Significance of Positive, Tall and Peaked Electrocardiographic T Waves in Early Diagnosis of Ischemic Heart Disease

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Tall peaked T waves have been found in 66 (0.64 percent) of 10,307 electrocardiograms. Forty-two of the patients showing this abnormality exhibited an anginal syndrome and six subsequently developed myocardial infarction. In addition to anginal pain, statistically significant abnormalities were found in one or more of the following: QT interval, QTC, QX/QT ratio and ST changes.

A tall, peaked, positive and symmetric T wave occurring in the presence of ST elevation and normal QT intervals may be the only preliminary electrocardiographic finding in an ischemic heart. On the other hand it may be innocent. The difficulty of differentiating the ischemic and nonischemic types1,2 made it desirable to review the circumstances in which this abnormality occurs and also its associated characteristics with the hope that means may be found for distinguishing the two conditions.

This communication describes the results of a retrospective examination of the electrocardiographic tracings exhibiting this abnormality in an Iranian population during a seven-year period.

MATERIALS AND METHOD

Between January 1963 and December 1969, a total of 10,307 electrocardiograms (ECG) were obtained in this center. There were 66 ECGs with sharp positive and tall T waves which form the basis of this study. The criteria for selection were the tent shape as well as the unusually high voltages in the precardial leads (exceeding 7 mm) of T waves. In 100 randomly selected normal control ECGs, it was found that the most prominent T voltages were in V2, V3, V4 and did not exceed 7 mm.

The patients visited the outpatient department either for a checkup or because of chest pain. None had taken drugs which might affect the ECG pattern and there was no evidence of electrolyte imbalance in any of them.

The 66 cases fell into two groups: group A consisted of 42 with anginal pain and group B, 24 without anginal pain. Group A included those with exertional, sharp constrictive and substernal chest pain, radiating to the left shoulder or left arm or both, and relieved by either rest or nitroglycerin.

The tall T waves in only six cases were transient, occurring during anginal pain and often associated with bradycardia. In 38 cases they were permanent without significant change during anginal pain, similar to the usual ECG finding in the so-called innocent T wave pattern.

In this group, repeated tracings over a number of weeks showed that the pattern was not a consequence of early infarction. Six patients, however, did develop acute myocardial infarction with the above pattern being present for at least some months prior to the infarction.

The average age of the 42 who fell in group A was 51 years, with a range of 24 to 80; that of the B group was 31, ranging from 21 to 50.

The measurements made on the tracings were: QT interval, the voltage of T waves, the deviation of ST segments, the deviation of J joints exceeding 1.5 mm, the heart rate and QX/QT ratio. Finally the QTC and QT ratio were measured with the use of a William Welsh ruler (a QT calculator manufactured by Bowen and Co Inc, Bethesda, Maryland).

RESULTS

Voltage of T Waves and Heart Rate: Table I shows that in group A (with anginal pain) the height of T waves averaged 9.7 mm (between 8 and 15 mm) and in group B, 9 mm (between 8 and 12 mm). The heart rate averaged 72/min (50 to 88) in group A and 62/min (50 to 68) in group B.

QT Interval: In group A 12 patients showed prolongation of QT interval. In group B the QT intervals were normal except for one. The difference is statistically significant.

QX/QT Ratio: The normal value of QX/QT ratio is less than 50 percent. In group A 15 patients had a raised QX/QT ratio, while in group B, only one patient had a QX/QT ratio of more than 50 percent. The difference is highly significant.

QTC(K): QTC was measured by application of
**Table 1—Electrocardiographic Findings in 66 Patients with Sharp, Positive and Tall T Waves**

<table>
<thead>
<tr>
<th></th>
<th>Ischemic T</th>
<th>Nonischemic T</th>
<th>Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>42</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Voltage of T, mean and range</td>
<td>9.7 mm (8-15)</td>
<td>9 mm (8-12)</td>
<td></td>
</tr>
<tr>
<td>QT interval, increased</td>
<td>12</td>
<td>1</td>
<td>&lt;0.05 &gt;0.02</td>
</tr>
<tr>
<td>ST, Elevation, 0.6 mm or above</td>
<td>1</td>
<td>12</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Notching of R</td>
<td>None</td>
<td>5</td>
<td>NS</td>
</tr>
<tr>
<td>QX/QT ratio, abnormal</td>
<td>15</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>QTC, abnormal</td>
<td>13</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>QT ratio, abnormal</td>
<td>9</td>
<td>1</td>
<td>NS</td>
</tr>
<tr>
<td>J Joint, abnormal</td>
<td>6</td>
<td>None</td>
<td>NS</td>
</tr>
</tbody>
</table>

*As measured by chi square with adjustment for discontinuity. p >0.05 is considered nonsignificant (NS).

the actual QT interval and the interval between two QRS complexes according to Bazett's formula:  

\[
QTC = K = \frac{QT}{\sqrt{R-R}}
\]

The normal values of this is 0.37 sec in adult men and 0.40 sec in adult women and it varies ±0.6 percent. Opinion varies about the upper normal value of QTC measurement. Pokress and Goldberger found it to be 0.409 sec, Craige and co-workers considered this value of QTC to be 0.412 sec while Taran mentioned 0.405 sec. In group A of the present series there were 13 patients with a QTC higher than Craig's value, ranging from 0.415 sec to 0.51 sec with an average of 0.436 sec; while in group B, only one patient had a high value of 0.45 sec. Again, the difference is significant.

**QT Ratio:** The QT ratio was calculated by the following formula:

\[
QT \text{ ratio} = \frac{QT}{0.40 \sqrt{R-R}}
\]

In group A, nine patients showed an abnormally high QT ratio (between 1.09 sec to 1.27 sec). In group B, only one patient had an abnormal QT ratio of 1.12 sec. This was the same patient in whom the value of QX/QT ratio and QTC were also significantly deviated from normal range and he was thought to have silent ischemic heart disease. The difference between groups is not significant.

**ST Changes and Notching in the Downstroke of**

**Left Ventricular R Waves:** In group A there was no significant elevation of the ST segment; indeed in six patients this segment was depressed. Notching was not observed. In group B, ST elevation of 0.6 mm or above was seen in 12 patients, a highly significant difference in response. Notching in this group was present in five patients.

**J Joints:** In six patients of group A there was definite depression of J junction, whereas depressed J joint above 1.5 mm was not present in group B.

**DISCUSSION**

Although it has often been mentioned that the presence of positive sharp and tall T waves could be either a sign of subendocardial ischemia or of impending infarction, their occurrence has not received much attention. This particular type of T wave is seen in the precordial leads, mostly in V2, V3 and V4. However, there are a variety of conditions in which such T waves may be encountered. These include: vagotonic adult sharp T waves which are supposedly due to the extrinsic influence of the vagal nerve and are associated with bradycardia and are noted commonly in the Jewish population in our area; exercise at high altitude; reciprocal changes in acute diaphragmatic or posterior myocardial infarction in which the voltage of T waves may be exceedingly high, rupture of myocardium and the development of hemopericardium; aortic insufficiency with diastole left ven-

![Figure 1](image1.png)

**Figure 1. ECG of a 28-year-old man showing peaked and tall T waves with ST elevation and notching of R waves. He had no chest pain.**

**Figure 2. ECG of a 43-year-old man showing peaked and tall T waves, ST elevation and notching of R waves. He had no chest pain.**
All conditions except vagotonic tall T waves were excluded in the 66 tracings of 10,307 ECGs which served as the basis of this study. The frequency of such T waves was found to be 1 percent in the adult population in the United States of America. The incidence was high in Negroes in whom malnutrition was thought to be a contributory factor. The frequency in the present series was 0.64 percent in all recorded ECGs. No particular relationship to social group was noted.

The characteristics of the innocent T waves (Fig 1 and 2) are said to be bradycardia and distinct notching (so-called reversed WPW) on the descending limb of the left ventricular R waves which are associated with an elevated take off of the ST segment at the J joint. This ST elevation may return to normal following exercise in most cases. In this study in group B, five patients had notching at the left ventricular R waves. The elevation of ST segment was statistically significant. The J joint was not altered and with the exception of in one case the QT, QTC and QX/QT ratio were normal (Table 1). This exceptional case was considered as silent myocardial ischemia. In contrast, the ischemic tall T waves (Fig 3, 4 and 5) in this study had some of the characteristics shown in Table 1. The abnormalities in QT interval, QX/QT ratio and QTC were statistically significant.

T wave changes noticed in conditions other than the ischemic types discussed could also be differentiated by their characteristics. In uremia the T waves are tall, symmetric and narrow, associated with prolongation of the QT interval. The T wave may become so tall as to exceed preceding R waves; usually there is an additional tachycardia. In acute myocardial infarction the positive tall and symmetric T waves are associated with marked elevation of ST segments (Fig 6). In acute posterior myocardial infarction there are such T waves in Vn, V2, V3 and V4, in addition to the depression of ST segments and increased voltage of R waves in the right precordial leads. In aortic insufficiency, the T waves are tent-shaped.

Figure 3. ECG of a 42-year-old man who was hypertensive, normal ECG during pain-free intervals; (b) ECG changes consisting of bradycardia, sharp and tall T waves during anginal pain.

Figure 4. ECG of a 39-year-old woman, obese and diabetic, showing (a) normal ECG during pain-free intervals; (b) ECG changes consisting of bradycardia, sharp and tall T waves during anginal pain.

Figure 5. ECG of a 50-year-old man with repeated episodes of anginal pain, showing: (a) positive tent-shaped tall T waves in V2, V3, V4; rate 65/min, QT 0.42 sec, QTC 0.438 sec and QT ratio 1.098, on April 16, 1969. (b) Acute inferior infarction on April 9, 1970.
SIGNIFICANCE OF POSITIVE, TALL AND PEAKED T WAVES

III aVR

FIGURE 6. ECG of a 65-year-old man with definite acute anterior myocardial infarction showing sharp and tall T waves with marked ST elevation in V₃, V₄. Waves are sharp in V₄ and V₅ with an increased intrinsicoid deflection and tall R waves. It should be kept in mind that a patient with the above changes in his ECG may suffer eventually an acute infarction. In this study six patients in group A suffered such a fate (Fig 5 and 7) with definite ECG changes in five and sudden death in one.

In 1909 Eppinger and Rothberger produced sharp T waves in dogs by cooling the left ventricular wall or injecting 5 percent mercuric chloride or 20 percent silver nitrate into the myocardium of the left ventricle and septum. They found that lesions made in the basal portion of the left ventricle and middle part of the septum caused increased voltage of R as well as T waves. There was gradual increase in voltage in both waves leading to the monophasic pattern within 20 minutes of injection. Cooling of the base of the right ventricle also caused sharp T waves. Bradycardia in this experiment was found following injection of the above substances in the superior portion of the septum and cooling of the atrial appendage. These authors concluded that no effect on ECG is noted if the substances are superficially injected. The pathologic lesions were found for the most part in the subendocardial areas of the left ventricle.

This T wave pattern has also been shown by ligation of coronary artery (Smith, 1918, quoted by Wasserberger and Corliss) and by application of a cold saline solution of 5° to 8° C on the endocardium or warm solution of 40° to 60° C on the epicardium (Hellerstein and Liebow, 1950). These experiments have given rise to the idea that in addition to ischemia, changes in temperature of the myocardium, differences in myocardial pressure between endocardium and epicardium, and exchange of potassium in the coronary artery may also be responsible for such T wave changes.

According to Lenegre and co-workers, vagotonia plays a role in producing bradycardia and peaked T waves. However, the influence of the vagal nerve on the ventricular recovery has never been shown in a satisfactory manner. Lengyel and associates found bradycardia and peaked T waves appearing within one minute of ligation of the coronary artery in the closed thorax and elevated ST segments two to four minutes later. They concluded that the early peaking of T waves was due to subendocardial ischemia. Freundlich found that about 58 percent of all patients with peaked and tall T waves had coronary insufficiency. In this study 62 percent of the patients showed clinical evidence of coronary insufficiency. Dressler and Roesler considered patients with positive and sharp T waves to have guarded prognosis. This was true in six of our patients who suffered myocardial infarctions which resulted in three deaths.

It may be concluded that the occurrence of sharp and tall positive T waves are helpful in the interpretation of the ECG.

ACKNOWLEDGMENTS: I gratefully acknowledge the help and criticism of Dr. Rejane Harvey, Professor of Cardiology, College of Physicians and Surgeons, Columbia University, New York, and of Dr. J. G. Reinhold, Director of the Pahlavi-Pennsylvania Nutrition Research Project at Pahlavi University, Shiraz, Iran.

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Editorial Expression

The author has performed a tedious and careful retrospective study. More data must be provided, however, before the clinician can have cause to place complete faith in the diagnostic significance of tall and peaked T waves as electrocardiographic evidence of myocardial ischemia. New light must be cast on an old finding.

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Invention of Telescope by Galileo Galilei
(1564-1642)

First I prepared a tube of lead at the end of which I fitted two glass lenses, both on one side, while on the other side, one was spherically convex and the other concave. Then placing my eye near the concave lens I perceived objects . . . three times closer and nine times larger than when seen by the naked eye alone. Next I constructed another one, more accurate, which represented objects as enlarged more than sixty times. Finally, sparing neither time or expense, I succeeded in constructing for myself so excellent an instrument that objects seen by it appeared nearly one thousand times larger and over thirty times closer than when regarded with our actual vision.

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