THE CLINICAL SIGNIFICANCE OF HIGH T WAVES IN THE ELECTROCARDIOGRAM

by

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INTRODUCTION

Most textbooks on electrocardiography give the normal amplitude of the T wave as 2 to 5 millimeters. The importance of abnormally low T waves is fairly well understood, but very little is known about the significance of high T waves, whose amplitude is 5 millimeters or over. This study was undertaken to determine, if possible, the clinical significance of high T waves appearing in the three standard leads of the electrocardiogram.

REVIEW OF LITERATURE

The literature was scanned through the Index Medicus for the years 1925-1938. All articles on high T waves or the theory of T waves were reviewed.

Velasco and Lombardini[16] explain the T wave in the following manner. Excitation invading the ventricular myocardium produces physico-chemical changes which provoke an electrical imbalance,-- the QRS wave. These reactions are reversible since, if the contrary were true, one could not explain the prolonged functioning of hearts deprived of their circulation. This manner of thinking is in accord with the well-known refractory period of heart muscle. The inverse reactions constitute the T wave. Thus are explained the differences in form, complexity and variation in direction between QRS and T waves. The T wave varies because of whatever locally modifies cellular metabolism.

Katz[12] believes that the T wave is caused by the unbalancing of electrical stresses during retreat of excitation which are in part the result of a nonsimultaneous onset of excitation and in part the result of an unequal duration of excitation in the various portions of the heart. The T wave decreases with age and increases after exercise.

Wilson and Macleod[15] believe that the T wave is produced by the return of the ventricular muscle from the excited to the resting state. The form of the T wave is determined by the form of QRS and by factors which modify the duration of the excited state locally.

Otto[9] states that right basal effects with prolongation of its activity or lessening of left apical ventricular effects elevate the T waves; also, when summation of the events of cardiac contraction are such as to favor the right ventricle by a prolongation of its activity or an algebraic increase in the muscle activity over that of the left side of the heart, the T wave tends to positivity.

Frucht[4] states that on warming the apex the T wave becomes upright if it has been inverted. Cooling the right ventricle heightens the upright T wave.

Otto[10] has shown that epinephrine injected into the aorta of a dog with vagi sectioned will cause increased height of the T wave.

Bonckaert and Czarnecki[2] have determined that the T wave is increased in 80% of the dogs by increasing the viscosity of the blood. Increased viscosity is produced by gum arabic and saline. In 20% there was no modification. The T wave is also increased by changes in position, and after artificial respiration.

Haymal[6] reported two cases of patients in hypoglycemic shock. In one case there was flattening of the T wave; in the other,

heightening of the T wave which decreased after the injection of glucose. He also states that there were negative T waves in the electrocardiograms of diabetics.

Stankovic and Arnovljevic[13] reported a case of mitral stenosis without apparent impairment of excitation conduction. There was longitudinal dissociation of ventricular action. The duration of right ventricular systole was one-third greater than the left. The end of left ventricular contraction was in constant relation to the T wave. The end of right ventricular contraction had no effect on the T wave.

Hamburger et al[5] have shown that Lugol's solution in hyperthyroidism results in most instances in a lowered T wave. Subtotal thyroidectomy is followed by greater decrease in the T wave and it may even go to inversion. The decrease in basal metabolic rate parallels the decrease in height of the T wave following iodine therapy and thyroidectomy.

Mc Guire and Foulger[8] believe that the high T waves of hyperthyroidism are not dependent on pulse rate or increased basal metabolic rate and are not specific for hyperthyroidism since they are seen also in neurocirculatory asthenia. Administration of thyroid extract to normal individuals will produce comparable alterations in the human electrocardiogram. In dogs the administration of thyroid extract causes tachycardia and increase in the height of the T waves.

Kammerer and Obermaier[7] have determined that in 28% of their cases of Basedow's disease there were high T waves. In 15% the high T waves were in leads I and II. The severity of the thyrotoxicosis seemed to be a factor in the post operative reversal of the T waves. This reversal occurred in the second week according to the author. This is in contradiction to the opinion of Parade and Haas who believe it occurs within three days post operatively.

MATERIAL STUDIED

The electrocardiographic files of the Wisconsin General Hospital were searched for tracings exhibiting a T wave of 5 millimeters or more in amplitude in any of the three standard leads. The precordial lead was not considered in this study. These electrocardiograms, for the most part, had been taken on in-patients and out-patients of the Wisconsin General Hospital and University students who had, for one reason or another, consulted the Student Health Department.

Most of the cases were those in the Wisconsin General Hospital and Student Health Department during the years 1930-1938. There were a few cases from previous years. Wherever possible the records of the cardiology department were consulted for the data. In the other cases hospital records and student health records were used.

The T waves were considered high if they were 5 millimeters or more above the base line. In doubtful cases, where the base line or T waves were indefinite, the records were discarded. An effort was made also to check the standardization of the electrocardiogram to make certain that it was not over 10 millimeters.

PRESENTATION OF RESULTS

There were 69 cases included in this study. Of these 47 were males and 22 were females.

The age incidence of the patients studied was as follows:

Age Period	No. of cases	Per cent
0 - 5	1	1.5
5 - 10	5	7
10 - 15	3	4
15-- 20	11	16
20 - 25	12	17
25 - 30	5	7
30 - 35	3	4
35 - 40	6	9
40 - 45	3	4
45 - 50	5	7
50 - 55	2	3
55 - 60	4	6
Above 60	7	10

Thus it is readily seen that the largest group of patients was represented in the age groups of 15 to 25. This may be partly explained by the fact that there are freshman physical examinations in which a large group of entering university students is examined and those with any suspected cardiac disease are re-examined by a cardiologist. Thus we get electrocardiograms of many individuals of college age. The oldest individual in this study was 83 years of age.

The relative frequency of high T waves in the various leads was determined. It was found in lead I in 25 cases (36%); in lead II in 53 (77%); and in lead III in 9 (13%). Here it is seen that high T waves occur much more frequently in lead II. This is readily understood when we remember that according to Einthoven's Law the waves in lead II are the algebraic sum of the waves in leads I and III, and when the T is upright in all three leads, T_2 will necessarily exhibit the greatest amplitude.

The average height of the high T waves in lead I was 5.5 millimeters with extremes of 5 to 7 millimeters; in lead II it was 5.4 millimeters with extremes of 5 to 8 millimeters; and in lead III it was 6.5 millimeters with extremes of 5 to 9.5 millimeters.

To determine the association of previous illnesses, the past medical history was investigated and a "rheumatic " history was found in 27 cases (39%). Of these there were 13 instances of acute rheumatic fever; 12 of tonsillitis; one of Syndenham's chorea, and two of scarlet fever. One patient had had both scarlet fever and acute rheumatic fever.

An attempt was made to find a relationship between high T waves and various cardiac diagnoses. The following results were noted.

Diagnosis	Cases	Per cent
Rheumatic heart disease	17	25
No clinical evidence of heart disease	16	23
Coronary sclerosis	11	16
Questionable heart disease	9	13
Congenital heart disease	6	9
Hypertensive heart disease	3	5
Thyrotoxic heart disease	2	4
Complete heart block with Adams-Stokes syndrome	2	4
Tobacco angina	1	2
Healed pericarditis	1	2
Syphilitic heart disease	1	2

This chart shows that there were 44 cases of definite organic heart disease (64%). There were 16 in which no organic heart disease could be demonstrated (23%) and 9 cases of questionable heart disease (13%).

It was felt that hypertension might be associated with high T waves so the number of cases with hypertension was determined. The latter was considered to be present if either the systolic pressure was above 150 millimeters of mercury or the diastolic pressure was above 100 millimeters. There was hypertension in 12 instances (17%). In three of these cases the heart was clinically normal. In seven the electrocardiogram showed delayed intraventricular conduction and other changes suggestive of such conditions as myocardial degeneration and coronary occlusion. In the remaining five cases the electrocardiogram showed only slight abnormalities such as notching and slurring of QRS, slight elevation of the S-T segment and left axis deviation.

Tabulation of functional capacity in the patients with evidence of organic heart disease showed the following.

Functional Capacity	Cases	Per cent
I	14	27
II A	22	43
II B	10	20
III	5	10

Of the 51 cases of organic heart disease 30 showed delayed intraventricular conduction or other serious electrocardiographic abnormalities indicative of coronary occlusion, and myocardial degeneration. Twenty-one showed only slight abnormalities such as notching and slurring of QRS, slight elevation of the S-T segment and axis deviation.

There was left axis deviation in 20 instances (30%); right axis deviation in 14 (20%); and no axis deviation in 35 (51%).

Of the total of 69 cases with high T waves 37 showed no other abnormality in the electrocardiogram (54%).

There were at least 6 deaths in this series. This value is probably much lower than the true number as many of the patients could not be followed after discharge.

The search through the files revealed one group of five patients who were being studied primarily for the purpose of determining the effect of pericarditis on the degree of shift of the electrical axis with change in position of the patient. The

electrocardiograms of these patients showed high T waves only with the patient lying on his right side while all the T waves were less than 5 millimeters in those taken with the patient in the sitting posture or lying on his left side. In the above mentioned cases only T_2 was high. The average height of these high T waves was 5.6 millimeters. All these patients were males, three in the age group of 18 to 23 years, one 51 years and the age of the fifth was unknown. There was a rheumatic history in four cases. In three cases there was no heart disease. In one case of rheumatic heart disease there was extreme cardiac enlargement. There were no instances of hypertension in this group. There was no axis deviation except in one instance of a normal heart which showed right axis deviation.

DISCUSSION

The literature reviewed in this study and the data collected have shown that there are many factors which may influence the T wave. This is a rather complex subject and as yet little understood. We have attempted to determine whether there was any demonstrable relationship between high T waves and any particular type of cardiac pathology. It is noteworthy that in only 23% of the group was the heart clinically normal. In the remaining 67%, practically all of the common types of heart disease were represented with rheumatic heart disease predominating. It is interesting to note that coronary sclerosis, which usually produces lowering of the T waves, formed 16% of the series. Thyrotoxicosis, which most textbooks list as a common cause of high T waves, was found in only 4%. Hypertensive heart disease, congenital heart disease, complete heart block, "tobacco angina", healed pericarditis and syphilitic heart disease were found associated with abnormally high T waves in smaller percentages. It is obvious that no one pathological process can be held responsible for this finding and the multiplicity of clinical conditions occurring in this series only tends to increase the complexity of the problem.

Even in the presence of organic heart disease, a high T wave does not necessarily mean serious heart damage as the functional capacity of the myocardium was reduced to a grade II B or III in only 15 of the 51 cases. In relation to the entire series the figures

indicate that three out of four of these patients had little or no cardiac disability. No extra-cardiac disease was found to play an important role in the heightening of the T waves.

Apparently mechanical factors can also play a part as demonstrated by a group of five patients who were being studied for evidence of pericarditis. In each instance the shift in the position of the heart, occasioned by the patient lying on his right side, was sufficient to produce definite increase in the amplitude of the T wave in lead II. The fact that in a number of instances an individual might show high T waves at one time but not another, confirms the impression that high T waves may be transient in character and simply an incidental finding secondary to changing conditions in the system.

Since T waves of 5 millimeters or more in amplitude occur with considerable frequency in patients with no clinical evidence of organic cardiovascular disease and since they may be transient in any one patient, it is highly probable that this arbitrary upper limit of normal may be incorrect and that T waves of 6 millimeters or more in amplitude, although uncommon, may lie within the normal range. The present study points to the fact that high T waves occur more commonly in the presence of cardiovascular disease than in the normal and should therefore be considered as presumptive evidence of cardiac pathology and an indication for further study of any patient in which they are found. As an isolated finding, they do not necessarily indicate the presence of disease.

CONCLUSIONS

1. The occurrence of an abnormally high T wave in a single tracing not exhibiting other abnormalities may be of no definite significance as, in some instances, this may be a transient finding.
2. High T waves may be considered presumptive evidence of some form of cardiovascular disease since over three-fourths of the patients showing high T waves at one time or another were found to have some clinical condition directly or indirectly affecting the cardiovascular system.
3. High T waves are not specific for any one type of disease process since they are found in a large variety of conditions.
4. The presence of high T waves is not necessarily an abnormal finding as it occurred in a number of cases in which no demonstrable cardiovascular disease was present.
5. Of 51 cases of organic heart disease only 14 had a functional capacity of I. In other words, nearly three-fourths of this group had heart disease with definite cardiac symptoms.
6. In this series high T waves occurred in the electrocardiograms of males twice as often as in females.
7. Most high T waves were found more frequently in the age group of 15 to 25 years although they may occur at any age.

8. In agreement with the opinion of Katz[12] our figures show that the occurrence of high T waves decreases with age.

9. High T waves occurred much more frequently in lead II than in either of the other standard leads.

10. High T waves may result from rotation of the heart caused by the patient lying on his right side.

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