Serial Electrocardiographic Findings in a Prospective Epidemiological Study

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THE PREVALENCE of a number of electrocardiographic findings among the adult population of a total natural community was reported in an earlier article. This community, Tecumseh, Michigan, is the site of a long-term study of a great variety of factors which may influence the health of the population. The first series of complete examinations of the participants was carried out in 1959 and 1960.

A second series of examinations of the Tecumseh population was completed in June 1965. It is now possible to compare the prevalence of electrocardiographic findings among most of the adult members of a single community at two periods about 4 years apart and to analyze the changes which have occurred among that segment of the population who had electrocardiograms during both examinations.

This report examines the problem of reproducibility of electrocardiographic classifications when a uniform coding system is used by different cardiologists and gives information about the stability of certain electrocardiographic abnormalities over a period of several years. It also allows an estimate of the value of nonspecific electrocardiographic changes in the prediction of more definite abnormalities.

Electrocardiographic findings rather than specific diagnoses are discussed. Diagnoses are based on information from the medical history, physical examination, and sometimes postmortem reports as well as the electrocardiogram. The incidence of new cardiovascular disease and the relationship of the various conditions to antecedent risk factors will be discussed in detail in subsequent reports.

Methods

Electrocardiograms were recorded from 5,129 examined persons 16 years of age and over in 1959 and 1960. During the second period of examinations from 1962 to 1965 tracings were obtained from 5,451 persons. Of the persons from whom electrocardiograms were recorded and classified in 1959 and 1960, 3,745 or 73% had a second tracing between 1962 and 1965. The percentage of participants who had an electrocardiogram on both examinations was considerably higher, but few of the tracings from the 16 to 21-year-old group were classified according to the adult criteria on their first examination because they were less than 16 years of age.

The interval between examinations varied from 20 to 72 months with a median interval of 47 months. Eighty percent of the participants were re-examined between 40 and 56 months after their first examination.

The electrocardiograms were recorded on direct writing single-channel instruments at a paper speed of 50 mm per second. Food and tobacco were not prohibited before the clinic visit, but participants did not smoke immediately before the electrocardiograms were recorded.

Almost all participants during the second series of examinations received 100 g of glucose as part of a modified glucose tolerance test, but the electrocardiograms were always recorded before the glucose was administered. During the first series of examinations 60% of the adult participants received a glucose challenge which was frequently ingested before the electrocardiogram was recorded.

All electrocardiograms were classified according to the coding system of Blackburn and associates, but a different cardiologist coded the tracings from each examination.

Results

Prevalence of Classified Items in Electrocardiograms from the Total Examined Population on Two Occasions (Tables 1 and 2)

Q and QS Items

The prevalence rate for codable Q and QS waves was slightly greater among the men who had electrocardiograms during the second series of examinations but there was a 50%
Table 1

Distribution of the Classified Electrocardiographic Findings According to Age and Sex in the 1959-1960 Examinations

<table>
<thead>
<tr>
<th>ECG category</th>
<th>16-19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70-79</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men Age group and number</td>
<td>214</td>
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<td>679</td>
<td>467</td>
<td>178</td>
<td>101</td>
<td>26</td>
<td>249</td>
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<td>I-1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>3</td>
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<td>19</td>
</tr>
<tr>
<td>I-2</td>
<td>0</td>
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<td>0</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>I-3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
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<td>0</td>
<td>8</td>
<td>17</td>
<td>16</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Rate I</td>
<td>0.0</td>
<td>0.2</td>
<td>0.0</td>
<td>1.7</td>
<td>5.1</td>
<td>9.0</td>
<td>9.9</td>
<td>7.7</td>
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<td>H-1</td>
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<td>24</td>
<td>26</td>
<td>28</td>
<td>32</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>Rate II-1</td>
<td>0.5</td>
<td>1.1</td>
<td>3.5</td>
<td>5.6</td>
<td>8.5</td>
<td>18.0</td>
<td>25.7</td>
<td>23.1</td>
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<td>H-2</td>
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<td>5</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>17</td>
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<tr>
<td>Rate III-1</td>
<td>17.8</td>
<td>7.1</td>
<td>3.0</td>
<td>4.1</td>
<td>3.3</td>
<td>8.4</td>
<td>7.9</td>
<td>11.5</td>
</tr>
<tr>
<td>V-1</td>
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<td>1</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>14</td>
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<tr>
<td>Rate IV</td>
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<td>0.9</td>
<td>1.0</td>
<td>3.2</td>
<td>3.3</td>
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<td>7.7</td>
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<td>2</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Rate V</td>
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<td>3.9</td>
<td>12.9</td>
<td>17.5</td>
<td>30.9</td>
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<table>
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<th>60-69</th>
<th>70-79</th>
<th>70+</th>
<th>Total</th>
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<tr>
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<td>0</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>I-2</td>
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<td>1</td>
<td>0</td>
<td>3</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>I-3</td>
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<td>0</td>
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<td>3</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Total</td>
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<td>1</td>
<td>0</td>
<td>8</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Rate I</td>
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<td>1.7</td>
<td>5.1</td>
<td>9.0</td>
</tr>
<tr>
<td>H-1</td>
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<td>5</td>
<td>24</td>
<td>26</td>
<td>28</td>
<td>32</td>
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<tr>
<td>Rate II-1</td>
<td>0.5</td>
<td>1.1</td>
<td>3.5</td>
<td>5.6</td>
<td>8.5</td>
<td>18.0</td>
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<tr>
<td>H-2</td>
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<td>5</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Rate III-1</td>
<td>17.8</td>
<td>7.1</td>
<td>3.0</td>
<td>4.1</td>
<td>3.3</td>
<td>8.4</td>
</tr>
<tr>
<td>V-1</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Rate IV</td>
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<td>0.9</td>
<td>1.0</td>
<td>3.2</td>
<td>3.3</td>
<td>6.2</td>
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<tr>
<td>V-2</td>
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<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rate V</td>
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<td>5.1</td>
<td>3.9</td>
<td>12.9</td>
<td>17.5</td>
<td>30.9</td>
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<table>
<thead>
<tr>
<th>Both sexes, grand total</th>
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<tbody>
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<td>I-1</td>
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<td>I-3</td>
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<tr>
<td>Total</td>
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</tr>
<tr>
<td>Rate I</td>
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</tr>
<tr>
<td>H-1</td>
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</tr>
<tr>
<td>Rate II-1</td>
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<tr>
<td>H-2</td>
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<tr>
<td>Rate III-1</td>
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<td>Rate IV</td>
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<td>V-2</td>
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<td>Rate V</td>
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### Table 2

**Distribution of the Classified Electrocardiographic Findings According to Age and Sex in the 1962-1965 Examinations**

<table>
<thead>
<tr>
<th>ECG category</th>
<th>Men Age group and number</th>
<th>Women Age group and number</th>
<th>Grand total</th>
</tr>
</thead>
</table>

- **I-1**
  - 1 3 6 8 2 24 0 0 1 2 4 3 15 39

- **I-2**
  - 0 2 0 4 2 6 0 2 0 0 0 1 0 15 35

- **I-3**
  - 3 2 6 5 2 2 0 1 0 1 5 1 1 0 13 33

- **I-1-3**
  - 0 3 7 11 14 15 10 5 65 0 0 1 5 10 14 8 4 42 107

- **Rate I**
  - 0.6 1.1 2.0 4.3 7.9 11.6 23.8 2.5 0 0 0.1 0.9 3.0 6.7 6.1 9.5 1 5.0

- **II-1**
  - 3 2 6 23 22 28 23 15 8 128 1 2 7 7 16 20 15 13 81 209

- **Rate II-1**
  - 1.0 1.3 3.7 4.1 8.6 12.0 17.4 38.1 5.0 0.3 0.3 1.0 1.3 4.8 9.5 11.5 31.0 2.8 3.8

- **II-2**
  - 1 2 1 2 0 1 0 0 7 1 2 1 2 1 0 0 0 0 5 12

- **III-1**
  - 18 14 11 9 5 10 8 2 77 0 0 2 3 4 14 7 2 52 109

- **Rate III-1**
  - 5.7 2.9 1.8 1.7 1.5 5.2 9.3 9.5 3.0 0 0 0.3 0.5 1.2 6.7 5.3 4.8 1.1 2.0

- **IV-1**
  - 0 0 0 0 1 2 5 3 2 2 15 0 1 2 3 3 8 7 4 28 43

- **IV-2**
  - 0 0 0 1 4 2 4 4 1 16 2 0 4 4 11 5 6 4 36 52

- **IV-3**
  - 3 2 2 3 2 7 2 2 23 1 2 4 7 11 7 6 6 44 67

- **Total IV**
  - 3 2 4 9 9 14 8 5 54 3 3 10 14 25 20 19 14 108 162

- **Rate IV**
  - 1.0 0.4 0.6 1.7 2.8 7.3 9.3 23.8 2.1 1.0 0.5 1.4 2.5 7.4 9.5 14.5 33.3 3.8 3.0

- **V-1**
  - 0 0 0 0 0 0 2 1 1 0 4 0 0 0 0 0 0 2 1 0 3 7

- **V-2**
  - 4 4 4 8 7 13 4 1 45 2 2 6 7 7 11 6 4 45 90

- **V-3**
  - 13 16 21 34 28 27 19 5 163 6 23 28 28 24 25 19 9 162 325

- **Total V**
  - 17 20 25 42 37 41 24 6 212 8 25 34 35 35 31 38 26 13 210 422

- **Rate V**
  - 5.4 4.2 4.0 7.7 11.3 21.5 27.9 28.6 8.2 2.7 4.2 4.8 6.3 9.2 18.1 19.8 31.0 7.3 7.7

- **VI-1**
  - 0 0 0 0 0 0 1 1 2 0 0 0 1 0 0 0 0 0 1 3

- **VI-3**
  - 3 1 7 8 4 7 6 3 39 0 1 5 5 2 3 5 6 27 66

- **Rate VI-3**
  - 1.0 0.2 1.1 1.5 1.2 3.7 7.0 14.3 1.5 0 0.2 0.7 0.9 0.6 1.4 3.8 14.3 0.9 1.2

- **VII-1**
  - 0 0 1 1 1 0 4 2 0 8 0 0 0 4 2 5 1 0 12 20

- **VII-2**
  - 0 2 1 1 1 2 5 2 14 0 0 0 0 3 1 2 2 8 22

- **VII-3**
  - 1 5 5 4 7 6 6 1 35 1 0 3 4 2 4 2 1 17 52

- **Rate VII-3**
  - 0.3 1.0 0.8 0.7 2.1 3.1 7.0 4.8 1.4 0.3 0 0.4 0.7 0.6 1.9 1.5 2.4 0.6 1.0

- **VIII-1**
  - 1 0 1 2 9 1 7 3 24 0 2 3 7 2 4 4 3 25 49

- **Rate VIII-1**
  - 0.3 0.2 0.4 2.8 0.5 8.1 14.3 0.9 0 0.3 0.4 1.3 0.6 1.9 2.1 7.1 0.9 0.9

- **VIII-3**
  - 1 0 0 0 0 0 5 4 2 12 0 0 0 2 3 5 1 3 14 26

- **Rate VIII-3**
  - 0.3 0 0 0 0 2.6 4.7 9.5 0.5 0 0 0 0.4 0.9 2.4 0.8 7.1 0.5 0.5

- **VIII-6**
  - 3 2 0 1 0 0 0 6 1 1 0 1 0 0 0 0 2 8

- **IX-1**
  - 0 0 3 4 5 4 4 0 20 0 5 3 6 1 1 1 0 17 37

- **Rate IX-1**
  - 0 0 0.5 0.8 1.5 2.1 4.7 0.8 0 0.8 0.4 1.1 0.3 0.5 0.8 0 0 0.6 0.7

- **IX-2**
  - 3 4 7 7 5 8 2 0 36 0 2 1 0 1 1 1 0 6 42

- **Rate IX-2**
  - 1.0 0.8 1.1 1.3 1.5 4.2 2.3 0 1.4 0 0.3 0.1 0 0.3 0.5 0.8 0 0 0.2 0.8
increase in the frequency of Q or QS waves in the tracings from women in the second examination. The more pronounced Q and QS abnormalities (items I-1 and I-2) were classified twice as often in the women's electrocardiograms from the second examination as in the previous series.

Forty-eight per cent of the men and 35% of the women with classified Q or QS waves in their first electrocardiogram were less than 60 years of age. The percentages from the second examination tracings were 54% for men and 38% for women.

**Axis Deviation**

Left axis deviation (II-1) was coded less frequently during the second examination, but the higher prevalence among males and the progressive increase in frequency with each successive decade of age were similar for both examinations.

Right axis deviation was rare in both series and was usually found among young persons, particularly men.

**High Amplitude R Waves (III-1)**

This category was classified only half as frequently in the second series of electrocardiograms as in the first. The age and sex distribution for this classification was similar in both series. Most of the III-1 classifications were among men less than 30 years of age or persons of either sex 60 years of age or older.

**ST-Segment Changes (IV-1, 2, and 3)**

The prevalence of ST-segment depression was less among the electrocardiograms from the second series of examinations, although the IV-1 and IV-3 categories were more frequent while the IV-2 classification was much less frequent.

The prevalence of ST items among men's tracings was only slightly less during the second series of examinations. Such changes were reported in 5.4% of the women's electrocardiograms from the first examination but only 3.8% from the second.

**T-Wave Inversion (V-1, 2, and 3)**

Classifications for T-wave inversion were also reported less frequently among electrocardiograms from the second series of examinations, although the most marked T-wave inversion, category V-1, was more prevalent. There was a modest decrease in frequency of the V-2 classification and a great decrease in prevalence of V-3 items, the flat, diphasic, or very slightly inverted T waves.

**Other Items**

The prevalence and age and sex distributions of complete bundle-branch block and atrial fibrillation were similar for the electrocardiograms from both examinations.

The prevalence rates were lower in the tracings from the second examination for a variety of classified items such as incomplete right bundle-branch block (VII-3), frequent premature beats (VIII-1), and low amplitude QRS complexes (IX-1).

**Changes in Q and QS Items Between Examinations Among Persons Who Had Electrocardiograms on Both Occasions (Tables 3 and 4).**

Ninety-one members of this cohort had classified Q or QS waves in their electrocardiograms from the second series of examinations. Thirty-three (36%) had no codable abnormality in their first electrocardiogram, 36 (40%) had classified Q or QS items, and 22 (24%) had nonspecific changes (17 had ST-segment depression or T-wave inversion and five had left axis deviation or high amplitude R waves).

Forty-nine persons in this cohort had classified Q or QS items in the electrocardiograms recorded during the first series of examinations. Thirty-six (73%) still had classified Q or QS changes in their second electrocardiograms, seven (14%) had no classified abnormality and six (12%) had nonspecific QRS, ST-segment or T-wave changes. Of the 13 participants whose electrocardiograms no longer had codable Q or QS waves at the time of the second examination, four had prior tracings classified as I-1, four as I-2, and five as I-3.

Eighty persons had classified Q or QS items in the electrocardiograms recorded during the first series of examinations, but 18 died before they could be re-examined.
SERIAL ELECTROCARDIOGRAPHIC FINDINGS

Table 3
Changes in Classification Between Examinations Among Ninety-one Persons Having Category I Items on Second Examination

<table>
<thead>
<tr>
<th>Category I</th>
<th>Examination II</th>
<th>Classification from examination I</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Normal</td>
</tr>
<tr>
<td>I items alone</td>
<td>37</td>
<td>16</td>
</tr>
<tr>
<td>I + IV or V items</td>
<td>45</td>
<td>14</td>
</tr>
<tr>
<td>I + II-1 or III-1</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Total I</td>
<td>91</td>
<td>33</td>
</tr>
</tbody>
</table>

I = Q or QS items; II-1 = left axis deviation; III-1 = high amplitude R waves; IV = ST-segment depression and V = T-wave inversion.

Table 4
Changes in Classification Between Examinations Among Forty-nine Persons Having Category I Items at First Examination

<table>
<thead>
<tr>
<th>Category I</th>
<th>Examination I</th>
<th>Classifications from examination II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Normal</td>
</tr>
<tr>
<td>I items alone</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>I + IV or V items</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>I + II-1 or III-1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total I</td>
<td>49</td>
<td>7</td>
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</tbody>
</table>

Changes in Nonspecific Electrocardiographic Items Between Examinations Among Persons Who Had Electrocardiograms on Both Occasions (Tables 5 and 6).

Left Axis Deviation (II-1)

One hundred sixty members of the cohort had left axis deviation classified in their electrocardiograms from the second series of examinations. Electrocardiograms of 101 persons had been classified as II-1 on the first series of examinations, 39 had no codable abnormality, three had Q or QS items, six had high amplitude R waves, and 11 had ST-segment depression or T-wave inversion.

One hundred sixty-seven members of the cohort had classified left axis deviation in their electrocardiograms from the first series of examinations. Besides the 101 persons whose tracings were again classified II-1 on the second examination, 43 had no codable abnormality in the second electrocardiogram, eight had Q or QS items, two had high amplitude R waves, 12 ST-segment depression or T-wave inversion, and one had high amplitude R waves and T-wave inversion.

High Amplitude R Waves (III-1)

One hundred thirty members of the cohort had classified high amplitude R waves in their electrocardiograms recorded during the first series of examinations but only 74 from the second series. The tracings of 42 persons were classified as III-1 on both occasions.

Of the 88 persons with high amplitude R waves classified only from first examination electrocardiograms, 66 had no coded abnormality of their second tracing, three had Q or QS items, nine had left axis deviation, and 10 had ST-segment depression or T-wave inversion.

Thirty-two persons had electrocardiograms classified as III-1 only in the second series of examinations. Twenty-five had no abnormality on their first tracing, four had left axis deviation, and three had ST-segment depression or T-wave inversion.

ST-Segment Depression or T-Wave Inversion (Categories IV and V)

ST-segment depression or T-wave inversion was classified in 392 electrocardiograms recorded during the first series of examinations of this cohort. From the electrocardiograms recorded at the time of the second examination, 251 had no classified abnormality, 13
Table 5

Changes in Nonspecific Electrocardiographic Items Between Examinations Among Persons Having These Items Classified on the Second Examination

<table>
<thead>
<tr>
<th>Examination II</th>
<th>Normal</th>
<th>I</th>
<th>IV or V</th>
<th>II-1</th>
<th>III-1</th>
<th>II-1 + IV or V</th>
<th>III-1 + IV or V</th>
<th>III-1 + IV or V</th>
<th>III-1 + IV or V</th>
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<tbody>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>IV or V</td>
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<td>3</td>
<td>114</td>
<td>2</td>
<td>4</td>
<td>9</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>III-1</td>
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<td>0</td>
<td>1</td>
<td>20</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
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<td>III-1 + IV or V</td>
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<td>3</td>
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<td>4</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>II-1</td>
<td>114</td>
<td>29</td>
<td>2</td>
<td>9</td>
<td>55</td>
<td>5</td>
<td>11</td>
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<td>3</td>
<td></td>
</tr>
<tr>
<td>II-1 + IV or V</td>
<td>40</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>16</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>II-1 + III-1</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>II-1, III-1 +</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>IV or V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I = Q or QS items, II-1 = left axis deviation, III-1 = high amplitude R waves, IV = ST-segment depression and V = T-wave inversion.

Table 6

Changes in Nonspecific Electrocardiographic Items at Second Examination Among Persons Having These Items Classified on First Examination

<table>
<thead>
<tr>
<th>Examination I</th>
<th>Normal</th>
<th>I</th>
<th>IV or V</th>
<th>II-1</th>
<th>III-1</th>
<th>II-1 + IV or V</th>
<th>III-1 + IV or V</th>
<th>III-1 + IV or V</th>
<th>III-1 + IV or V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV or V</td>
<td>392</td>
<td>251</td>
<td>13</td>
<td>114</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>III-1</td>
<td>86</td>
<td>52</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>III-1 + IV or V</td>
<td>29</td>
<td>9</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>II-1</td>
<td>101</td>
<td>29</td>
<td>2</td>
<td>55</td>
<td>1</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>II-1 + IV or V</td>
<td>51</td>
<td>9</td>
<td>4</td>
<td>9</td>
<td>11</td>
<td>0</td>
<td>16</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>II-1 + III-1</td>
<td>12</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II-1, III-1 + V or V</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

had Q or QS items, 114 ST-segment depression or T-wave inversion, two left axis deviation and T-wave changes, three high amplitude R waves and T-wave changes, and nine left axis deviation. The electrocardiograms recorded at the first examination from the 251 persons without codable items on their second tracing had the following classifications: 48 IV-2 or IV-3; 19 IV-2 or IV-3 and V-3; 166 V-3; four IV-1; and 14 V-2. The IV-1, V-1, and V-2 classifications identify more definite abnormalities than the IV-2, IV-3, and V-3 categories which have been considered borderline changes in the Tecumseh analyses. Only 48 members of the cohort had IV-1 or V-2 items on this first electrocardiogram and 18 of these had no classified abnormality on their second tracing.

During the second series of examinations 294 persons in the cohort had coded ST-segments or T-wave items in their electrocardiograms. In their first examination 156 had normal electrocardiograms, three had Q or QS items, 114 ST-segment depression or T-wave inversion, two left axis deviation, four high amplitude R waves, nine left axis deviation and ST-segment or T-wave changes, five high amplitude R waves and ST-segment or T-wave changes, and one left axis deviation, high amplitude R waves, and T-wave inversion.

Of the 53 members of the cohort whose second electrocardiogram revealed the most pronounced ST-segment or T-wave changes (classification IV-1, V-1, and V-2), 32 (60%) had classified items in their tracings from the first examination. Of the 241 persons with less marked ST-segment or T-wave changes (classification IV-2, IV-3, and V-3) in their second
electrocardiograms, 106 (44%) had classified items in their tracings from the first examination.

Small Quantitative Changes in Serial Electrocardiograms Which Resulted in Reclassification of the Q or QS Items

The electrocardiograms of 18 persons had Q or QS changes classified as I-1 or I-2 in the second series of examinations but not in the first. When these tracings were compared to the previous ones, the differences were minute and the general configurations of the serial records were similar (fig. 1). Tracings from five other participants with less marked Q or QS items (I-3) at the second examination were also similar to the previous electrocardiogram.

Three persons whose tracings on first examination had coded Q or QS changes had electrocardiograms during the second series of examinations without classified category I items, although the differences between the serial tracings were slight.

Changes in Classification of Serial Electrocardiograms Which Inadequately Express the Magnitude of Abnormality

In some cases QRS changes appeared between examinations but did not satisfy any criteria for classification in the I category. When such a tracing is compared to an earlier normal electrocardiogram and the serial ST-segment and T-wave changes as well as the subtle QRS changes are taken into account, the probability of myocardial infarction is great (fig. 2).

Discussion

Several investigators have reported an increased incidence for overt cardiovascular disease among members of large population samples with certain nonspecific electrocardiographic abnormalities.\textsuperscript{3, 4} Mathewson and Varnam\textsuperscript{5} made similar observations from periodic examinations of a cohort of young men over a 10-year period.

Because the electrocardiogram is such an important tool in the diagnosis of coronary heart disease, although not the sole criterion of this condition, it seemed desirable to compare the electrocardiographic findings at two different times among a large proportion of a total population, with particular attention to the cohorts who were examined on both occasions.

Although the response rates were similar for both examinations and there is little reason to suspect a change in the prevalence of cardiovascular disease in so short a time, the discovery of asymptomatic or unrecognized abnormalities during the first series of examinations prompted many participants to seek medical care. The subsequent treatment may have influenced the number and type of electrocardiographic findings in the second series of examinations.

The Minnesota code\textsuperscript{2} was used for classification of the electrocardiograms from both series of examinations. The principal advantage of this system is that all classifications are based on the magnitude of specific items. This should improve comparability both within a single study and between different studies. This semiquantitative feature should more clearly define observed abnormalities and allow for a rough gradation of the severity of the abnormalities.

The major disadvantage of the Minnesota code is the fairly high rate of inter-observer and intra-observer variation in classification.\textsuperscript{6, 7} Another less obvious disadvantage is the difficulty in identification of new events. Minor quantitative changes, which may be due to artifact or slight differences in technique between examinations, sometimes result in reclassification. On the other hand, serial changes which are very suggestive of new cardiac disease may not be classified in a category which is indicative of their true importance. If these limitations are recognized and tracings are examined serially, the Minnesota code is a useful set of criteria for the classification of large numbers of electrocardiograms.

The different prevalence rates for numerous items classified in the electrocardiograms from the two series of examinations probably result from several factors. In some classifications, such as VII-1 and VII-2 (complete left
The upper tracing was classified as normal. The lower tracing, which was recorded 4 years later, was classified I-2d because the Q-wave duration in lead III was between 0.04 and 0.05 second and a Q wave was present in lead aVF. The differences between the two electrocardiograms are slight and would not justify the diagnosis of a new myocardial infarction.
The upper tracing was classified as normal. The lower tracing, which was recorded 4 years later, was classified IV-1 and V-1 because of the RST-segment depression and T-wave inversion in leads I, II, aV₂, aV₆ and V₂ to V₆. The loss of amplitude and slurring of the residual R waves in chest leads V₁ to V₅ are important serial changes which suggest that the RST-segment and T-wave changes resulted from myocardial infarction. Such changes are not codable in the Minnesota system.

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and right bundle-branch block), the rates were similar for both examinations. There is usually little disagreement about such items.

Agreement was usually good for Q and QS items (category I) among men. The differences in prevalence among women cannot be readily explained, but it may be due to the improved technical quality of the second examination electrocardiograms which permitted more accurate classification of borderline intervals or amplitudes.

The marked decrease in prevalence of coded high amplitude R waves (III-1) may have resulted in part from differences in reader attention. Early in the analysis of electrocardiographic classifications from the first series of examinations, it became apparent that the III-1 criteria did not discriminate well between normal persons and those with other evidence of left ventricular hypertrophy or a reasonable cause for it. Recognition of the deficiencies of the criteria for high amplitude R waves probably biased the classification of subsequent tracings.

The difference in prevalence of the III-1 classification between the two examinations probably did not result from reader differences alone. Of the 52 persons who participated in both series of examinations and whose electrocardiograms were coded III-1 at the time of the first examination but were unclassified on the second examination, only five had R wave amplitudes sufficiently great to fulfill the III-1 criteria when all 52 second examination records were re-examined.

R wave amplitudes probably decrease with age, particularly among young men.

The ingestion of glucose by some participants in the first series of examinations before the electrocardiogram was recorded may have caused a greater prevalence of high amplitude R waves. Such an effect from a meal has been reported by Simonson.9

The much lower prevalence of classified ST-segment depression and T-wave inversion among the electrocardiograms recorded during the second examination was the most striking change between the two sets of tracings.

There was an increased prevalence of the most marked ST-segment and T-wave changes (IV-1 and V-1 items) in the electrocardiograms from the second series of examinations, a modest decrease in the V-2 category and a more pronounced decrease in frequency of the total of the IV-2 and IV-3 classifications. The most marked change was the decrease in prevalence of flat or very slightly inverted T waves (V-3) among the second examination electrocardiograms.

Reader variability accounts for some of the differences. Two different electrocardiographers would not be expected to agree regularly about such items as flatness of T waves or whether the ST segment reaches a point 0.5 mm below the PR segment in any of a number of leads.

The practice of always recording the electrocardiogram before the glucose challenge during the second series of examinations was probably the most important factor in the lower prevalence of minor ST-segment or T-wave changes. Among men without apparent cardiovascular disease on a hospital ward10 and in a sample of women in the Tecumseh study11 ingestion of glucose produced classified ST-segment or T-wave changes in 10% of persons with normal electrocardiograms before challenge. During the first series of examinations in Tecumseh, the proportion of challenged participants who ingested glucose before the electrocardiogram was recorded is unknown, but 60% of examined adults received glucose. If half of those examined ingested glucose before the electrocardiogram was recorded, about 5% of the participants would be expected to have classified ST-segment or T-wave changes due to the challenge.

The total IV or V items from the second examination was 584 or 10.8% of those examined. The addition of 5% would result in a prevalence rate of 15.8%, which is similar to the combined prevalence of IV and V items from the first examination electrocardiograms, 16.4%. There is little reason to doubt that ingestion of glucose before the electrocardiogram was an important factor in the higher prevalence of classified ST-segment and T-wave items among the first series of tracings.
The comparison of electrocardiographic classifications at two different times among the cohorts who participated in both examinations is of particular interest. Most persons with classified Q or QS items in their first electrocardiograms had similar changes on their second tracing. Seven persons (14%) had no classified abnormality on the second tracing, but regression of Q waves is not unusual.

Of the 91 persons who had classified Q or QS waves on this second electrocardiogram, only 33 (36%) had normal tracings on the first examination. Thirty-six (40%) had Q or QS items in their first electrocardiogram, and 22 (24%) had nonspecific QRS or T-wave changes.

Among the cohorts who had two electrocardiograms, ST-segment depression and T-wave inversion were unstable items, although the effect of glucose was an important uncontrolled variable. Still, 3.3% (13 of 392) of persons with only ST or T items in this first electrocardiogram had classified Q or QS waves in their second tracing. Only 1.1% (33 of 3,022) of persons without ST-segment, T-wave, or nonspecific QRS items in their first electrocardiogram had classified Q or QS waves in their second tracing. These figures are a little misleading, however, since the ST-segment and T-wave changes were most prevalent among the older participants. Although the differences suggest that ST-segment or T-wave abnormalities predispose persons to subsequent myocardial infarction, the Tecumseh data would be more convincing if the numbers were larger and the variables of glucose ingestion and age differential were controlled. Subsequent examinations should help clarify these points.

Only one of the 13 persons with ST-segment or T-wave abnormalities who developed classified Q or QS waves had a V-2 classification on the first electrocardiogram. Nine had V-3 classifications, two IV-2 and V-3 classifications, and one had IV-3 and V-3. This distribution would suggest that the prognostic implications of minor ST-segment or T-wave abnormalities are as serious as more marked abnormalities. It must be recalled that these figures are from a cohort of living individuals and the numbers are small. The relationship of ST-segment depression and T-wave inversion to the development of coronary heart disease as manifest by angina pectoris, physical signs, or death as well as classified Q or QS waves in the electrocardiogram will be reported later.

The importance of ST-segment depression or T-wave inversion as predictors of more specific electrocardiographic abnormalities could be more accurately determined if it were possible to study people under standardized conditions. Many abnormalities may be related to medication, recent meals, or smoking before the electrocardiogram is recorded.

In epidemiological studies a uniform system for electrocardiographic classification is desirable. When a system such as the Minnesota code is used, variation in classification of serial electrocardiograms is inevitable and the cardiologist must decide which changes represent new cardiovascular disease. He must also be alert to clinically important changes within a classification or those classifications which do not adequately express the magnitude of change.

It has been suggested that trained lay persons classify electrocardiograms as well as cardiologists. When serial tracings are available, however, those with certain classifications must also be examined by an experienced cardiologist to achieve optimal diagnostic accuracy.

Summary

The prevalence of classified electrocardiographic items among the adult population of Tecumseh, Michigan, during two examinations approximately 4 years apart is reported. Changes in the prevalence rates of certain items are probably due to reader differences, the effect of prior ingestion of glucose in the first series of examinations, and possibly the treatment of abnormalities detected during the first examinations.
Among the cohort of 3,745 persons who had classified electrocardiograms on both examinations, the Q and QS items were relatively stable, the more marked ST and T items were less stable, and the minor ST or T classifications were extremely variable. Still, 31% of persons whose second electrocardiogram revealed codable Q or QS items for the first time had classified ST-segment or T-wave items in their previous electrocardiogram and another 9% had nonspecific QRS abnormalities, either high amplitude R waves or left axis deviation.

The Minnesota code is a useful system for the classification of large numbers of electrocardiograms, but for accurate identification of new events, tracings exhibiting category I, IV, or V items must be examined serially.

References

Literary Borrowing

Next to the originator of a good sentence is the first quoter of it. Many will read the book before one thinks of quoting a passage. As soon as he has done this, that line will be quoted east and west. Then there are great ways of borrowing. Genius borrows nobly. When Shakespeare is charged with debts to his authors, Landor replies: "Yet he was more original than his originals. He breathed upon dead bodies and brought them into life."—Emerson: A Modern Anthology. Alfred Kazin and Daniel Aaron (Eds.). New York, Dell Publishing Co., 1958, p. 367; also in The Complete Works of Ralph Waldo Emerson, vol. 8. Boston, Houghton, Mifflin & Co., 1903-4, p. 191.
Serial Electrocardiographic Findings in a Prospective Epidemiological Study
LEON D. OSTRANDER, JR.

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