Association of Nonspecific Minor ST-T Abnormalities With Cardiovascular Mortality

The Chicago Western Electric Study

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ELECTROCARDIOGRAMS (ECGs) MAY be obtained at intervals from adults with a variety of cardiac or noncardiac diseases and from persons who undergo periodic health examinations. Nonspecific abnormalities are frequently observed in tracings of persons without clinical signs of heart disease. The most common nonspecific findings, ST segment or T-wave abnormalities or both (ST-T abnormalities), can be disquieting hints of latent abnormality that the physician may not be able to confirm or completely dismiss. Association of ST-T abnormalities, particularly major abnormalities, with increased risk of coronary heart disease (CHD) incidence and mortality has been reported.\(^1\),\(^2\),\(^3\),\(^4\),\(^5\),\(^6\),\(^7\),\(^8\),\(^9\),\(^10\),\(^11\),\(^12\),\(^13\),\(^14\),\(^15\),\(^16\),\(^17\),\(^18\) However, the prognostic significance of minor ST-T abnormalities is less conclusive.\(^2\),\(^3\),\(^4\),\(^5\),\(^10\),\(^11\),\(^12\),\(^13\),\(^17\),\(^18\) Especially since most studies have not investigated minor ST-T abnormalities in the absence of other ECG findings.\(^2\),\(^3\),\(^4\),\(^5\),\(^10\),\(^11\),\(^17\),\(^18\)

Context Minor electrocardiographic (ECG) ST-T abnormalities are common, but their prognostic importance has not been fully determined.

Objective To examine associations of single (1 time only) and multiple (2 times only and \(\geq 3\) times) nonspecific minor ST-T abnormalities in 5 years with long-term mortality due to myocardial infarction (MI), coronary heart disease (CHD), cardiovascular disease (CVD), and all causes in middle-aged men.

Design Prospective cohort study (29-year follow-up after 5 annual examinations).

Setting and Participants A total of 1673 men employed at the Western Electric Company in Chicago, Ill, aged 40 to 55 years at entry, with no evidence of CHD and no major ECG abnormalities throughout the first 5-year period.

Main Outcome Measures Minor ST-T abnormalities identified from annual resting ECGs and mortality ascertained from death certificates.

Results Of the 1673 men, 173 had evidence of isolated nonspecific minor ST-T segment abnormalities. During the follow-up period, there were 234 deaths due to MI, 352 deaths due to CHD, 463 deaths due to CVD, and 889 deaths due to all causes. For men with 3 or more annual recordings of minor ST-T abnormalities, risk of death due to MI, CHD, CVD, and all causes was significantly greater than for those with normal ECG findings. For men with 3 or more ECGs with minor ST-T abnormalities, relative risks (and 95% confidence intervals) adjusted for cardiovascular and other risk factors were 2.28 (1.16-4.49), 2.39 (1.39-4.12), 2.30 (1.44-3.68), and 1.60 (1.06-2.42), respectively, with a graded relationship between frequency of occurrence of ST-T abnormalities and mortality risk (linear trend, \(P \leq 0.007\)).

Conclusions Persistent, minor, nonspecific ST-T abnormalities are associated with increased long-term risk of mortality due to MI, CHD, CVD, and all causes; the higher the frequency of occurrence of minor ST-T abnormalities, the greater the risk. These data underscore the potential value of including nonspecific ECG findings in the overall assessment of cardiovascular risk.

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See also pp 524 and 565.
study examines whether there is an independent relationship of isolated, non-specific minor ST-T abnormalities to long-term risk of mortality due to myocardial infarction (MI), CHD, cardiovascular diseases (CVDs), and all causes, and evaluates whether frequency of occurrence of these abnormalities, as well as their severity and extent, in annual examinations for 5 years is associated with risk.

**METHODS**

**Study Sample**

Data are from the Chicago Western Electric Study initiated in the fall of 1957 as a long-term prospective investigation of CHD. Details of the selection of participants and their demographic characteristics have been reported. Briefly, a group of 2107 middle-aged men employed by the Hawthorne Works of the Western Electric Company, Chicago, Ill, underwent an extensive baseline examination, including a 12-lead ECG at rest. For available survivors of this cohort, examinations including ECG were repeated annually for 11 subsequent years. This study used data from the first 5 examinations (ie, baseline and first 4 annual reexaminations). The decision to limit the baseline period to the first 5 annual examinations was made because (1) complete data on CVD risk factors were available for substantially more men for this period, and (2) this approach yielded a longer subsequent follow-up period.

**Exclusions and Inclusions**

Participants included in these analyses were men aged 40 to 55 years at baseline. Five men who were not in this age range, 43 men who had a history of CHD at entry, and 105 men who were diagnosed as having CHD during the 4 subsequent annual examinations were excluded. In addition, because the focus of these analyses was on isolated, minor ST-T abnormalities, 127 other men were excluded because they had 1 or more of the following major ECG abnormalities at baseline (n = 40) or at 1 or more of the 4 annual reexaminations (n = 87). These abnormalities may cause secondary ST-T change and affect prognosis: Q-QS wave

abnormalities (Minnesota Code [MC], 1-1 to 1-2-8); left ventricular hypertrophy (MC, 3-1 and 4-1-1 to 4-3 or 5-1 to 5-3); complete atioventricular block (MC, 6-1); Wolff-Parkinson-White syndrome (MC, 6-4-1 or 6-4-2); complete bundle branch block or intraventricular block (MC, 7-1-1, 7-2-1, 7-4, or 7-8); atrial fibrillation or flutter (MC, 8-3); and other major ST-T segment abnormalities (MC, 4-1 to 4-2 or 5-1 to 5-2). Furthermore, 29 men who died prior to the fourth annual reexamination and 125 men who did not complete the 5 consecutive annual examinations were also excluded. The remaining 1673 men constitute the cohort of this study.

**ECG Criteria**

All ECGs were read according to the MC as at the University of Minnesota ECG reading center. Serial ECGs for the same person were coded and compared during the same coding period to ensure comparability of coding for serial tracings recorded in different years. All ECGs were coded without knowledge of clinical or demographic data.

Criteria for minor ST-segment depression were either of the following: (1) no ST-J depression as much as 0.5 mm but ST segment downward sloping and segment T-wave nadir at least 0.5 mm below P-R baseline, in any of leads I, II, aVL, or V2 to V6 (MC, 4-3); or (2) ST-J depression of 1.0 mm or greater and ST segment upward sloping or U-shaped, in any of leads I, II, aVL, or V1 to V6 (MC, 4-4). Criteria for minor T-wave abnormality were either of the following: (1) T-wave amplitude zero (flat), negative, or diphasic (negative-positive type only) with less than 1.0 mm negative phase in lead I, II, V1 to V6, or in lead aVL when R-wave amplitude is 5.0 mm or greater (MC, 5-3); or (2) T-wave amplitude positive and T-to R-wave amplitude ratio of less than 1.20 in any of leads I, II, aVL, or V1 to V6 when R-wave amplitude in the corresponding leads was 10.0 mm or greater (MC, 5-4). These definitions parallel those used in clinical practice.

Over the past 25 years, the reproducibility of ECG coding has been checked regularly in the Minneapolis ECG reading center (approximately every 3 months) on existing and surrogate ECG dossiers. The intercoder and intracoder reliability and k values for ST-wave patterns consistently are between 96% to 97% agreement (k, 0.82-0.86; SE, 0.03-0.06) and for T-wave patterns are 96% to 98% (k, 0.90-0.92; SE, 0.04-0.05). In the present study, ST-segment depression and T-wave abnormality were combined into 1 group of primary ST-T abnormalities. These minor ST-T abnormalities were then categorized according to frequency of appearance (recurrence) during 5 consecutive annual examinations into 4 groups: no abnormalities, 1 time only, 2 times only, and 3 or more times. In addition, the MCs were grouped according to severity of abnormality. The MC 4-4 and 5-4 were classified as less severe forms of abnormality, and MC 4-3 and 5-3 were considered more severe. Furthermore, extent of abnormality was assessed by counting the number of lead groups, ie, anterior (leads V1-V5), anterolateral (I, aVL, V6), and posterior (inferior) (II, III, aVF) in which the ST-T abnormality occurred.

**Clinical Data and Follow-up**

Other annual data collected and used in this study were age at baseline examination and average values from the first 5 examinations for body mass index (BMI) (weight in kilograms divided by height in meters squared), systolic and diastolic blood pressure (BP), serum total cholesterol, and cigarette smoking. Men continuing in the study were reexamined annually up to 1969. Vital status was subsequently determined by mailed questionnaires or telephone interviews through 25 years; data were available for all 2107 men. For year 33, data on vital status were obtained from the National Death Index, the Health Care Financing Administration, and surviving participants’ responses to questionnaires; data were available for 2084 participants (98.9%). For analyses herein, follow-up began after the fifth examination and continued through the thirty-third anniversary of the initial examination.

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Mortality End Points
Causes of death were classified by reviewing death certificates and were coded according to the International Classification of Diseases, Eighth Revision (ICD-8).26 Coding was done independently in duplicate without knowledge of other information about participants. While the primary focus of this report is on associations of isolated nonspecific minor ST-T abnormalities with death due to MI (ICD-8 codes 410.0-410.9) and CHD (ICD-8 codes 410.0-414.9), results also are presented for CVDs (ICD-8 codes 400.0-445.9) and all causes of death.

Statistical Methods
Average values of characteristics at the first 5 annual examinations were calculated for groups of men defined based on frequency of minor ECG ST-T abnormalities: none, 1 time only, 2 times only, and 3 or more times, and compared using the Bonferroni method. Age-adjusted rates for mortality due to MI, all deaths due to CHD, all deaths due to CVDs, and deaths due to all causes were calculated per 10 000 person-years of follow-up for each group of men. Cox proportional hazards regression model27 was calculated for groups of men defined based on cumulative frequency of minor ST-T abnormalities: none, 1 time only, 2 times only, and 3 or more times, and compared using the Bonferroni method. Age-adjusted rates for mortality due to MI, all deaths due to CHD, all deaths due to CVDs, and deaths due to all causes were calculated per 10 000 person-years of follow-up for each group of men. Cox proportional hazards regression model27 was used to estimate the relative risks (RRs) of death and 95% confidence intervals (CIs) for each group of men (compared with men without ST-T abnormalities) with adjustment for age, education, family history of heart disease, systolic BP, serum cholesterol level, cigarettes per day, BMI, and BMI squared, and to test for linear trend (for the 4 groups of minor ST-T abnormalities, classified as 0, 1, 2, and 3).

To evaluate the prognostic significance of severity and extent of these abnormalities, scores were computed by assigning 1 point to ST-T abnormalities coded as MC 4-4 or 5-4 (ie, less severe) and 2 points to those abnormalities coded as MC 4-3 or 5-3 (ie, more severe). Cumulative severity score (range, 0-10) for a man was computed by summing the scores across the 5 annual examinations. Cumulative extent score (range, 0-15) was calculated by summing the number of lead groups with any of these minor abnormalities in the 5 examinations.

RESULTS
Single and Recurrent Minor ST-T Abnormalities
TABLE 1 shows the frequency and percentage distribution of men with single (1 time only) or repeated minor ST-T abnormalities during 5 consecutive annual examinations. Of the 1673 men, 173 showed evidence of isolated nonspecific minor ST-T abnormalities, which were detected only once in 105 of these men; only 2 times in 36 men; and 3 or more times in the remaining 32 men.

Descriptive Characteristics
TABLE 2 presents data on age and risk factors for CHD in the 4 ST-T groups and

Table 1. Distribution of Men With Single and Repeat Minor ST-T Abnormalities During 5 Annual Examinations

<table>
<thead>
<tr>
<th>No. of Annual Electrocardiograms</th>
<th>With Minor ST-T Abnormalities</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>All 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of men (N = 1673)</td>
<td></td>
<td>1500</td>
<td>105</td>
<td>36</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>All men, %</td>
<td></td>
<td>89.6</td>
<td>6.3</td>
<td>2.2</td>
<td>1.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Men with any minor ST-T abnormality (n = 173), %</td>
<td>...*</td>
<td>60.7</td>
<td>20.8</td>
<td>11.6</td>
<td>2.9</td>
<td>4.0</td>
</tr>
</tbody>
</table>
*Ellipses indicate data not applicable.

Table 2. Characteristics of 1673 Men According to Frequency of Minor ST-T Abnormality During 5 Annual Examinationsa

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of Electrocardiograms With Minor ST-T Abnormalities</th>
<th>0 (n = 1500)</th>
<th>1 (n = 105)</th>
<th>2 (n = 36)</th>
<th>≥3 (n = 32)</th>
<th>Total (N = 1673)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y†</td>
<td></td>
<td>47.5 (4.4)</td>
<td>47.6 (4.3)</td>
<td>47.6 (4.3)</td>
<td>48.5 (4.1)</td>
<td>47.4 (4.4)</td>
</tr>
<tr>
<td>Body mass index, kg/m²‡</td>
<td></td>
<td>25.6 (3.1)</td>
<td>25.6 (2.7)</td>
<td>25.3 (3.3)</td>
<td>26.2 (3.5)</td>
<td>25.6 (3.1)</td>
</tr>
<tr>
<td>Blood pressure, mm Hg</td>
<td></td>
<td>131.9 (15.4)</td>
<td>139.2 (19.6)§</td>
<td>138.9 (18.5)</td>
<td>140.3 (20.7)§</td>
<td>132.7 (16.0)</td>
</tr>
<tr>
<td>Systolic</td>
<td></td>
<td>84.6 (8.7)</td>
<td>87.7 (10.3)§</td>
<td>88.9 (9.9)§</td>
<td>89.2 (12.7)§</td>
<td>85.0 (9.3)</td>
</tr>
<tr>
<td>Diastolic</td>
<td></td>
<td>6.10 (1.02)</td>
<td>6.33 (1.13)§</td>
<td>6.09 (0.84)</td>
<td>6.14 (0.83)</td>
<td>6.11 (1.02)</td>
</tr>
<tr>
<td>Serum cholesterol, mmol/L [mg/dL]</td>
<td></td>
<td>10.2 (1.02)</td>
<td>10.4 (1.13)§</td>
<td>10.2 (1.13)</td>
<td>10.4 (1.13)</td>
<td>10.3 (1.13)</td>
</tr>
<tr>
<td>No. of cigarettes per day</td>
<td></td>
<td>10.0 (11.3)</td>
<td>11.2 (10.6)</td>
<td>10.4 (10.8)</td>
<td>10.4 (10.4)</td>
<td>10.4 (11.2)</td>
</tr>
<tr>
<td>Current smokers, %</td>
<td></td>
<td>54.0</td>
<td>64.8</td>
<td>56.6</td>
<td>56.3</td>
<td>54.8</td>
</tr>
<tr>
<td>Smokers only, No./d</td>
<td></td>
<td>18.1 (9.2)</td>
<td>17.9 (7.8)</td>
<td>17.9 (8.4)</td>
<td>18.5 (6.4)</td>
<td>18.1 (9.1)</td>
</tr>
<tr>
<td>Family history of cardiovascular disease, %</td>
<td></td>
<td>18.8</td>
<td>20.0</td>
<td>16.7</td>
<td>15.6</td>
<td>18.8</td>
</tr>
<tr>
<td>Education, y†</td>
<td></td>
<td>11.2 (2.5)</td>
<td>11.2 (2.6)</td>
<td>11.6 (2.5)</td>
<td>11.3 (2.5)</td>
<td>11.2 (2.5)</td>
</tr>
<tr>
<td>ST-T abnormalities coded as Minnesota Code 4-3 or 5-3, %</td>
<td>0</td>
<td>38.1§</td>
<td>52.8§</td>
<td>81.3§</td>
<td>81.3§</td>
<td>81.3§</td>
</tr>
<tr>
<td>ST-T abnormalities in multiple lead groups, %</td>
<td>0</td>
<td>19.1§</td>
<td>41.7§</td>
<td>68.8§</td>
<td>68.8§</td>
<td>68.8§</td>
</tr>
</tbody>
</table>

aAll data are average of first 5 examinations, 1957 to 1958 through 1961 to 1962, except for age and education. Unless otherwise indicated, values are mean (SD).
bBased on baseline examination during 1957 to 1958.
†Defined as the weight in kilograms divided by the square of the height in meters.
§By Bonferroni method of multiple comparisons for the comparison with no minor ST-T abnormality or for the comparison among 3 subgroups, P<.05.

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Table 3. Age-Adjusted Mortality Rate at 29 Years According to Frequency of Minor ST-T Abnormalities in 5 Annual Examinations

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Total No. of Deaths</th>
<th>0</th>
<th>1 Only</th>
<th>2 Only</th>
<th>≥3</th>
<th>≥1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial infarction†</td>
<td>234</td>
<td>198 (58.8)</td>
<td>20 (100.2)</td>
<td>7 (102.7)</td>
<td>9 (159.8)</td>
<td>36 (108.5)</td>
</tr>
<tr>
<td>Coronary heart disease‡</td>
<td>352</td>
<td>295 (87.7)</td>
<td>30 (148.3)</td>
<td>13 (192.1)</td>
<td>14 (222.3)</td>
<td>57 (169.7)</td>
</tr>
<tr>
<td>Cardiovascular diseases§</td>
<td>463</td>
<td>397 (118.0)</td>
<td>34 (165.8)</td>
<td>13 (192.1)</td>
<td>19 (293.4)</td>
<td>66 (192.3)</td>
</tr>
<tr>
<td>All causes</td>
<td>889</td>
<td>780 (231.9)</td>
<td>63 (306.0)</td>
<td>22 (338.6)</td>
<td>24 (354.2)</td>
<td>100 (323.3)</td>
</tr>
</tbody>
</table>

*Death rates are per 10,000 person-years. Number of men per number of person-years is as follows: 0, 1500/32,444; 1 only, 105/2125; 2 only, 36/718; more than 3, 32/581; more than 1, 173/3423.
†Defined as International Classification of Diseases, Eighth Revision (ICD-8) codes 410.0-410.9.
‡Defined as ICD-8 codes 410.0-414.9.
§Defined as ICD-8 codes 400.0-445.9.

Table 4. Age- and Multivariate-Adjusted Relative Risks (RRs) of Death During 29 Years According to Frequency of Minor ST-T Abnormalities in 5 Annual Examinations

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>0</th>
<th>1 Only</th>
<th>2 Only</th>
<th>≥3</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial infarction</td>
<td>1.00</td>
<td>1.66 (1.05-2.62)</td>
<td>1.77 (0.83-3.76)</td>
<td>2.63 (1.35-5.12)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>1.00</td>
<td>1.68 (1.16-2.45)</td>
<td>2.25 (1.29-3.92)</td>
<td>2.84 (1.66-4.86)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Cardiovascular diseases</td>
<td>1.00</td>
<td>1.42 (1.01-2.02)</td>
<td>1.70 (0.98-2.94)</td>
<td>2.88 (1.81-4.56)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>All causes</td>
<td>1.00</td>
<td>1.34 (1.04-1.73)</td>
<td>1.45 (0.95-2.21)</td>
<td>1.88 (1.25-2.82)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*CI indicates confidence interval.
†P values are for linear trend across the 4 strata of ST-T abnormalities.
‡The Cox multivariate proportional hazards model was used to adjust for age in year 5, education at baseline, family history of cardiovascular disease, and average of first 5 examinations, 1957 to 1968 through 1961 to 1962, systolic blood pressure, number of cigarettes smoked per day, serum cholesterol level, body mass index, and body mass index squared.
§Defined as ICD-8 codes 410.0-414.9.

Mortality and Minor ST-T Abnormalities
During 29 years of follow-up, there were 234 deaths due to MI, 352 deaths due to all CHD, 463 due to all CVDs, and 889 due to all causes (Table 3).

Higher age-adjusted rates of MI, CHD, CVDs, and mortality due to all causes were observed in men with 1 only, 2 only, and 3 or more minor ST-T abnormalities than men with none (Table 3). There was a graded increase in 29-year mortality from those with normal ECG findings to those with ST-T abnormalities 1 time only, to those with abnormalities on multiple occasions (linear trend, P < .001). Men with 3 or more occurrences of ST-T abnormalities had 2.5 times the death rate due to MI, CHD, and all CVDs than men with normal ECG findings; they also had higher death rates due to all causes. Age-adjusted mortality rates for the 173 men with any recording of minor ST-T abnormalities (ie, ≥ 1 in 5 annual examinations) were higher for all end points compared with those with normal ECG findings throughout.

Two proportional hazards regression models were used to calculate RR of mortality for the 4 groups of men with adjustment for: (1) age only, and (2) age, systolic BP, serum cholesterol level, cigarettes per day, education, family history of CVD, BMI, and BMI squared (Table 4). With control for age only or for multiple confounders, there was a significant direct graded relationship between minor ST-T abnormalities and mortality due to MI, all CHD, all CVDs, and mortality due to all causes.

for all men. On average, the study cohort was overweight (BMI ≥ 25 kg/m²), had higher than desirable levels of BP (ie, > 120/80 mm Hg), and was hypercholesterolemic. More than half were current smokers (54.8%), with a mean of 18 cigarettes smoked per day. On average, they had slightly less than a high school education and 19% had a family history of CVD. Age, BMI, serum total cholesterol levels, cigarette smoking, education, and family history of CVD did not differ significantly among the 4 groups. Systolic and diastolic BP were higher for those with minor ST-T abnormalities. Men with more frequent occurrence of ST-T abnormalities had higher percentage of a more severe form (ie, MC 4-3 or 5-3) and of abnormalities involving multiple lead groups.
and all causes. Men with ST-T abnormalities on only 1 occasion had a greater risk of death (all end points) than did those without abnormalities (multivariate RRs, 1.13-1.40). Risk was higher for men with abnormalities on repeat annual examinations (multivariate RRs, 1.27-2.39; linear trend, \( P < .001 \) to \( P = .007 \)).

Model 1 and 2 Cox analyses were repeated for men with any occurrence of minor ST-T abnormalities in 5 years of examinations, ie, men with 1 or more recordings of minor ST-T abnormalities. A significant relationship was found for any recording of minor ST-T abnormalities and death due to MI, CHD, CVDs, and all causes (TABLE 5). Multivariate RRs for these end points ranged from 1.28 to 1.67 with 95% CIs that did not include values of 1.00 or lower. When diastolic BP was substituted for systolic BP in multivariate Cox analyses, results were consistent with those reported for systolic BP (results not shown).

Similar Cox analyses for the prognostic significance of severity or extent score of minor ST-T abnormalities were performed. Multivariate adjusted RRs (95% CIs) for MI, CHD, CVD, and all cause mortality associated with a 1-point increase in cumulative severity score were 1.18 (1.07-1.30), 1.20 (1.11-1.29), 1.16 (1.08-1.25), and 1.11 (1.04-1.17), respectively. Corresponding risks for extent of ST-T abnormalities score were 1.18 (1.07-1.31), 1.19 (1.10-1.29), 1.18 (1.09-1.27), and 1.12 (1.05-1.12), respectively.

### COMMENT

This prospective study demonstrates that in employed middle-aged men isolated, nonspecific ST-segment and/or T-wave abnormalities on repeat annual examinations were independently associated with increased risk of death due to MI, CHD, CVDs, and all causes. Risks were greater for men with only 2 and 3 or more occurrences of ST-T abnormalities than for men with abnormalities on only 1 occasion. Of clinical relevance for screening, compared with men with no abnormalities, men with 1 or more recordings of minor ST-T abnormalities in 5 years of annual examinations had an increased risk of 38% to 67% for cardiovascular, coronary, and MI death.

Our analysis focused on minor ST-T findings, which constitute a class of abnormalities generally considered less severe than the combined (minor and major) ST-T wave changes reported in most other studies. Ten percent of these middle-aged men, who were otherwise free of evidence of CHD, had minor ST-T abnormalities at least once in annual resting ECG examinations during 5 years. Other studies report similar rates of occurrence. Minor T-wave abnormality (MC, 5-3) was found in 12% of men aged 40 to 59 years in the community population in Tecumseh, Mich, and in 9% of men of similar age in a religious sect living in the northwestern United States and southwestern Canada. Kannel et al reported that in Framingham Study examinations 8 to 12 (ie, over 4 years), 14.1% of men aged 44 to 74 years had nonspecific ECG abnormalities (ST-segment depression ≥ 1 mm and/or T-wave flattening or inversion). Thus, nonspecific ST-T abnormalities are common in apparently healthy people.

Consistent with the longstanding but unconfirmed impression of clinicians and epidemiologists, the Western Electric data demonstrate that there was considerable intrapersonal variation in frequency of occurrence of minor ST-T abnormalities over time. The ST-T abnormalities have been described in a number of situations besides the presence of organic heart disease, including with change in posture, hyperventilation, ingestion of food, the hyperkinetic heart syndrome, imbalance of the sympathetic nervous system, or anxiety. These factors, difficult to delineate and control, contribute to this variability. Hence, some authors believe that these abnormalities are the result of physiological influences and are not prognostically relevant. It is also true that persons with confirmed CHD may manifest only transient asymptomatic ST-T changes. One limitation of our study is that data on exercise were not available for inclusion in these analyses. Furthermore, information on use of medication and serum electrolytes were not collected. However, the likelihood is that the majority of participants were not taking medications that would affect ST-T waves (eg, digitalis) and that abnormal serum electrolyte levels were uncommon, given that the study cohort was a healthy working population and that participants with CHD or MI were excluded from these analyses.

Other possible noncardiac causes of variation are errors or differences in ECG recording technique and differences in interpretation across examinations. The MC used in this study has been widely recommended for classification of ECGs for epidemiological purposes. The principal advantage of this system is that all classifications are based on the semi-quantitative magnitude of specific items, which should improve comparability between ECG readings taken on different occasions. In this study, all ECGs were coded at the same time in a serial, stan-

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**Table 5. Age- and Multivariate-Adjusted Relative Risks of Death During 29 Years With Presence of Any Minor ST-T Abnormalities in 5 Annual Examinations**

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Age-Adjusted</th>
<th>Multivariate-Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocardial infarction</td>
<td>1.85 (1.30-2.64)‡</td>
<td>1.58 (1.09-2.28)§</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>2.00 (1.50-2.65)‡</td>
<td>1.67 (1.25-2.25)‡</td>
</tr>
<tr>
<td>Cardiovascular diseases</td>
<td>1.73 (1.33-2.24)‡</td>
<td>1.38 (1.05-1.80)§</td>
</tr>
<tr>
<td>All causes</td>
<td>1.46 (1.19-1.77)‡</td>
<td>1.28 (1.04-1.58)§</td>
</tr>
</tbody>
</table>

*Compared with men with no minor ST-T abnormalities. All data are presented as relative risk (95% confidence interval).

†Adjustment variables in the Cox multivariate proportional hazards model were age in year 5, education at baseline, family history of cardiovascular disease, and average of first 5 examinations, 1957 to 1958 through 1961 to 1962, systolic blood pressure, number of cigarettes smoked per day, serum cholesterol level, body mass index, and body mass index squared.

‡\( P < .001 \).

§\( P < .05 \).
higher risk of death.1-16 Minor abnormalities include Q wave, ventricular hypertrophy, and others (eg, atrial flutter and/or fibrillation, frequent ectopic ventricular beats, ventricular conduction defect, and complete left bundle branch block).3.79 In the Western Electric cohort, the multivariate-adjusted RRs of death due to CHD in 29 years for men with major abnormalities on their baseline ECG were: abnormal Q wave, 2.35 (95% CI, 1.41-3.90); left ventricular hypertrophy, 2.02 (95% CI, 1.01-4.26), and other major ECG abnormalities combined, 1.89 (95% CI, 1.03-3.47). The magnitudes of these risks were greater compared with that of any minor ST-T abnormalities from coexisting cardiovascular risk, these data do provide evidence that minor isolated nonspecific ECG findings are prognostically important. Our findings suggest that recurrent nonspecific minor ST-T abnormalities on repeat examinations in middle-aged men indicate increased mortality risk and warrant especially vigorous preventive management against the occurrence of clinical CHD.

The existing literature consistently shows an association of total or major prevalent ST-T abnormalities with a higher risk of death.1-16 Minor abnormalities, eg, ST-segment depression less than 0.5 mm (MC, 4-3), or junctional ST depression with upward-sloping (MC, 4-4), or decreased T-wave amplitude without inversion of 1.0 mm or more (MC, 5-3, 5-4), also have been examined in some studies, with inconsistent results, eg, reported as being of prognostic importance,2,4,11,18,20 of some importance,10,17 and no prognostic significance.19 Of particular concern, most investigations3,5,10,11,17,18 did not isolate minor ST-T abnormalities from coexisting major ECG abnormalities, did not examine whether the relationship of these abnormalities to outcome was independent of other established coronary risk factors, and did not determine the meaning of occurrence of these abnormalities only 1 time vs more than once, in repeat examinations. Based on data from the Honolulu Heart Program, Knutsen et al14 noted that individual ECG abnormalities frequently were correlated and that subsequent CHD rates were lower for each ECG category examined as an isolated abnormality, and some major ischemic ECG findings such as ST depression did not seem to indicate substantially increased risk when it was an isolated ECG finding in clinically disease-free men.

In light of these concerns, our present analyses excluded persons with CHD or major ECG abnormalities, including major ST-segment (MC, 4-1 and 4-2), T-wave (MC, 5-1 and 5-2) abnormality, or both, in the first 5 years. This ensured that the prognostic evaluation involved only isolated minor nonspecific ST-T abnormalities. No previous study has examined the predictive value of more than 1 occurrence of minor ST-T abnormalities on repeat annual examinations. Our data show that there was a significant trend of graded increase in RR from absence of abnormalities to serially recurring abnormalities. In addition, men with more frequent recurring abnormalities were also more likely to have the more severe codes (ie, MC, 4-3 and 5-3) and to have ST-T abnormalities in multiple lead groups. Both severity and extent apparently contribute to the higher mortality observed in persons with more frequent occurrence of minor ST-T abnormalities. Co-linearity among these variables makes assessment of their separate impact on risks virtually impossible.

A great deal is now known about the frequency and prognosis of ECG abnormalities in patients with clinically overt heart disease. However, the practicing physician is often confronted with an ECG abnormality, such as minor ST-T change, as an incidental finding during a routine evaluation of an asymptomatic individual without a clinically apparent cardiac disorder. Our study implies that attention should be given to such an ECG finding as possibly clinically significant, worthy of diagnostic evaluation, and warranting interval ECG reexamination. Data from a careful history taking, physical examination, and laboratory assessment must be correlated with the ECG. It is also important to consider other major cardiovascular risk factors such as the patient’s sex, age, population of origin, major modifiable-preventable traits (elevated BP, dyslipidemia, adverse dietary pattern, and cigarette smoking), and other lifestyle habits, because these may give meaning to the ECG finding.8,9,13,16

Although data from the Western Electric Study provide no direct evidence of the value of ECG screening for reducing cardiovascular risk, these data do provide evidence that minor isolated nonspecific ECG findings are prognostically important. Our findings suggest that recurrent nonspecific minor ST-T abnormalities on repeat examinations in middle-aged men indicate increased mortality risk and warrant especially vigorous preventive management against the occurrence of clinical CHD.

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REFERENCES


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It has often been said that to make discoveries, one must be ignorant. This opinion... means that it is better to know nothing than to keep in mind fixed ideas based on theories whose confirmation we constantly seek, neglecting meanwhile everything that fails to agree with them.

—Robert Browning (1812-1889)