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EVALUATION OF CLINICAL, RADIOLOGICAL AND ELECTROCARDIOGRAPHICAL METHODS IN THE DIAGNOSIS OF LEFT VENTRICULAR HYPERTROPHY *

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INTRODUCTION

Left ventricular hypertrophy can be diagnosed antemortem by three methods—clinical, radiological and electrocardiographical. Conflicting reports have been made in the past about their relative importance specially about the role of electrocardiography. While Paul Wood (1953) claims that electrocardiography provides the most accurate means by which the degree of left ventricular enlargement and stress may be assessed ; others like Goldberger (1953) and Stroud (1952) maintain that left ventricular hypertrophy is compatible with a perfectly normal E.C.G. tracing. Rodstein (1955) noted positive E.C.G. criteria in 19 out of 37 aged patients of left ventricular hypertrophy proved postmortem. Goulder and Kissane (1951) found 83 per cent positive results in lead aVL alone in their series of 65 patients of left ventricular hypertrophy in the horizontal or semi-horizontal E.C.G. position.

The purpose of the present investigation is to evaluate the relative importance of clinical, radiological and electrocardiographical methods in the diagnosis of left ventricular hypertrophy ; and also to determine the relative sensitivity of the different diagnostic E.C.G. criteria formulated by Gubner and Ungerleider (1943) and later by Sokolow and Lyon (1949) and by Goldberger (1953).

METHODS AND MATERIALS

75 cases of left ventricular hypertrophy admitted in the Medical College Hospital, Calcutta, during the period of 1-5-1955 to 30-9-1955 were studied and analysed. All cases showing right ventricular enlargement, mitral stenosis, evidence of myocardial infarction, questionable Q waves or intraventricular block were excluded.

Left ventricular hypertrophy was considered to be present if it fulfilled the following criteria:

(*a*) Clinical evidence of a disease process known to effect left ventricular hypertrophy.

* Essay awarded Hemchandra Sett prize, 1956.

(*b*) Either clinical or radiological or electrocardiographical or subsequent postmortem evidence of left ventricular hypertrophy.

I. *Clinical evidence*:

All cases were thoroughly examined and left ventricular hypertrophy was diagnosed on the basis of the presence of one or more of the following criteria:

(1) Apex beat displaced downwards with or without outward displacement.

(2) Forcible or heaving character of apical impulse.

(3) Booming character of mitral first sound.

II. *Radiological evidence*:

Fluoroscopy and roentgenograms were taken in P.A. and L.A.O. positions, when the patients were turned at an angle of 55°.

The presence of one or more of the following radiological criteria (Shanks and Kerley, 1951; Sante, 1947) was taken to be diagnostic of left ventricular hypertrophy.

(A) P. A. position—

indicates mainly the enlargement of outflow tract which is the part of left ventricle to enlarge first because increased work first affects this tract.

(1) Elongation and bulging of left ventricular curve as shown by

(*a*) extension of left ventricular shadow below the diaphragm with an increase in the distance between the point of reversal pulsation along the left border and the apex;

(*b*) rounding of the upper contour of left ventricle not disappearing on taking a long breath.

(2) Later on, the point of opposite pulsation may be actually pushed up indicating enlargement of the inflow tract.

(B) L.A.O. position—

indicates mainly the enlargement of inflow tract.

(1) Inability of left ventricular shadow to clear the spine.

(2) Downward and forward displacement of the intraventricular groove.

Cases of left ventricular hypertrophy were divided for the purpose of this study into mild, moderate and marked group basing upon the following clinical and radiological criteria.

(A) Mild.

(1) Clinically, apex beat in the left fifth space but forcible in character.

(2) Radiologically, some amount of elongation of left ventricular curve in P.A. with apex below the dome of the diaphragm but still in the fifth space, and just encroachment of spine (upto $\frac{1}{2}''$) in L.A.O.

(B) Moderate.

(1) Clinically, apex beat in the left fifth space but heaving in character.

(2) Radiologically, moderate elongation and bulging of left ventricular curve with actual raising of the point of opposite pulsation in P.A. and encroachment of spine by $\frac{1}{2}''$ to $1''$ in L.A.O.

(C) Marked.

(1) Clinically, apex beat in the left sixth or seventh space—heaving in character.

(2) Radiologically, classical boot-shaped heart with apex in left sixth or seventh space in P.A. and encroachment of spine by more than $1''$ in L.A.O.

III. *Electrocardiographic evidence*:

Electrocardiograms were taken in the supine position with a Siemen's Cardiostat direct writing apparatus. The six unipolar precordial leads were taken with the Wilson central terminal and the three unipolar augmented extremity leads of Goldberger were taken with 5000 ohms resistance in each extremity wire leading to the central terminal. Measurements were made with the aid of a magnifying glass and calipers, wherever necessary. The amplitudes were averaged when variations in amplitude were encountered due to respiratory influence. The amplitude of upright waves were measured from the upper edge of the base line to the peak of the wave; that of inverted waves from the lower edge of the base line. Particular attention was paid to the voltage of R and S waves in the precordial and limb leads. Appropriate corrections were made for minor technical errors in standardisation (1·0 cm = 1·0 mv), if any.

The time of onset of the intrinsicoid deflection was measured from the onset of QRS to the peak of R wave. The QT ratio was determined with the help of Goldberger's nomogram (Goldberger, 1953) and an average of at least 5 consecutive cycles was taken.

The presence of one or more of the following criteria formulated by Gubner and Ungerleider (1943) and later by Sokolow and Lyon (1949) and by Goldberger (*loc. cit.*) was taken to be diagnostic of left ventricular hypertrophy.

(A) With horizontal heart

(1) Standard leads (Gubner and Ungerleider, 1943).

The sum of amplitude of R in L_1 and S in L_3 equals or exceeds 25 mm.

(2) Unipolar leads (Sokolow and Lyon, 1949).

(*i*) The amplitude of R in aVL exceeds 11 mm.

(*ii*) The amplitude of R in V_5 or V_6 exceeds 26 mm.

(*iii*) The time of onset of intrinsicoid deflection in V_5 or V_6 exceeds 0·05 second.

(*iv*) The sum of amplitude of S in V_1 and R in V_5 or V_6 (whichever is higher) exceeds 35 mm.

(B) With vertical heart (Goldberger, 1953).

(1) Standard leads.

The sum of amplitude of R in L_2 and R in L_3 exceeds 40 mm.

(2) Unipolar leads.

Amplitude of R in aVF exceeds 20 mm.

Precordial lead criteria same as in horizontal heart.

The criteria for hypertrophy based on the configuration of the ST segments and T waves were not employed because of the possibility of conditions other than hypertrophy causing alteration of these components of the electrocardiogram. However, if these changes were present mainly on the left ventricular surface leads and their corresponding limb leads they were grouped under the heading of left ventricular strain.

IV. *Postmortem evidence*:

Postmortem examination was done in four cases and all four of them showed left ventricular hypertrophy. Of these four cases, two had electrocardiagraphical evidence of left ventricular hypertrophy, three had clinical evidence and all the four had radiological evidence.

RESULTS AND DISCUSSIONS

The group consists of 75 cases. 67 cases were males and 8 were females. The ages range between 6 to 80 years, the average age being 41·5 years. Of the 75 cases, 51 (68 per cent) had essential hypertension, 16 (21·3 per cent) had aortic valvular disease, 4 (5·3 per cent) had renal hypertension. Of the rest, I was a case of Cushing's syndrome, 1 had coarctation of aorta and in 2 cases the cause of hypertrophy could not be determined.

20 (27 per cent) cases belonged to mild hypertrophy group, 16 (21 per cent) belonged to moderate hypertrophy group and 39 (52 per cent) belonged to marked hypertrophy group.

Assessment of clinical method:

A survey of the accuracy of clinical examination in the detection of left ventricular hypertrophy is shown in Table 1.

TABLE 1

INCIDENCE OF DIAGNOSIS OF LEFT VENTRICULAR HYPERTROPHY ON CLINICAL EXAMINATION

Degree of left ventricular hypertrophy (Radiological)	*Total No. of cases*	*No. of cases showing hypertrophy on clinical examination*	*Percentage*
Mild	20	14	70
Moderate	16	13	81
Marked	39	37	95

Analysis of Table 1 reveals that in the marked group 37 out of 39 cases showed clinical evidence of left ventricular hypertrophy. In the remaining 2 cases the apex beat was not palpable due to thick chest wall. Similarly, 3 cases of the moderate group did not show any clinical evidence. Of these, one had apparently normal position and character of apex beat with normal mitral first sound ; in the other two the apex beat was not palpable due to thick chest wall in one and anasarca in the other. Out of 6 mild cases without any clinical evidence of left ventricular hypertrophy, 4 had apparently normal position and character of the apex beat and in 2 cases the apex beat was not palpable.

Assessment of radiological method:

74 out of 75 cases had radiological evidence of left ventricular hypertrophy. The one case not showing any radiological evidence had definite E.C.G. evidence of left ventricular hypertrophy. Thus radiology provides a very effective way of diagnosing left ventricular hypertrophy.

Assessment of electrocardiographical methods:

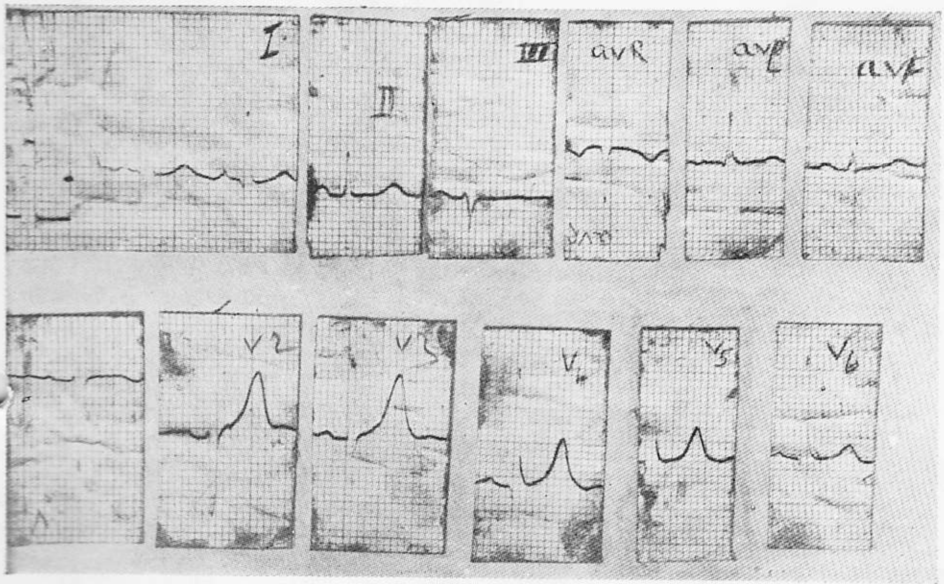
TABLE 2

INCIDENCE OF DIAGNOSIS OF LEFT VENTRICULAR HYPERTROPHY BY ELECTROCARDIOGRAPHIC METHOD

Degree of left ventricular hypertrophy	*Total No. of cases*	*Cases with evidence of left ventricular hypertrophy only*		*Cases with evidence of both left ventricular hypertrophy and strain*		*Cases with evidence of left ventricular strain only*	
		No.	%	*No.*	%	*No.*	%
Mild	20	4	20	7	35	3	15
Moderate	16	3	18·7	9	56·4	2	12·5
Marked	39	4	10·5	20	51·3	6	15·5

Analysis of Table 2 reveals that in mild cases, we get definite evidence of left ventricular hypertrophy in 55 per cent and evidence of left ventricular strain in another 15 per cent of cases. Moderate cases show definite evidence of left ventricular hypertrophy in 75 per cent and evidence of left ventricular strain in another 12·5 per cent. Marked cases show definite evidence of left ventricular hypertrophy in 61·8 per cent and evidence of left ventricular strain in another 15·5 per cent.

Thus about 25 per cent and 38·2 per cent cases of moderate and marked group respectively did not show any E.C.G. evidence of left ventricular hypertrophy though x-ray clearly revealed left ventricular hypertrophy. It may be of interest to note the greater percentage of absence of diagnostic E.C.G. criteria in marked cases than in moderate ones. This may be accounted by the fact that decompensation and pulmonary congestion was present in 30·8 per cent of cases in the marked group but only in 12·5 per cent of cases in the moderate group. This pulmonary congestion may to some extent diminish the voltage and may also cause some amount of right ventricular hypertrophy which tends to mask the evidences of left ventricular hypertrophy. Moreover, myocardial changes are prone to be more common in marked cases than in the moderate ones, which may further decrease the voltage of QRS. So pulmonary congestion, associated right ventricular hypertrophy and myocardial damage may be responsible for the lower incidence of diagnostic E.C.G. changes in the marked group. Thus Paul Wood's contention that "electrocardiography provides the most accurate means by which the degree of left ventricular enlargement and stress may be assessed", could not be justified.



FIG, 1
B.C., 50 years, M. Left ventricular hypertrophy is not seen.

An example of group of patients showing definite radiological evidence of left ventricular hypertrophy with a normal electrocardiogram is provided in Figs. 1, 2A and 2B.

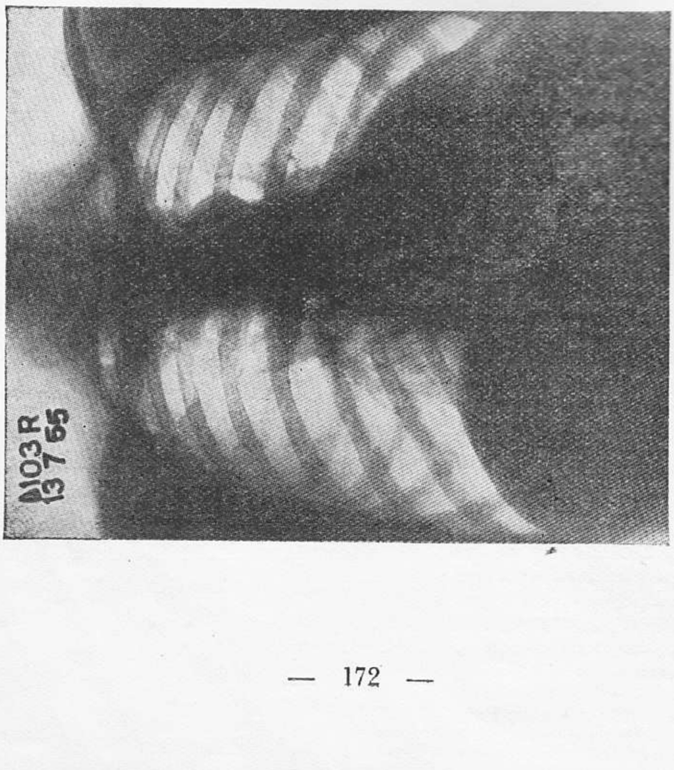


FIG. 2A

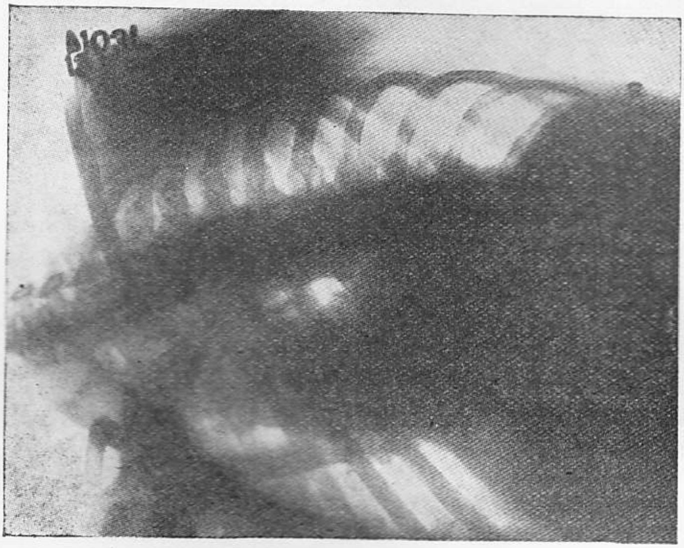


FIG. 2B

P.A. and L.A.O. views of the same patient as in Fig. 1 showing definite evidence of marked left ventricular hypertrophy.

Analysis of the relative importance of the different E.C.G. criteria employed in the diagnosis of left ventricular hypertrophy:

TABLE 3

INCIDENCE OF DIFFERENT ELECTRICAL POSITIONS IN CASES OF LEFT VENTRICULAR HYPERTROPHY

Total No. of Cases = 75

Electrical position	*No. of cases*	*Percentage*
Horizontal	26	34·6
Semi-horizontal	10	13·3
Intermediate	17	22·6
Semi-vertical	5	6·6
Vertical	13	17·3
Indeterminate	4	5·3

Thus in 48 per cent of cases, the heart is horizontal or semihorizontal and only in 24 per cent cases the heart is vertical or semi-vertical. This preponderant horizontal position of heart can be accounted by the enlargement of left ventricle downward, posteriorly and to the left in cases of left ventricular hypertrophy. This is in agreement with the observation of Goldberger (1953).

The measurements obtained from the unipolar leads are summarised in Table 4.

TABLE 4

AMPLITUDE OF VENTRICULAR DEFLECTION IN UNIPOLAR LIMB AND PRECORDIAL LEADS IN CASES OF LEFT VENTRICULAR HYPERTROPHY—MEASUREMENTS IN MM.
(Mean values and range of values are indicated)

	R			*S*		
	Minimum	*Maximum*	*Mean*	*Minimum*	*Maximum*	*Mean*
V_1	—	—	—	4	33	13
V_2	—	—	—	7	35	15·4
V_5	3	29	19·1	—	—	—
V_6	4	31	15·2	—	—	—
aVL (in horizontal heart)	2	20	11·2	—	—	—
aVF (in vertical heart)	6	25	14	—	—	—

TABLE 4—(Extension)

Criteria	Measurements		
	Minimum	*Maximum*	*Mean*
1. Sum of RV_5 or RV_6 and SV_1	15 mm.	60 mm.	35·5 mm.
2. Duration of QRS	0·04 sec.	0·11 sec.	0·07 sec.
3. Intrinsicoid deflection in V_5 or V_6 (whichever is higher)	0·03 sec.	0·065 sec.	0·048 sec.
4. QT ratio	0·90	1·30	1·045

Study of Table 4 reveals that the present data closely resemble that obtained by Sokolow and Lyon (1949) in their series of 167 cases of left ventricular hypertrophy.

Tables 5, 6 and 7 show the relative importance of the unipolar limb and precordial leads in the diagnosis of left ventricular hypertrophy.

TABLE 5

SHOWING INCIDENCE OF CASES WITH EVIDENCE OF LEFT VENTRICULAR HYPERTROPHY IN UNIPOLAR LIMB LEADS BUT NO SIGNIFICANT CHANGE IN PRECORDIAL LEADS

Electrical Position	*Total No. of cases*	*No. of cases with evidence in limb leads only*	*Percentage*
Horizontal and semi-horizontal	36	4	11·1
Vertical and semi-vertical	18	nil	nil
Intermediate and Indeterminate	21	nil	nil

TABLE 6

SHOWING INCIDENCE OF CASES WITH EVIDENCE OF LEFT VENTRICULAR HYPERTROPHY IN PRECORDIAL LEADS ONLY WITHOUT ANY EVIDENCE IN UNIPOLAR LIMB LEADS

Electrical Position	*No. of cases*	*Evidence in precordial leads alone*	*Percentage*
Horizontal or semi-horizontal	36	11	30·7
Vertical or semi-vertical	18	5	27·7
Intermediate or Indeterminate	21	10	47·6

TABLE 7

TABLE SHOWING INCIDENCE OF CASES WITH EVIDENCE OF LEFT VENTRICULAR HYPERTROPHY IN BOTH PRECORDIAL AND UNIPOLAR LIMB LEADS

Electrical Position	*No. of cases*	*Evidence in both precordial and unipolar limb leads*	*Percentage*
Horizontal or semi-horizontal	36	13	36·1
Vertical or semi-vertical	18	3	16·6
Intermediate or Indeterminate	21	1	4·76

Evaluation of standard limb leads—Analysis reveals that standard leads are not of much value in the diagnosis of left ventricular hypertrophy and are practically useless in cases with intermediate and indeterminate lies. This is quite expected as in this electrical position of heart, the left ventricular surface pattern is transmitted to both aVL and aVF and hence to both L_1 and L_3, the one neutralising the effect of the other. Hence the standard lead pattern described in the literature as typical of left ventricular hyperprophy is seldom met in cases with intermediate and indeterminate lies.

Evaluation of unipolar limb leads—Out of 75 cases, only 4 show changes exclusively in unipolar limb leads, whereras 26 cases show evidence in precordial leads alone without any evidence in unipolar limb leads. It is of interest to note that all 4 cases showing changes exclusively in unipolar limb leads were in horizontal or semi-horizontal electrical position of heart and showed characteristic changes in aVL. Moreover out of 36 cases with horizontal or semi-horizontal lie, aVL showed changes in 17 (47·2 per cent) cases whereas lead V_5 or V_6 showed characteristic changes in only 4 or 11·1 per cent cases. Theoretically, this can be explained on the basis of Grant's (1950) study of the spatial vector electrocardiogram for in horizontal or semi-horizontal lie, the spatial vector of the ventricular potential is often best projected on the left arm lead.

However, our percentage of characteristic changes in aVL in horizontal or semi-horizontal lie is rather less than that obtained by Goulder and Kissane (1951) who found R. aVL greater than 11 mm. in 63 per cent of their series of 45 patients.

Evaluation of precordial leads—Analysis of precordial leads reveals as noted before that while as many as 26 cases showed evidence exclusively in precordial leads, the reverse was found in only 4 cases. This preponderance of changes in precordial leads is specially marked in intermediate and indeterminate posi-

TABLE 8

TABLE SHOWING THE RELATIVE IMPORTANCE OF DIFFERENT E.C.G. CRITERIA IN THE DIAGNOSIS OF MILD, MODERATE AND MARKED CASES OF LEFT VENTRICULAR HYPERTROPHY.

E.C.G. criteria	*A. Mild Group*			*B. Moderate Group*			*C. Marked Group*		
	Total No. of cases	*No. of cases with positive criteria*	*Percentage*	*Total No. of cases*	*No. of cases with positive criteria*	*Percentage*	*Total No. of cases*	*No. of cases with positive criteria*	*Percentage*
(a) $R_1+S_3=25$ mm. or more or $R_2+R_3=40$ mm. or more	20	3	15	16	7	43·75	39	11	28·2
(b) R in aVL=11 mm. or more or R in aVF=20 mm. or more	20	4	20	16	6	37·5	39	11	28·2
(c) R in V_5 or $V_6=26$ mm. or more	20	2	10	16	2	12·5	39	5	12·8
(d) R in V_5 or V_6+S in $V_1=35$ mm. or more ..	20	10	50	16	10	62·5	39	23	58
(e) Intrinsicoid deflection in V_5 or V_6 more than 0·05 sec.	20	3	15	16	5	31·25	39	13	33·3
(f) Duration of QRS 0·10 to 0·11 sec.	20	1	5	16	0	0	39	7	17·9

tions of heart where out of 21 cases, 10 (47·7 per cent) showed changes in precordial leads alone without any evidence in unipolar limb leads, but the reverse was not found even in a single case.

Analysis of the different precordial lead criteria reveals that the criterion sum of RV_5 or $RV_6 + SV_1 = 35$ mm. or more gives positive result inasmuch as 43 out of 75 (57·3 per cent) cases. It may be repeated here that only 47 (62·6 per cent) cases have shown diagnostic E.C.G. changes. So, if only this single criterion is used for electrocardiographic diagnosis of left ventricular hypertrophy, only 5·3 per cent cases will be missed.

Delayed onset of intrinsicoid deflection in V_5 or V_6 provides the second best precordial lead criterion and is found positive in 21 or 28 per cent of cases. The minimum I.D. was found to be 0·03 sec. and maximum 0·065 sec. with the mean of 0·048 sec.; which is much higher than 0·04 sec. obtained by Sokolow and Lyon (1949) in the group of 151 normal cases and is closely similar to 0·0485 sec. obtained by them in their group of 147 cases of left ventricular hypertrophy.

Criterion R in V_5 or $V_6 = 26$ mm. or more does not seem to be of much value as it is positive in only 9 or 12 per cent of cases.

Duration of QRS—Increased duration of QRS was found in 8 or 10·6 per cent of cases of which 7 belonged to marked hypertrophy group. The minimum duration of QRS was 0·04 sec. and the maximum duration 0·11 sec. with the average of 0·07 sec.

QT Ratio—The QT ratio was calculated in each case. The mean QT ratio was found to be 1·045 with the range of 0·90 to 1·30. The average normal QT ratio for men and children is 1·01 and for women 1·02. The maximum normal QT ratio for men and children is 1·08 and for women 1·09, calculated from the date of Ashman and Hull (1941). As 69 out of 75 cases of this series were men or children, 1·08 was taken to be maximum normal. 24 (32 per cent) cases showed QT ratio more than 1·08. This contrasts with the findings of Elek *et al* (1953) who found no significant alteration of QT interval in their series of 120 cases of left ventricular hypertrophy comparing favourably with the observations of Phang and White (1943) who found a significant relative prolongation of QTc in the majority of their cases of cardiac enlargement.

It is possible that the cardiac enlargement with longer pathways of impulse conduction and greater bulk of contracting muscle is one of the factors responsible for the prolongation of QT interval. The associated myocardial changes and cardiac failure may further increase the QT interval.

CONCLUSIONS

(1) A statistical study of 75 cases of left ventricular hypertrophy is presented to evaluate the relative importance of clinical, radiological and electrocardiographical methods in the diagnosis of left ventricular hypertrophy and also to determine the sensitivity of different E.C.G. criteria which have been described in the literature as diagnostic of left ventricular hypertrophy.

(2) Radiology is found to be by far the best method showing diagnostic changes in 74 (98·7 per cent) cases, the one case not showing any radiological evidence had definite E.C.G. evidence of left ventricular hypertrophy.

(3) Left ventricular hypertrophy could be diagnosed by physical examination alone in 64 (85·3 per cent) cases.

(4) Of the three methods, electrocardiography was found to be the least effective as diagnostic E.C.G. changes were found only in 47 (62·6 per cent) cases and 11 more cases showed evidence of left ventricular strain. Moreover, no correlation could be made between the degree of left ventricular hypertrophy and E.C.G. changes. In fact, the characteristic E.C.G. changes were found in greater percentage of cases in the moderate group than in the marked one. This may be due to increased incidence of pulmonary congestion, associated right ventricular hypertrophy and myocardial damage in cases with marked left ventricular enlargement. So, Paul Wood's contention that "electrocardiography provides the most accurate means of determining the degree of left ventricular enlargement and stress" could not be justified.

(5) By far the most sensitive E.C.G. criterion was found to be RV_5 or $RV_6 + SV_1$ greater than 35 mm. which was positive in 43 (57·3 per cent) cases. So, if only this one single criterion is taken for electrocardiographic diagnosis of left ventricular hypertrophy, only 5·3 per cent of cases showing characteristic E.C.G. changes will be missed. The other E.C.G. criteria in the order of importance are—

(*a*) R in aVL = 11 mm. or more or R in aVF = 20 mm. or more.

This criterion was positive in 21 (28 per cent) cases and was found to be specially important in cases with horizontal or semi-horizontal lie where the criterion R in aVL greater than 11 mm. was positive in 47·2 per cent cases.

(*b*) Intrinsicoid deflection in V_5 or V_6 more than 0·05 sec.
—positive in 21 (28 per cent) cases.

(*c*) $R_1 + S_3 = 25$ mm. or more or $R_2 + R_3 = 40$ mm. or more
—positive in 21 (28 per cent) cases.

(*d*) R in V_5 or $V_6 = 26$ mm. or more.
—positive in 9 (12 per cent) cases.

(*e*) Duration of QRS 0·10 to 0·11 sec.
—positive in 8 (10·6 per cent) cases.

(6) QT ratio was found to be increased beyond the maximum normal in 24 (32 per cent) cases.

SUMMARY

(1) 75 cases of left ventricular hypertrophy were studied and analysed clinically, radiologically and electrocardiographically.

(2) Radiology was found to be by far the most effective method for the diagnosis of left ventricular hypertrophy, physical examination being second and electrocardiography the least effective of the three.

(3) RV_5 or $RV_6 + SV_1 = 35$ mm. or more was found to be by far the most important electrocardiographic criterion for the diagnosis of left ventricular hypertrophy.

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