“Nonspecific” ST and T-Wave Changes

By CHARLES K. FRIEDBERG, M.D., AND ALBERT ZAGER, M.D.

ONE of the commonest problems in electrocardiography is the interpretation of ST-segment depression and T-wave inversion without other characteristic changes, particularly when there is clinical uncertainty regarding the presence and nature of an acute coronary attack. A common solution, often unsatisfactory to the clinician receiving the report, is the statement “The ST-segment and T-wave changes are nonspecific abnormalities.” A careful analysis of the degree of ST depression and character and depth of inversion of the T waves and a correlation of these findings with clinical conditions may enable us to arrive at a more definite electrocardiographic diagnosis. Since no such systematic analysis has been reported, this study was undertaken.

Method

The electrocardiograms of 1,000 consecutive adult in-patients interpreted by the members of the cardiology staff of The Mount Sinai Hospital, were reviewed and correlated with the clinical status of the patients.

The findings are representative of records of a large, voluntary metropolitan hospital. The adult patients were from both the ward and private medical and surgical services during a period of approximately 4 months. Although usually the records were taken for specific clinical indications, some represented routine preoperative electrocardiograms in the elderly age group. Records that primarily involved abnormalities in rhythm were excluded from the study.

The abnormal electrocardiograms were classified into the following groups: acute and healed transmural myocardial infarction; bundle-branch block; ventricular hypertrophy; pericarditis. There remained a large abnormal group that did not satisfy recognized criteria for any of the above groups, with changes that were designated nonspecific ST-segment and T-wave abnormalities.

The depth of ST-segment depression and of T-wave inversion was contrasted in those patients who had no recent cardiac pain, in those who had pain of less than one-half hour duration and in those who had pain of longer duration. The frequency with which isolated T-wave abnormalities, isolated ST-segment abnormalities, or combined abnormalities occurred in the various categories was also analyzed.

A similar analysis was made relating abnormalities in contour of the ST segment and T waves in the same groups of patients. The recorded depth of T-wave inversion or ST-segment depression was the maximum change in precordial leads V3 to V6. Tracings considered to have abnormal contour of the ST segment exhibited an upward convexity of the ST segment or a long, straightened or downward sloping ST segment. The term “ischemic T wave” in this paper included both the “coronary T wave” of Pardee,1 which is a downward sharply peaked T wave with symmetrical limbs following an upward convexity of the R-T interval and the “cove plane” T wave of Oppenheimer, Rothchild, and Mann2 with a curved descending limb, peaked apex, and straight ascending limb.

Results

Of the study group of 1,000 electrocardiograms there were normal findings in 590 and abnormal in 410 cases. The abnormal ones were subdivided into 93 cases of acute transmural myocardial infarction, 63 cases of healed myocardial infarction, 24 cases of bundle-branch block, 18 cases of ventricular hypertrophy, three cases of pericarditis and 209 cases in which the ST-segment and T-wave changes were nonspecific abnormalities (table 1).

In the latter group of 209 patients with nonspecific ST-segment and T-wave changes, 46 were receiving digitalis, 22 had recent cardiac pain of less than ½ hour duration, 35 patients had recent cardiac pain of ½ hour or longer in duration (table 2). Twenty additional patients had had recent cardiac pain ½ hour or longer but were already included in the previous categories because they had received digitalis or had other causes for ST-segment and T-wave abnormalities.
Analysis of 1,000 Consecutive Adult Electrocardiograms

<table>
<thead>
<tr>
<th>Analysis of Electrocardiographic Abnormalities</th>
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</thead>
<tbody>
<tr>
<td>Normal</td>
<td>590</td>
</tr>
<tr>
<td>Abnormal</td>
<td>410</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B.B.B. = Bundle branch block; R.V.H. = Right ventricular hypertrophy; L.V.H. = Left ventricular hypertrophy.</td>
<td></td>
</tr>
</tbody>
</table>

listed in table 1. One-half hour of cardiac pain was selected as the dividing point in an effort to distinguish patients with angina pectoris from those in whom the cardiac pain might be associated with myocardial necrosis.

The remaining 106 patients with electrocardiographic ST-segment and T-wave changes had had no digitalis therapy or recent cardiac pain, and the electrocardiographic abnormalities did not satisfy the criteria for any specific abnormality. By correlation with the clinical histories a possible etiology for the ST-segment and for T-wave changes was uncovered in 57 of these 106 patients (table 3).

Clinical Correlation with Depth of ST-Depression and T-wave Inversion

In the group of patients with no apparent explanation for the ST-segment and T-wave changes, 84 per cent had less than 0.5 mm. of ST-segment depression and less than 1 mm. of T-wave inversion; only 32 per cent of the group for whom there was a postulated explanation had such minimal changes (table 4).

Frequency of Combined and Isolated ST and T-wave Changes

In the patients with recent cardiac pain of 1/2 hour or longer duration, 11.4 per cent of the electrocardiograms were classified as abnormal solely on the basis of T-wave inversion (table 5); in the group with recent cardiac pain of less than one-half hour, 4.6 per cent were classified as abnormal on this basis. By contrast, of the patients with no recent cardiac pain 42 per cent were classified as abnormal, solely because of T-wave inversion.

Table 2

| Clinical Analysis of 209 Cases with Nonspecific ST-segment or T-wave Changes |
|---------------------------------------------|-----|
| Digitalis therapy                           | 46  |
| Recent cardiac pain                         |     |
| 1/2 hour or longer                          | 35  |
| Recent cardiac pain                         |     |
| less than 1/2 hour                          | 22  |
| No recent cardiac pain                      | 106 |
| Total                                       | 209 |

Depth of T-wave Inversion and ST-Segment Depression

The depth of T-wave inversion was 2 mm. or more in 10 (26.6 per cent) of the 35 cases with recent cardiac pain lasting 1/2 hour or longer, in 11 (50 per cent) of 22 cases with recent cardiac pain for less than 1/2 hour, and in only 12 (11 per cent) of the 106 cases without recent cardiac pain (table 6). A clinical review of the 12 patients with T-wave inversion of 2 mm. or greater, but no history of recent cardiac pain disclosed that six patients had blood pressures of 170/90 or above, two had abnormal serum electrolytes, one had central nervous system disease, two had postoperative shock, and one arteriosclerotic heart disease.

The depth of ST-segment depression was also studied in relation to the same clinical groups (table 7). T-wave inversion between 3/4 and 2 mm. in depth did not appear to be significantly different in the groups with or without recent cardiac pain. Recent cardiac pain had been present in all 10 patients with electrocardiographic ST-segment depressions of more than 2 mm. ST-segment depression exceeding 0.5 mm., but less than 2 mm. occurred much more frequently in patients with recent cardiac pain than in those without such pain. There were only 14 among the 106 patients in the category with "no recent
cardiac pain” with ST depression greater than 0.5 mm. Three of these patients had a blood pressure of 170/90 or more, four had clinical arteriosclerotic (coronary) heart disease, one had thyrotoxic heart disease, one had abnormal serum electrolytes, two had severe cerebral disease, one had sprue with normal serum electrolytes, and two had no clinical heart disease but were over 80 years of age.

Ischemic ST Segment and Ischemic T Waves

The clinical groups with and without cardiac pain were correlated with the presence of the ischemic type of ST segment and ischemic T wave (table 8). There was no significant difference in frequency of the ischemic contour of the ST segment among the three groups. On the other hand, there was a definitely higher incidence of ischemic type of T wave in the groups with recent cardiac pain than in those without pain, and the difference was even greater in terms of the combination of ischemic ST segment and ischemic T wave.

Discussion

Of the 410 abnormal electrocardiograms more than 50 per cent were reported as showing nonspecific ST-segment or T-wave abnormalities. The 209 cases in the latter category, when correlated with the clinical history fell into four groups:

1. Forty-six (22 per cent) had received digitalis, which could account for the ST-T changes;

2. Forty-nine (24 per cent) had no apparent cause for the ST-T abnormalities.

3. Fifty-seven (27 per cent) had an acute episode of cardiac pain within 5 days prior to the electrocardiogram; the pain lasted a half-hour or longer in 35 and less than 1/2 hour in 22;

4. Fifty-seven (27 per cent) had no recent cardiac pain but suffered from some disease that could be regarded as a possible cause for the electrocardiographic changes.

A consideration of these groups suggests an approach to a more definite diagnosis than “nonspecific ST and T-wave abnormalities.” It seems desirable first to determine whether the patient has been receiving digitalis. Although characteristic ST-T-wave changes have been described following digitalis the changes are not always characteristic.

If digitalis is excluded as the cause of electrocardiographic changes, the problem is to determine whether the ST-T changes developed in connection with recent cardiac pain and may therefore indicate myocardial ischemia or necrosis. If there is no history of a recent acute attack of cardiac pain, it is necessary to distinguish between ST and T-wave changes due to some competent clinical cause (other than acute myocardial ischemia or necrosis) and ST and T-wave changes that are of no clinical significance. This study has indicated that such differentiation can almost always be made on the basis of the clinical history and the observation that the combination of ST-segment depression of less than

Table 3

Possible Etiologies of One-Hundred and Six Cases with Nonspecific ST and T-Wave Abnormalities

|                | No known cause | ASHD | HBP 170/90 | HBP and ASHD | Anemia | Pulmonary embolus | CNS disease | Post-op. shock | Arteriosclerotic | Pericarditis | Pulmonic | Rheumatic | Valvular | Electrolytes | Total |
|----------------|----------------|------|------------|--------------|--------|-------------------|-------------|---------------|-----------------|--------------|----------|----------|----------|----------|-------------|-------|
| T              | 25             | 2    | 6          | 1            | 2      | 1                 | 4           | 2             | 1               | 0            | 1        | 0        | 1        | 0        | 45         |
| ST and T       | 19             | 4    | 6          | 2            | 0      | 2                 | 5           | 0             | 2               | 2            | 4        | 2        | 4        | 2        | 48         |
| ST             | 5              | 2    | 2          | 2            | 0      | 0                 | 1           | 1             | 0               | 0            | 0        | 0        | 0        | 0        | 13         |
| Totals         | 49             | 8    | 14         | 5            | 2      | 3                 | 10          | 3             | 3               | 2            | 5        | 2        |          |          | 106        |

ASHD, Arteriosclerotic (coronary) heart disease; HBP, hypertension; CNS, central nervous system.
Table 4

Contrast of ST-Segment Depression or T-Wave Inversion in Group with No Apparent Explanation and Group with Possible Explanation for Abnormalities

<table>
<thead>
<tr>
<th></th>
<th>Insignificant ST and T changes*</th>
<th>ST depression and T inversion†</th>
<th>Isolated T inversion more than 1 mm.</th>
<th>Isolated ST depression more than 1/2 mm.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent explanation</td>
<td>18 32</td>
<td>20 35</td>
<td>16 28</td>
<td>3 5</td>
<td>57</td>
</tr>
<tr>
<td>No apparent explanation</td>
<td>41 83.7</td>
<td>0 0</td>
<td>7 14.3</td>
<td>1 2</td>
<td>49</td>
</tr>
</tbody>
</table>

*ST depression less than 0.5 mm.; T flat or inverted less than 1 mm.
†ST depressed more than 0.5 mm.; T inverted more than 1 mm.

Table 5

Classification Based on Isolated T-Wave Inversion, ST-Segment Depression, or Combined T-Wave Inversion and ST-Segment Depression

<table>
<thead>
<tr>
<th></th>
<th>Both ST and T abnormalities No. %</th>
<th>Only T-wave inversion No. %</th>
<th>Only ST segment depression No. %</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent cardiac pain 1/2 hr. or longer in duration</td>
<td>25 71.4</td>
<td>4 11.4</td>
<td>6 17</td>
<td>35</td>
</tr>
<tr>
<td>Recent cardiac pain less than 1/2 hr. in duration</td>
<td>19 88.4</td>
<td>1 4.6</td>
<td>2 9</td>
<td>22</td>
</tr>
<tr>
<td>No recent cardiac pain</td>
<td>57 53.7</td>
<td>45 42.4</td>
<td>4 3.6</td>
<td>106</td>
</tr>
</tbody>
</table>

0.5 mm. and T-wave inversion of less than 1 mm. is unaccompanied by a reasonable cause for electrocardiographic changes and that such minor ST-T changes are probably within the range of normal. The hyperventilation syndrome or unrecognized physiologic changes must be excluded.

In this series of 106 cases of nonspecific ST and T-wave changes in patients without recent acute cardiac pain there appeared to be a reasonable explanation in 57 patients with such clinical abnormalities as pericarditis, postoperative shock, clinical chronic cor pulmonale, pulmonary embolism, electrolyte disturbances, and chronic angina etc. (Table 3). Intracranial disease, which included 10 cases in this series, has been reported as a cause of abnormalities of the ST segment or T wave, or both, when as a direct result of cerebral lesions or mediated through an alteration in serum electrolytes. In almost all of the 49 cases in which there was no apparent clinical cause, the ST-segment and T-wave changes were of minimal degree and may have been insignificant. In the cases of ST-segment and T-wave inversion, which were found in patients with recent acute cardiac pain, the problem was to determine whether the electrocardiographic changes actually developed in connection with the acute pain or were previously present. This could be resolved by a study of previous and subsequent serial electrocardiograms.

Cases with recent cardiac pain could generally be differentiated from those without such pain by an ST-segment depression of more than 1/2 mm. in the former. In no instance was the ST segment depressed more than 2 mm. in cases without recent cardiac pain, whereas this degree of depression was not uncommon in cases with recent cardiac pain. The difference between cases with and without cardiac pain was more striking if 5 mm. of inversion of the T wave was used as the criterion. In the cases with recent cardiac pain ST-segment depression alone or in combina-
"NONSPECIFIC" ST AND T-WAVE CHANGES

Table 6

<table>
<thead>
<tr>
<th>Depth of T-Wave Inversion</th>
<th>5 mm. or greater</th>
<th>2-5 mm.</th>
<th>More than 0.5 mm. up to 2 mm.</th>
<th>0.5 mm. or less</th>
<th>Normal T wave</th>
<th>Total cases in group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent cardiac pain</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>½ hr. or longer in duration</td>
<td>6</td>
<td>17.1</td>
<td>4</td>
<td>11.4</td>
<td>12</td>
<td>34.3</td>
</tr>
<tr>
<td>Recent cardiac pain less than ½ hr. in duration</td>
<td>6</td>
<td>27.4</td>
<td>5</td>
<td>22.7</td>
<td>7</td>
<td>31.8</td>
</tr>
<tr>
<td>No recent cardiac pain</td>
<td>4</td>
<td>3.8</td>
<td>8</td>
<td>7.8</td>
<td>43</td>
<td>42.1</td>
</tr>
</tbody>
</table>

Attention was directed to deep T-wave inversions in the midprecordial leads as described by Pruitt et al. They reported a study of 62 cases with at least 5 mm. of T-wave inversion which was maximal in lead V3. In 38 of these there was clinical evidence suggesting myocardial infarction or severe ischemia, but in 24 no such clinical evidence was present. Four of the patients in the group with cardiac pain who died and were studied at autopsy showed evidence of subendocardial infarcts. In our series there were 12 cases that showed electrocardiographic changes similar to those in Pruitt's cases. In seven of these there had been recent cardiac pain of ½ hour or longer duration; in two, recent cardiac pain of less than ½ hour duration; and in three, no recent cardiac pain.

An analysis of the ST and T contours disclosed no significant difference between the frequency of an "ischemic" type of ST segment in patients with and without recent cardiac pain. But if the criterion of ½ mm. or greater depression of the ST segment is added to that of ischemic contour, the combination was found in 78 per cent of the cases of recent cardiac pain and in only 21 per cent of those without such pain. The presence of an "ischemic" contour of T wave appeared to show a good correlation with recent cardiac pain, since such a T wave was observed in 49 per cent of the cases with recent cardiac pain and in only 10 per cent of those without such pain.

To summarize, the probability that the ST-segment depressions and T-wave inversions were associated with and due to the episode of recent acute cardiac pain was indicated by the combination of ST depression and T-wave inversion with a depth of more than ½ mm. of the ST depression and more than 1 mm. inversion of the T wave, by isolated T-wave inversion of more than 2 mm. and especially by more than 5 mm. in the midprecordial leads, and by an ischemic contour of the ST segment that is depressed more than ½ mm.

The combination of such electrocardiographic findings and a history of recent acute cardiac pain usually indicates that the electrocardiographic changes were caused by recent myocardial ischemia or necrosis. However, it is desirable to confirm such an interpretation by a comparison with previous electrocardiograms if available. Furthermore, serial electrocardiograms showing progressive change or disappearance of the abnormalities usually attest to a relationship to the recent cardiac pain but care should be taken to be sure that there is identical electrode placement and minimal changes should not be emphasized. The effort to differentiate ST-T changes denoting acute myocardial ischemia from acute myocardial necrosis was made by correlating these changes with recent cardiac pain of less than or more than ½ hour duration. It was thought that the pain of briefer duration might represent myocardial ischemia and that of longer duration might indicate myocardial necrosis. But no significant dif-
ferences could be found in the degree of character of ST and T-wave changes in these two groups.

Several considerations may explain the lack of electrocardiographic difference in these two groups of cases classified according to the duration of acute cardiac pain. Many of the patients with recent cardiac pain for more than 1/2 hour unquestionably experienced extensive myocardial necrosis. But when this was indicated by Q waves as well as ST-T changes they were separated from the group with non-specific ST-T abnormalities. Evidence has been presented by Cook and others that acute myocardial necrosis is associated with abnormal Q waves as well as ST and T changes when more than 75 per cent of the thickness of the myocardial wall underwent necrosis. When subendocardial necrosis did not exceed 50 to 75 per cent of the thickness of the ventricular wall there was only ST-segment depression and T-wave inversion. Such changes are indistinguishable from subendocardial ischemia in the same area. In fact it is probable that the ST-segment depression and T-wave inversion observed in patients with subendocardial necrosis are due to the associated ischemia rather than to the necrosis itself. Thus, if subendocardial necrosis occurred in the patients with pain lasting more than 1/2 hour, the electrocardiographic changes would be undistinguishable from those in patients experiencing recent cardiac pain for less than 1/2 hour even if ischemia and no necrosis was present in the latter group. A differentiation between subendocardial ischemia and subendocardial necrosis would be indicated by differences in the duration and severity of the pain and by various observations and laboratory findings. The electrocardiographic changes themselves could only be reported as indicating subendocardial ischemia or necrosis.

**Table 7**

*Depth of ST-Segment Depression*

<table>
<thead>
<tr>
<th></th>
<th>Greater than 2 mm.</th>
<th>More than 1/2 mm. up to 2 mm.</th>
<th>1/2 mm. or less</th>
<th>Isoelectric ST segment</th>
<th>Total cases in group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent cardiac pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 hr. or longer in duration</td>
<td>6 17.1</td>
<td>18 45.7</td>
<td>11 31.4</td>
<td>2 5.7</td>
<td>35</td>
</tr>
<tr>
<td>Recent cardiac pain less than 1/2 hr. in duration</td>
<td>4 18.2</td>
<td>10 45.4</td>
<td>8 36.4</td>
<td>0 0</td>
<td>22</td>
</tr>
<tr>
<td>No recent cardiac pain</td>
<td>0 0</td>
<td>14 13.2</td>
<td>47 44.3</td>
<td>45 42.5</td>
<td>106</td>
</tr>
</tbody>
</table>

**Table 8**

*Contrast of Contour Abnormalities in Cases with and without Recent Cardiac Pain*

<table>
<thead>
<tr>
<th></th>
<th>Ischemic ST segment and ischemic T wave</th>
<th>Ischemic T wave only</th>
<th>Ischemic ST segment only</th>
<th>Neither ischemic ST segment nor ischemic T wave</th>
<th>Total cases in group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent cardiac pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2 hr. or longer in duration</td>
<td>14 40</td>
<td>6 17.1</td>
<td>10 28.6</td>
<td>5 14.3</td>
<td>35</td>
</tr>
<tr>
<td>Recent cardiac pain less than 1/2 hr. in duration</td>
<td>6 27.3</td>
<td>2 9.1</td>
<td>7 31.8</td>
<td>7 31.8</td>
<td>22</td>
</tr>
<tr>
<td>No recent cardiac pain</td>
<td>8 7.5</td>
<td>3 2.8</td>
<td>29 27.3</td>
<td>66 62.2</td>
<td>106</td>
</tr>
</tbody>
</table>

Summary

A study was made of 1,000 consecutive adult in-patient electrocardiograms to deter-
mine the possibility of making a more precise
diagnosis than "nonspecific ST and T-wave
changes." More than 50 per cent (209)
of the 410 abnormal electrocardiograms (exclu-
sive of arrhythmias) were characterized by
nonspecific depression of ST segment or T
wave inversion, or both.

These 209 cases comprised four groups: (1)
46 patients (22 per cent) had received digi-
talis, which could account for the ST-T
changes; (2) 57 patients (27 per cent) had
had an acute episode of cardiac pain within
5 days prior to the electrocardiogram; (3) 57
patients (27 per cent) had had no recent car-
diac pain but suffered from some disease that
could be regarded as a possible cause for the
ST-T changes; and (4) 49 patients (24 per
cent) had no apparent cause for the electro-
cardiographic changes.

In the last group, in contrast with the others, the ST-segment
depression was less than 0.5 mm. and the T-wave
inversion less than 1 mm.

In patients with recent cardiac pain, as
contrasted with those without such pain, the
electrocardiograms were characterized by a
combination of ST depression and T-wave
inversion, with a depth of more than 1/2 mm.
of the ST depression and more than 1 mm.
inversion of the T wave, by isolated T-wave
inversion of more than 2 mm. and especially
by more than 5 mm. in the midprecordial
leads, and by an ischemic contour of the ST
segment that is depressed more than 1/2 mm.

There was no definite difference in the
electrocardiographic findings in the patients
with recent cardiac pain of less than 1/2 hour
and those with recent cardiac pain of more
than 1/2 hour when the cases with transmural
infarction (Q-wave changes) were excluded.
This is compatible with the concept that the
electrocardiogram usually does not distin-
guish between subendocardial ischemia and
subendocardial necrosis. The latter differenti-
ation would depend on multiple clinical and
laboratory findings.

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Electrocardiographic changes in acute sub-
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The fantastic economies of successful research swiftly go beyond any method of
accurate accounting. As an example, I would estimate that the work on the sulfa drugs
up to and including the proof of their efficiency in the treatment of lobar pneumonia did
not cost more than $150,000. But in as short a time as three years after their value in
pneumonia was shown, the saving in life insurance policies that would have been paid
by one life insurance company for deaths from lobar pneumonia alone only, on the West
Coast of the United States, over one year only, was calculated at $3,000,000. In such ways
research gives a continuing and a permanent lift to Great Medicine.—Alan Gregg, M.D.,
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