi: Wiley India; 2013.
10. Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J 1949;37:161.
11. Casale PN, Devereux RB, Alonso DR et al. Improved sex specific criteria of left ventricle hypertrophy for clinical and computer interpretation of electrocardiograms: validation with autopsy finding. Circulation 1987;75(3):565-72.
12. Armstrong WF, Ryan T, editors. Feigenbaum's Echocardiography, 7th ed. Lippincott Williams & Wilkins; 2010.
13. Lang RM, Bieng M, Devereux RB et al. A report from the American Society of Echocardiography's Guidelines and Standard Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Society Echocardiography 2005;18:1440-63.
14. Yuda S, Khoury V, Marwick TH. Influence of wall stress and left ventricular geometry on the accuracy of dobutamine stress echocardiography. J Am Coll Cardiol 2002;40:1311-9.
15. Holt JH Jr, Barnard AC, Kramer JO Jr. A study of the human heart as an multiple dipole source: IV: Left ventricular hypertrophy is the presence of right bundle branch block. Circulation 1977;56(3):391-4.
16. Reichek N, Devereux RB. Left ventricular hypertrophy: relationship of anatomic, echocardiographic and electrocardiographic findings. Circulation 1981;63 (6):1391-8.
17. Prakash O, Karki P, Sharma SK. Left ventricular hypertrophy in hypertension: correlation between electrocardiography and echocardiography. Kathmandu Univ Med J 2009;7(26):97-103.
18. Levy D, Labib SB, Anderson KM et al. Determinants of sensitivity and specificity of electrocardiographic criteria for left ventricular hypertrophy. Circulation 1990;81(3):815-20.
19. Sobolev AV, Riabykina GV, Dorofeeva ZZ et al. Diagnosis of combined myocardial ventricular hypertrophy using pre-cordial mapping. II. Selection of the parameters of the cartogram of diagnostic significance for the differential diagnosis of combined myocardial hypertrophy and its isolated forms. Biull Vsesoiuznogo Kardiol Nauchin Tsentra AMN SSSR 1988;11(1):89-95.
20. Pannarale G, Gattini G, Ciolli A et al. Validity of some electrocardiographic criteria in left ventricular hypertrophy. Cardiologia 1989;34(6):559-62.
21. Schillaci G, Verdecchia P, Borgioni C et al. Improved electrocardiographic diagnosis of left ventricular hypertrophy. Am J Cardiol 1994;74(7):714-9.