A New Epidemiologic Classification System for Interim Myocardial Infarction from Serial Electrocardiographic Changes

Richard S. Crow, MD, Ronald J. Prineas, MBBS, PhD, David R. Jacobs, Jr., PhD, and Henry Blackburn, MD

Many clinical trials or population studies have used change in Minnesota Q code, ST-segment depression code or T-wave inversion code as evidence of new myocardial infarction or new coronary heart disease event. Direct electrocardiogram (ECG) waveform comparison is a new standardized procedure for diagnosing interim myocardial infarction from ECGs classified according to the Minnesota code (serial Q-wave pattern change). This procedure was investigated for its application in epidemiologic studies. Use of this procedure in the Multiple Risk Factor Intervention Trial resulted in a 50% increase in the positive predictive accuracy, improved agreement with clinically defined myocardial infarction and a strong independent prognostic association with total and coronary heart disease mortality. Among those with major Minnesota Q-code findings, there was substantial variation in mortality. The 5-year coronary heart disease death rates estimated by life table analysis were 8.5% for those with major serial Q-wave pattern change, 5.1% for those with minor serial Q-wave pattern change and 1.5 to 2.6% for those with major or minor Minnesota Q-code change not substantiated by direct waveform comparison, compared with 2.4% for those with no Minnesota Q-code findings. The coronary heart disease death rate for those with major serial Q-wave pattern change was greater than that for the other ECG groups (p <0.01). Adjustment for age and other risk factors did not qualitatively alter these findings. This new approach is eminently suitable for export to other investigators, for incorporation into computer analysis programs and for statistical analysis.

(Am J Cardiol 1989;64:454-461)

A central requirement for epidemiologic studies and clinical trials is a bias-free, objective measurement of cardiovascular occurrence rates between comparison groups. The electrocardiogram (ECG) is well suited to central standardized measurement and handling by blinded, repeatable procedures, thus providing an objective method to document study endpoint information without bias of ascertainment.

The Minnesota code was originally developed for determining prevalence information in epidemiologic studies and it functions well in that capacity. Later, criteria for documenting significant change between Minnesota codes were developed from "armchair rationale" with general knowledge of the classification error in ECG coding, and then modified after testing against an autopsy-proven sample from Mayo clinic records and a normal sample. However, criteria for significant change between Minnesota code classifications, used as an index of incidence rates for new myocardial infarction (MI), tended to produce high false positive misclassifications as judged by clinical assessment. Because ECGs are continuous and "infinitely gradable," whereas Minnesota code items are categorical, a minor amplitude or duration change can sometimes produce a significant Minnesota code change. In spite of these limitations, criteria based on change in Minnesota code were routinely used for ischemic endpoint determination in many epidemiologic studies in the United States and abroad since the 1960s.

During the Multiple Risk Factor Intervention Trial (MRFIT), we introduced a new approach to classification of ECG changes. First, computer-generated Minnesota Q codes were identified for all baseline or annual ECG recordings. Second, for each participant with a new major Minnesota Q code detected at an annual visit, 2 cardiologists directly compared the baseline ECG with the annual ECG to determine whether or not the new Q code represented a major serial Q-wave pattern change. The cardiologists followed predefined rules for serial ECG change that mimic the physician's clinical reading approach. These rules were developed in the Minnesota ECG Coding Center and provide categorization of new MI or coronary heart disease event without the limitations of the original procedure, which compared only Minnesota Q codes. This comparison procedure is based on direct comparison of ECG waveforms. It was incorporated into the Minnesota ECG Center's standardized training procedures and taught to all cod.
ing staff. This coding procedure has been evaluated in the MRFIT using nonphysician coders and is the subject of this report.

METHODS

Study population: Analysis of baseline and follow-up ECG data from the MRFIT form the basis of this report. The MRFIT was a randomized clinical trial in men, ages 35 to 57 years, at 22 participating clinical centers, recruited between 1973 and 1976. A total of 12,866 men without clinical evidence of definite coronary heart disease were enrolled in the trial. Eligibility criteria, statistical design and methods are described in detail elsewhere.

Electrocardiogram recording at rest and analysis: Electrocardiograms were recorded at baseline and at the 6 to 8 subsequent annual examinations on FM cassettes using a Marquette 3500 recorder. The ECG at rest included the conventional 12-leads plus the 3 orthogonal X, Y, Z Frank leads and were taken in the recumbent position, after an overnight fast. The FM cassettes recorded at the clinical centers were played back using 1 centralized unit located at the computer ECG center at Halifax, Nova Scotia. Paper tracings were produced for visual coding and sent to the Minnesota ECG Coding Center. All ECGs were Minnesota-coded independently 3 times by trained coders, with disagreements settled by the laboratory supervisor or the investigators.

Procedures for electrocardiographic diagnosis of myocardial infarction: The original procedure, comparison of Minnesota Q codes, is based on indirect comparison of ECG waveforms. Here, the Minnesota codes, assigned independently to each ECG, are compared without further reference to the ECG waveform (see Appendix A for Minnesota Q/QS codes). The new procedure, direct comparison of ECG waveforms, compares pairs of ECGs, selected because they have significantly different Minnesota Q codes. Direct comparison of waveforms uses the baseline ECG as the reference for comparison to all subsequent tracings. Any follow-up ECG with a major or minor Minnesota Q-code change is compared in turn with the reference ECG to confirm or negate a serial Q-wave pattern change from baseline. This procedure uses triplicate, independently read ECG pairs with adjudication by the ECG Center supervisor. The side-by-side ECG comparison using the rules given in Appendix B determines 3 waveform change categories: (1) no change; (2) serial Q-wave pattern change (minor or major); or (3) technical problem. Table I lists the major and minor Minnesota code change criteria that prompt serial ECG comparisons; note that only ECG items a and b are used in this study. Figures 1 and 2 show the procedure for a serial Q-wave pattern change and for no change. These comparison rules require that the majority of beats under evaluation fulfill the change criterion. For example, let us assume that the baseline ECG showed that the majority of QRS complexes had a Q/R ratio ≤ 1/6 in standard lead II. In order to document a significant Q-wave pattern change by direct waveform comparison, the event ECG must have the majority of Q/R ratios in lead II measured at ≥ 1/4. The approach of using the majority rule for determining change is part of the visual coding method. A more accurate approach would be to measure change from computer-generated averaged beats.

Annual visit electrocardiographic criteria for nonfatal myocardial infarction: Standard Minnesota coding of ECGs was performed in the MRFIT at baseline and at the 6 to 8 annual follow-up examinations; major change in specific Minnesota Q-code items between baseline and any follow-up ECG was used to identify pairs of ECGs for direct comparison. Appendix A shows the Minnesota Q/QS code definitions. An annual visit ECG was judged to have a new major Q code if Minnesota Q code 1-l or 1-2-7 was coded on an annual visit but no Q codes were found on the baseline ECG, or if Minnesota Q code 1-l was found on an annual visit and a less severe Q code (1-2-8 or any 1-3) was coded on the baseline ECG. For all participants with these changes, the new objective rules, shown in Appendix B, were used to confirm whether or not the major Minnesota Q-code change was a major serial Q-wave pattern change. The new procedure was applied by the 2 cardiologists and later by the Minnesota ECG Center coding staff using the same rules.

Terminology: In this study, we define a major change in Minnesota Q code as a "worsening" by 2 classes of Q-code class (for example, 1-0 to 1-2 or 1-1 to 1-3). We define a minor change in Minnesota Q code as a "worsening" by 1 Q-code class (for example, 1-3 to 1-2, or 1-2 to 1-1). We form 5 Q-code categories that are mutually exclusive and based on the most severe ECG classification from baseline to any annual ECG comparison during a 6- to 8-year follow-up. These categories include (a) no Minnesota Q code ever, when no Q code is identified.
(b) no minor serial Q-wave pattern change, when there is a minor change in Minnesota Q-code not confirmed by direct waveform comparison; (c) no major serial Q-wave pattern change, if a major change in Minnesota Q code is not confirmed by direct waveform comparison; (d) minor serial Q-wave pattern change, when there is a minor change in Minnesota Q-wave code confirmed by direct waveform comparison; and (e) major serial Q-wave pattern change, when a major change in Minnesota Q code is confirmed by direct waveform comparison. Note that each category except no Q code ever uses major or minor Minnesota Q-code change in the structure of the classification.

The severity of these categories is assumed to be least for categories “a”, “b” and “c”, intermediate in category “d” and worst in category “e.”

**Definition of clinical endpoints:** Clinical nonfatal MI was defined by affirmative responses on the annual medical history questionnaire to all of the following (1) history of hospitalization by self-report; (2) participant report that a non-MRFIT physician had told him he had had a heart attack during the past 12 months; and (3) a study physician noted at annual examination either that a myocardial infarction during the prior year was "present or suspect" or that there was new clinical ECG evidence of MI at that annual visit.

**Mortality assessment:** Classification of cause of death was performed by a committee of 3 cardiologists not affiliated with the MRFIT. They evaluated hospital records, physician reports, next-of-kin interviews, death certificates and autopsy reports. Randomized group assignment was carefully masked. Deaths were subclassi-
fied as (1) myocardial infarction (documented by clinical or autopsy evidence) with death occurring within 30 days of onset of symptoms or during hospitalization for acute myocardial infarction; (2) sudden death (within 24 hours of symptom onset and without documented myocardial infarction); (3) congestive heart failure due to coronary heart disease; (4) death associated with surgery for coronary heart disease or from complications of such surgery; or (5) noncoronary heart disease death.

**Statistical methods:** Levels of agreement in labeling of serial Q-wave pattern change coding results were assessed by the Kappa statistic. Using life table analysis, we investigated coronary heart disease mortality according to the 3 ECG severity categories stated above ("a through e"). For men who had a Minnesota Q code at any annual visit, follow-up begins in the year when the most severe Q code occurs. A random year has been selected for start of follow-up in the men with no Q code. There are 2 rationales for the selection of this random start year. First, it assures that ages of men who never had a Q code are increased from the MRFIT baseline in the same distribution as ages of those who had any Q code. Second, it assures equal MRFIT exposure, by assuring that the same postbaseline years of that trial are being compared for those with no Q code as for those with any Q code. The distribution of follow-up start years in men with no Q code is: year 1, 23.2%; year 2, 16.0%; year 3, 13.4%; year 4, 13.8%; year 5, 11.4%; year 6, 14.2%; year 7, 7.9%. We repeated the life table analysis among men without documented clinical MI ("silent MI"). Mortality rates before and after adjusting for age, serum cholesterol, diastolic blood pressure and cigarette smoking status were evaluated for statistical significance using the Cox-Mantel statistic in the proportional hazards regression analysis.

**RESULTS**

Table II presents the agreement between the cardiologist-labeled major serial Q-wave pattern change and the Minnesota ECG Center-identified major serial Q-wave pattern change among the 557 MRFIT participants who had any major Minnesota Q-code change. Agreement was observed in 478 (86%) patients. Thirty-nine physician readings were discordant with the coder classification; the reverse was observed in 40 patients. Overall, the Kappa statistic was 0.68 (p <0.01). Two hundred ECGs were recoded by the coding staff using triplicate independent reading and compared with the original results. The agreement across lead groups between the first and second adjudicated coding ranged from 0.86 to 0.97 by Kappa statistic.

Table III lists the results of the association between clinical MI status and major serial Q-wave pattern change, no major serial Q-wave pattern change or no major Minnesota Q-code change ever. Among the 516 men with clinical MI, 182 (35.3%) had a major serial Q-wave pattern change and 21 (4%) had no major serial Q-wave pattern change. Among the 12,350 men without clinical MI, 155 (1.3%) were identified as major serial Q-wave pattern change, and an additional 199 (1.6%) as no major serial Q-wave pattern change. Before using the direct ECG waveform procedure, all the 354 (155+199) men would have been labeled definite interim MI by Minnesota Q-code change criteria.

The categories “major serial Q-wave pattern change” and “no major serial Q-wave pattern change” from Table III are analyzed in detail in Table IV according to the presence or absence of clinical MI and the specific Minnesota Q-code change that prompted the direct ECG waveform comparison. In most patients in whom clinical MI is present, direct ECG waveform comparison agrees closely with the Minnesota Q-code change, whereas in patients with clinical MI absent, direct ECG waveform comparison agrees with Minnesota Q-code change in 45% of the patients. In the lateral leads (I, aVL, V6), Minnesota Q-code change to 1-1-3 was not substantiated by direct ECG waveform comparison in 4 of 8 patients in whom clinical MI was present, and 18 of 21 patients in whom clinical MI was absent. In the inferior leads (II, III, aVF), most cases not substantiated by direct comparison occurred in Minnesota Q-code changes to 1-2-4 and 1-2-6, namely, 5 of 17 patients with clinical MI present and 83 of 123 patients with clinical MI absent. Finally, in the anterior leads (V1 through V6), several unsubstantiated cases occurred in Minnesota Q-code changes to 1-1-2 when clinical MI was present (7 of 9 patients); to 1-1-1, 1-1-2 and 1-1-6 when clinical MI was absent (81 of 123).

**Table II Level of Agreement Between Cardiologists and Minnesota Coders for Identifying Major Serial Q-Wave Pattern Change Among 557 Multiple Risk Factor Intervention Trial Participants with Major Minnesota Q-Code Change from Baseline to Any Annual Examination**

<table>
<thead>
<tr>
<th>Cardiologists' Results</th>
<th>Cardiologists' Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI+ MI− Totals</td>
<td>MI+ MI− Totals</td>
</tr>
<tr>
<td>Coder's Results</td>
<td>Coder's Results</td>
</tr>
<tr>
<td>MI+ 297 40 337</td>
<td>MI+ 297 40 337</td>
</tr>
<tr>
<td>MI− 39 181 220</td>
<td>MI− 39 181 220</td>
</tr>
<tr>
<td>Totals 336 221 557</td>
<td>Totals 336 221 557</td>
</tr>
</tbody>
</table>

MI+ = major serial Q-wave pattern change was present; MI− = major serial Q-wave pattern change was absent.

**Table III Relation Between Electrocardiographic Status and Clinical Myocardial Infarction Among Multiple Risk Factor Intervention Trial Men**

<table>
<thead>
<tr>
<th>Major Minnesota Q-Code Change</th>
<th>Major Minnesota Q-Code Change</th>
<th>Major Minnesota Q-Code Change</th>
<th>Major Minnesota Q-Code Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q-Wave</td>
<td>Q-Wave</td>
<td>Q-Wave</td>
<td>Q-Wave</td>
</tr>
<tr>
<td>Change</td>
<td>Change</td>
<td>Change</td>
<td>Change</td>
</tr>
<tr>
<td>Clinical MI</td>
<td>Clinical MI</td>
<td>Clinical MI</td>
<td>Clinical MI</td>
</tr>
<tr>
<td>Present (%)</td>
<td>182 (35.3)</td>
<td>21 (4.1)</td>
<td>313 (60.0)</td>
</tr>
<tr>
<td>Absent (%)</td>
<td>155 (1.3)</td>
<td>199 (1.6)</td>
<td>11,996 (97.1)</td>
</tr>
<tr>
<td>Total (%)</td>
<td>337 (2.6)</td>
<td>220 (1.7)</td>
<td>12,350 (100.0)</td>
</tr>
</tbody>
</table>

* Major Minnesota Q-code change (1 at baseline to 1-2 or 1-1 at any follow-up visit) or a change from Q-3 at baseline to 1-1 at any follow-up visit confirmed by direct ECG comparison; † major Minnesota Q-code change (4 at baseline to 1-2 or 1-1 at any follow-up visit, or a change from 1-3 at baseline to 1-1 at any follow-up visit not confirmed by direct ECG comparison. Only the most severe Q-code change was considered.
Figures 3 and 4 show coronary heart disease mortality rates by clinical MI status and by the 5 levels of Q-code severity using life table analysis. Figure 3 shows the coronary heart disease mortality rates for all men regardless of clinical MI status, whereas Figure 4 shows these data excluding the 516 with clinical MI ("silent MI"). In both figures, the numbers of men at risk at baseline (year 0) and years 3, 5 and 7 are displayed below the corresponding study year. Coronary heart disease mortality curves are ranked as hypothesized by the presence of serial Q-wave pattern change (major higher than minor). The coronary heart disease mortality curves differed from one another (p < 0.001, Cox-Mantel statistic) after adjusting for age and after adjusting for age, serum cholesterol, diastolic blood pressure and cigarette smoking status. Overall, coronary heart disease mortality rates were highest in major serial Q-wave pattern change whether or not a clinical MI was documented. When men with clinical MI were included in the analysis, there was a tendency (not statistically significant) toward higher mortality rates for those with minor serial Q-wave pattern change. The remaining 3 groups had lower coronary heart disease mortality rates that were similar to each other.

DISCUSSION
Most published reports14-16 of ECG diagnostic criteria for MI have dealt primarily with static ECG findings; only infrequently has attention been given to the importance of ECG change. Minnesota code change criteria, based on change of individual code items evaluated separately, were first used to identify treatment group differences and trends in ECG events, and to assess possible bias in treatment or in diagnosis among the 53 Coronary Drug Project clinics.17 In that study, "worsening" by ≥2 classes of Minnesota Q code in any anatomic site was considered a "significant" index of change for specific items (Q-QS patterns, T-wave findings and ST depression). These criteria for significant "worsening" have been used as an objective categorization of new MI and incident coronary heart disease in most major US epidemiologic studies, clinical trials and coronary heart disease surveillance studies from that time to the present, including the MR FIT; Chicago-Western Electric, Hypertension Detection and Follow-up Trial; Beta Blocker Heart Attack Trial; Minnesota Heart Health Program; Minnesota Heart Survey; and the Seven Countries Study.18-22 The prognostic importance of the Minnesota code change in population studies has been clearly demonstrated. In the Coronary Drug Project,23 ST depression and major Q codes provided prognostic information independent of clinical status.

However, Minnesota Q-code category change may result from biologic variation of the ECG. In a study by Rautaharju et al,24 the short-term variability (>2 weeks) of Q-code change was assessed in a group of 104 clinically stable MR FIT participants. This group was an enriched sample of men with respect to Minnesota Q-code findings. A significant worsening, that is, an in-
crease by >1 Q-code category occurred in 7 of 104 patients (6.7%) and a significant improvement, that is, a decrease by >1 Q-code category occurred in 10 of 104 patients (9.6%) during this short time period. Because in 16% of the patients there were spurious findings using change in Minnesota code categories, the investigators conclude that ECG endpoint detection may require comparison of changes in continuous ECG measurements.

Tomina et al.25 did study change in continuous ECG measurements in relation to diagnosis of myocardial infarction. They attempted to elucidate the relative contribution of serial electrocardiographic change to the diagnosis of coronary events compared with the absolute value of the measurement of specific ECG waveform at or after the event (Q-wave duration, Q/R ratio). They considered the use both of an ECG known to be post-event and of serial change from a pre-event to a post-event ECG. In contradistinction to the findings of our study, the work of Tomina et al.25 found that only a modest improvement in diagnostic value was obtained from information about serial ECG change beyond findings from an individual postevent ECG. The primary difference between the 2 studies may be in the sample selection. Their samples were selected to clearly distinguish between the MI and non-MI groups, minimizing the false positive rate in the postevent ECG. In an unselected sample such as ours, there may be false positives in the clinical MI group, and the serial measurement may clarify the diagnosis of these false positives by reducing the variability of categorical change.

Recognizing the inherent limitations in using changes in Minnesota code, we developed the direct ECG waveform comparison to confirm or negate whether Minnesota Q-code changes represented a diagnostic change. Because this procedure uses Minnesota codes to select ECGs for direct comparison, it can be applied retrospectively to stored ECGs in any study with Minnesota-coded ECGs. The use of this serial comparison procedure was hypothesized to improve the association with clinical status beyond that noted by Tomina et al.25 and to eliminate the dependence on categorical data identified by Rautaharju et al.24

In considering agreement with clinical status, we note that Minnesota codes have been routinely used for evidence of new MI in population studies (usually any new Minnesota Q code of 1-1 to 1-2 excluding 1-2-6 and 1-2-8). The findings from our study partially disagree with the wisdom of this approach. These results suggest that new Minnesota codes 1-1-1, 1-1-2 and 1-1-6 (major Q codes in V1 through V6) and 1-1-3 (major Q codes in leads I, aVL and V6) should not be routinely used for annual ECG evidence of new MI unless ECG waveforms are compared directly. Further, a new 1-2-6 appears to have little relation with clinical MI even with serial change comparison. Nevertheless, the fact that some patients have a major Minnesota Q code but no increased coronary heart disease mortality risk is important to note. It suggests that some major Q codes reflect physiologic damage, whereas others reflect physiologic variation. The latter would not be expected to carry excess risk. In contradistinction, serial Q-wave pattern change reflects more reliably physiologic damage.

In our study, the prognostic significance of change in major Minnesota Q code, not confirmed by direct waveform comparison, adjusted for major risk factors, was not associated with an increased coronary heart disease mortality rate, whereas major serial Q-wave pattern change was associated with an increased rate. Major serial Q-wave pattern change also identified men with silent MI who had prognostic outcomes equivalent to men with documented clinical MI. The Framingham study also documented that coronary heart disease mortality was as prognostically important in men with silent MI as in those with recognized MI.26 This study identified 3 important findings related to the direct ECG comparison procedure. First, this procedure resulted in ECG findings that corresponded more closely to the clinical status and to the prognostic outcome (Table II, Figures 3 and 4). Second, the Cox proportional hazard regression analysis confirmed that major serial Q-wave pattern change was a statistically significant predictor of coronary heart disease mortality.

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>Relation Between Major Serial Q-Wave Pattern Change and No Major Serial Q-Wave Pattern Change Among Multiple Risk Factor Intervention Trial Men With and Without Clinical Myocardial Infarction for Specific Q-Code Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota</td>
<td>Clinical MI Present</td>
</tr>
<tr>
<td>Q-Code</td>
<td>Major</td>
</tr>
<tr>
<td>Change from</td>
<td>Serial</td>
</tr>
<tr>
<td>I-3 or I-0</td>
<td>Q-wave Change</td>
</tr>
<tr>
<td>Baseline</td>
<td>Total</td>
</tr>
<tr>
<td>Lead group</td>
<td>I, aVL, V6</td>
</tr>
<tr>
<td>I-1-1</td>
<td>20</td>
</tr>
<tr>
<td>I-1-2</td>
<td>0</td>
</tr>
<tr>
<td>I-1-3</td>
<td>4</td>
</tr>
<tr>
<td>I-2-1</td>
<td>15</td>
</tr>
<tr>
<td>I-2-2</td>
<td>1</td>
</tr>
<tr>
<td>I-2-3</td>
<td>2</td>
</tr>
<tr>
<td>I-2-4</td>
<td>8</td>
</tr>
<tr>
<td>I-2-5</td>
<td>4</td>
</tr>
<tr>
<td>I-2-6</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
</tr>
</tbody>
</table>

* See Table III for definition of major serial Q-wave change; + see Table III for definition of no major serial Q-wave change.

THE AMERICAN JOURNAL OF CARDIOLOGY SEPTEMBER 1, 1989 459
after adjusting for the major risk factors of age, serum cholesterol, diastolic blood pressure and cigarette smoking status. Third, the other 4 Q-code classes (no Minnesota Q code ever, no minor serial Q-wave pattern change, no major serial Q-wave pattern change and minor serial Q-wave pattern change) were not significantly different from each other in prognostic associations, nor did they show any significant independent association with coronary heart disease mortality.

Based on the findings described in the previous paragraph and considering that the direct ECG comparison procedure is objective and standardized for research applications, we recommend this procedure in studies in which etiologic linkage to risk factors or other findings is important, because it will substantially reduce false positive events and lessen the likelihood of attenuated associations.

The primary objective of this study was to document the impact of using an objective direct ECG waveform comparison procedure in identifying new interim MI in population studies or clinical trials. Our results indicate that this procedure, in current use in several studies, results in better agreement between ECG diagnosis of MI and clinically determined MI status, and is related to future coronary heart disease mortality. Although this study focused on comparing Q codes for serial Q wave pattern change, this procedure also includes proposed rules for direct comparison of ECCs prompted by ST-depression change, T-wave inversion change, new left ventricular hypertrophy, new ECG left bundle branch block and new ST elevation. Further studies will investigate how these ECG findings are affected using direct ECG waveform comparison.

Acknowledgments We acknowledge the excellent assistance of Gary Aldrich for secretarial assistance and Peter Hannan for expert statistical consultation.

REFERENCES

APPENDIX A
Minnesota Code Q and QS Patterns

(Do not code in the presence of WPW code 6 4 1.) To qualify as a Q wave, the deflection should be at least 0.1 mV (1 mm in amplitude).

Anterolateral site (leads I, aVL, V6)
1-1 Q/R amplitude ratio ≥1/3, plus Q duration ≥0.03 s in lead I or V6.
1-1-2 Q duration ≥0.04 s in lead I or V6.
1-1-3 Q duration ≥0.04 s, plus R amplitude ≥2 mm in lead aVL.
1-2-1 Q/R amplitude ratio ≥1/3, plus Q duration ≥0.02 s and <0.03 s in lead I or V6.
1-2-2 Q duration ≥0.03 s and <0.04 s in lead I or V6.
1-2-3 QS pattern in lead I. Do not code in the presence of 7-1-1.
1-2-8 Initial R amplitude decreasing to ≤2 mm in every beat (and absence of codes 3-2, 7-1-1, 7-2-1 or 7-3-1 between V6 and V7). (All beats in lead V6 must have an initial R ≥2.2 mm.)
1-3-1 Q/R amplitude ratio ≥1/3 and <1/3, plus Q duration >0.02s and <0.03s in lead I or V6.
1-3-3 Q duration ≥0.03s and <0.04s, plus R amplitude ≥3 mm in lead aVL.

460 THE AMERICAN JOURNAL OF CARDIOLOGY VOLUME 64
**APPENDIX B**

**Rules for Direct Electrocardiographic Waveform Comparison of New Minnesota Q Codes**

**Event Electrocardiogram Minnesota Q-Code Comparison Rule for Determining Significant Electrocardiographic Waveform Change**

1-1-1 Requires >50% increase in event Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-1-2 Requires >50% increase in event ECG Q/R ratio and >1.5 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-1-3 Requires >75% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-1-4 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-1-5 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-1-6 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.

1-1-7 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.

1-2-1 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-2-2 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-2-3 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.

1-2-4 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-2-5 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-2-6 Requires >75% increase in event ECG Q/R ratio plus the appearance of a codable and new Q wave in aVF or >1 mm initial R-wave amplitude decrease in event ECG plus the appearance of a new codable Q wave in aVF compared with corresponding lead(s) of baseline ECG.

1-2-7 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.

1-2-8 Requires >1 mm decrease in event ECG initial R-wave amplitude in the "lead to the left" compared with corresponding lead(s) of baseline ECG.

1-3-1 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-3-2 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.

1-3-3 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-3-4 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-3-5 Requires >50% increase in event ECG Q/R ratio or >1 mm initial R-wave amplitude decrease in event ECG compared with corresponding lead(s) of baseline ECG.

1-3-6 Requires >1 mm decrease in event ECG initial R-wave amplitude compared with corresponding lead(s) of baseline ECG.