T WAVE INVERSION, HEART SIZE, AND FUNCTIONAL CAPACITY

THE CORRELATION BETWEEN THESE IN 100 PATIENTS WITH HYPERTENSION

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Received October 8, 1940

T wave inversion and RS-T segmental deviation have been emphasized as evidence of myocardial infarction and coronary disease. It is not, however, rare to encounter these changes in tracings of those who do not exhibit the clinical picture of these conditions—the only demonstrable pathology being enlargement. Barnes and Whitten (1929), on careful post-mortem examination, were unable to detect gross or microscopic damage to the myocardium in a large series of cases presenting these electrocardiographic findings. Master (1939) and Barnes (1940) have noted progressive changes in the T wave and RS-T segment as enlargement proceeds; they contend there is a characteristic configuration for relative preponderance of one or the other ventricle, and have suggested the term “ventricular preponderance or strain” for use in cardiographic interpretation.

An investigation was undertaken, in the attempt (1) to correlate these changes with the degree of enlargement of the heart and with functional capacity; (2) to determine whether the cardiographic pattern is sufficiently characteristic and clinically valuable to warrant its retention; and (3) to determine the types of heart disease associated with “left ventricular preponderance.”

MATERIAL AND CRITERIA

One hundred consecutive clinic and hospital patients with hypertension were the subjects of this study. The series included white and coloured patients and Mexicans, of all ages and both sexes. Five were classified clinically as malignant hypertension (nephrosclerosis) and the remainder as essential hypertension. There was unequivocal evidence of over-digitalization in four, and of recent coronary occlusion in five.

Patients with blood pressures above 150/90 determined by the method prescribed by the American Heart Association and the Cardiac Society of Great Britain and Ireland (1939) were considered to have hypertension and were included in this series.

The standard leads of the cardiogram of each patient were studied for axis deviation, amplitude of the QRS complex, RS-T segmental deviation, and T wave direction. The angle of direction of the electrical axis was determined

by the method devised by Einthoven (1908), and further developed by Carter, Richter, and Greene (1919). The amplitude of QRS was counted as increased if the R or S wave or both were 15 mm. or more. The RS-T segment or T take-off was considered displaced if it was 0.5 mm. or more from the isoelectric line. The criteria for left ventricular preponderance were (1) left axis deviation, (2) negative T₁, or T₁ and T₂, with a positive T₃, and (3) the negative T arising from the S wave, 0.5 mm. or more below the isoelectric line, or from a depressed RS-T segment.

In 55 cases the cardiac size was measured by the cardiothoracic ratio determined by teleo-radiography. A ratio below 50 per cent was considered normal, 50-54 per cent slightly enlarged, 55-61 per cent moderately enlarged, and 62 per cent and above extremely enlarged. In the remainder of the cases enlargement was determined clinically. If the apex beat was palpable in the fifth intercostal space within the midclavicular line, the size was considered to be within normal limits; from the midclavicular to the nipple line slightly enlarged; from the nipple to the anterior axillary line or in the sixth intercostal space, moderately enlarged; and at or beyond the anterior axillary line or in the seventh intercostal space, extremely enlarged.

Classification of functional capacity was determined from the history and physical examination according to the criteria of the American Heart Association as laid down in the *Nomenclature for Criteria for Diagnosis of Diseases of the Heart* (1939).

CORRELATION OF FUNCTIONAL CAPACITY WITH CARDIAC ENLARGEMENT

The clinical impression of a positive correlation between the size of the heart and the functional capacity is confirmed by Table I. Were it not for the accidents occurring in the course of hypertensive heart disease (coronary occlusion, arrhythmias, and conduction disturbances), the correlation would probably be even more complete.

TABLE I.—CORRELATION OF FUNCTIONAL CAPACITY WITH CARDIAC ENLARGEMENT

Size of Heart	Functional Capacity				Total
	I	II	III	IV	
Normal	7	7	—	—	14
Slightly enlarged..	1	10	5	3	19
Moderately enlarged ..	—	3	14	15	32
Externally enlarged ..	—	—	4	31	35
Total	8	20	23	49	100

CORRELATION OF T WAVE DIRECTION AND RS-T SEGMENTAL DEVIATION WITH CARDIAC ENLARGEMENT

Typical electrocardiograms from patients with hypertension, with varying degrees of enlargement of the heart, are shown in Fig. 1. Other authors have

FIG. 1.—Common types of electrocardiograms in hypertensive heart disease with various degrees of cardiac enlargement.

published tracings showing similar progressive changes in individual patients as the enlargement progressed.

In lead I the T wave tended to become inverted as the heart increased in size; 75 per cent of extremely enlarged hearts had inverted T waves, whereas there was no case of inversion in a normal-sized heart. The RS-T segment tended to become depressed as enlargement progressed, but this occurred less frequently than T wave changes, as approximately 50 per cent of extremely enlarged hearts had depressed RS-T segments or low T take-offs.

In lead II the T wave and RS-T segments both tended to become inverted as enlargement progressed. However, it only occurred half as frequently as in lead I. Its presence was more likely to signify moderate to extreme enlargement than final deflection changes limited to lead I.

In lead III 57 per cent of normal-sized hearts had inverted T waves. As enlargement progressed there was less tendency to inversion; 28 per cent of extremely enlarged hearts had inverted T waves. The tendency to positivity of T wave was mirrored in the RS-T segment, which became elevated as enlargement progressed. More detailed results with figures and tables follow.

T Wave

Lead I—The T wave was upright in all normal-sized hearts. But 37 per cent of slightly and moderately enlarged hearts had inverted T waves, and this was true in 74 per cent of extremely enlarged hearts. 45 per cent of the entire series had negative T waves.

Lead II—Here again no negative T waves were found in normal-sized hearts. There was inversion in 20 per cent of slightly and moderately enlarged hearts, whereas in extremely enlarged hearts, there was 57 per cent inversion. Of the entire series, the T wave was negative in 31 per cent.

Lead III—The T wave was inverted in 57 per cent of hearts of normal size, in 37 per cent of slightly enlarged, and in 24 per cent of moderately and extremely enlarged hearts.

These results are illustrated in Fig. 2.

FIG. 2.—Correlation of heart size with inversion of T waves and depression of the RS-T segment in standard leads, expressed as percentages.

N indicates normal-sized, SL slightly, MOD moderately, and EXTR extremely, enlarged hearts.

RS-T Segment

Lead I—Of those with hypertension and normal-sized hearts 7 per cent had depressed RS-T segments. (One patient had a posterior coronary occlusion; another with positive RS-T segment had an anterior occlusion.) In slightly and moderately enlarged hearts, 33 per cent had depressed RS-T segments or low T take-off, whereas this was present in 48 per cent of extremely enlarged hearts. 35 per cent of the entire series had a low T take-off or a depressed RS-T segment.

Lead II—There was no deviation of the RS-T segment in any of the normal-sized hearts, whereas 16 per cent of the slightly and moderately enlarged hearts, and 26 per cent of the extremely enlarged hearts had depression of the RS-T segment.

Lead III—Of the normal-sized hearts 7 per cent had elevated RS-T segments, whereas in slightly enlarged it was 11 per cent, in moderately enlarged 22 per cent, and in extremely enlarged hearts 23 per cent.

CORRELATION OF LEFT AXIS DEVIATION, AMPLITUDE OF QRS, AND LEFT VENTRICULAR PREPONDERANCE WITH CARDIAC ENLARGEMENT

Left axis deviation—There appears to be no positive correlation between the degree of cardiac enlargement and the angle of deviation of the electrical axis, or the frequency of left axis deviation; 64 per cent of normal, 53 per cent of slightly enlarged, 50 per cent of moderately enlarged, 65 per cent of extremely enlarged hearts, and 58 per cent of the entire group showed left axis deviation. Right axis deviation did not occur in this series. These results are given in Table II and Fig. 3.

TABLE II—CORRELATION OF CARDIAC ENLARGEMENT WITH LEFT AXIS DEVIATION, INCREASED AMPLITUDE OF QRS, AND LEFT VENTRICULAR PREPONDERANCE

	Normal Size	Degree of Enlargement			Total
		Slight	Moderate	Extreme	
Left axis deviation (L.A.D.) ..	9	10	16	23	58
L.A.D. with high amplitude ..	4	2	10	3	19
L.A.D. with T ₁ inverted and T ₃ upright ..	—	4 (1)*	8 (2)	5 (2)	17
L.A.D. with T ₁ and T ₂ inverted and T ₃ upright ..	—	2 (1)	2 (2)	9 (4)	13
Complete left ventricular preponderance ..	—	6	10	14	30
Total cases ..	14	19	32	35	100

* Figures in brackets refer to number of cases showing increased amplitude of QRS.

Increased Amplitude of QRS—31 per cent of the entire series showed an increased amplitude of QRS: 28 per cent of the normal, 21 per cent of the slightly enlarged, 43 per cent of the moderately enlarged, and 26 per cent of extremely enlarged hearts had increased amplitude. Again, there is no positive correlation and its frequency does not appear related to the degree of enlargement (see Fig. 3).

FIG. 3.—Correlation of heart size with left axis deviation, increased amplitude of QRS, and left ventricular preponderance, expressed as percentages.

In the right-hand third of the figure, the light area indicates T_1 inverted and T_3 upright; and the shaded area, T_1 and T_2 inverted and T_3 upright.

Left Ventricular Preponderance—No patient with a normal-sized heart exhibited left ventricular preponderance: 31 per cent of slightly and moderately enlarged and 40 per cent of extremely enlarged hearts showed preponderance. As the heart increased in size there was an increase in the frequency of occurrence of left ventricular preponderance, inversion of T_2 , and depression of RS- T_2 segment (see Fig. 3). The slight proportionate increase of high amplitude QRS occurring with preponderance in the larger hearts appears not to be statistically significant; 30 per cent of the entire series had left ventricular preponderance. If the normals were eliminated, the frequency of left ventricular preponderance in enlarged hypertensive hearts was 35 per cent.

ÆTIOLOGY OF CARDIAC ENLARGEMENT IN LEFT VENTRICULAR PREPONDERANCE

Hypertension (82 per cent) was the most common ætiological factor associated with left ventricular preponderance. Lues (15 per cent) was next in frequency (see Table III). The patient with rheumatic fever had marked mitral regurgitation with left ventricular enlargement. Possibly the case of arteriosclerosis should be listed under (pre-existing) hypertension, since the patient had a pressure of 140/80, was in marked congestive failure, had extreme enlargement of the heart, and died eight days later. It appears that the electrocardiographic pattern described as left ventricular preponderance occurs only in those diseases of the heart that lead to enlargement of the left ventricle.

TABLE III

ÆTIOLOGY OF HEART DISEASE IN 60 CASES OF LEFT VENTRICULAR PREPONDERANCE

	Number of Cases	Percentage of Total
Hypertension	42	70.0
Hypertension and lues	6	10.0
Hypertension and emphysema	1	1.7
Lues	9	15.0
Rheumatic fever	1	1.7
Arteriosclerosis	1	1.7
Total	60	100.0

SUMMARY AND CONCLUSIONS

(1) The electrocardiogram, functional capacity, and cardiac size were correlated in a study of 100 consecutive patients with hypertension. There is a positive correlation between the size of the heart and functional capacity.

(2) As the heart enlarges in hypertension, the T wave progressively becomes inverted in leads I and II and upright in lead III. The RS-T segment follows the T wave in its direction.

(3) Left ventricular preponderance is a characteristic electrocardiographic pattern occurring in 35 per cent of patients with enlarged left ventricles. It occurs with increasing frequency as the heart enlarges, and is characterized by (1) left axis deviation, (2) inversion of T_1 or of T_1 and T_2 with T_3 upright, and (3) a depressed RS-T segment in lead I or in leads I and II and an elevated RS-T segment in lead III.

(4) Since functional capacity and cardiac size are both directly related to left ventricular preponderance, one may estimate, with some degree of accuracy in many cases, the functional capacity and approximate size from the electro-cardiographic picture.

(5) Because depressed RS-T segments in leads I and II and elevated RS-T in lead III are found in 35 per cent of enlarged hypertensive hearts, and this deviation is one of the cardinal patterns of posterior coronary occlusion, one should be extremely careful in making the latter diagnosis on the cardiographic evidence alone. The origin of the RS-T take-off and the presence of Q waves are of value in the differential diagnosis.

(6) Hypertension is the most frequent ætiological cause of left ventricular preponderance. Lues is the next most common ætiological factor.

(7) There is no positive correlation between the level of the blood pressure and these changes. Our data do not solve the problem of whether the duration of hypertension, enlargement *per se*, or some other factor associated with enlargement is responsible for the T and RS-T changes.

(8) We do not believe the few cases of coronary occlusion or over-digitalization in the series affect the general conclusions.

Acknowledgment is made to Dr. Ghent Graves for helpful suggestions, and to Dr. G. C. Lechenger of the Jefferson Davis Hospital for use of the radiological material.

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