The Electrocardiogram in Epidemiologic Investigations

A New Classification System

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SUMMARY A new coding system for ECG abnormalities was developed, based on Frank's orthogonal ECG leads. In contrast to other systems, such as the Minnesota Code (MC), the new system was based on data collected prospectively in a cooperative study of 5031 records. The records were classified solely on the basis of non-ECG information. A record sample from normal women was also available. The large data base allowed stratification of ECG criteria according to sex and race.

ECG criteria were determined at two levels of sensitivity and specificity. Specificity was 80–100% at the first level and 90–90% at the second.

The new system has fewer criteria than other codes, which leads to reduction of coding errors and coding time. For common problems in differential diagnosis, optional criteria were included. A computer program for automated coding was also developed.

THE ECG is a standard tool in epidemiologic studies of cardiovascular disease. To report ECG findings in uniform, clearly defined terms, Blackburn et al. introduced the Minnesota Code (MC), which has been widely used.

The original MC was based on the more reliable and generally accepted diagnostic criteria known at that time (1960). Little was known then about actual distributions of ECG findings in large populations, and the criteria proved to have a large observer variation. Another serious shortcoming was the lack of information on the effect of constitutional variables on the ECG, which was later studied extensively. Thus, a code based on actual ECG data from large normal and abnormal populations that takes into account differences in ECG findings according to sex and race would be desirable. In the present study, we attempted to take these factors into consideration.

Corrected orthogonal leads have contributed substantially to a better understanding of ECG lead performance and are being used in most of the larger epidemiologic studies. One major advantage of these leads is the substantial data reduction (12 leads vs three leads) without appreciable loss of clinical information. The Frank system has gained greatest popularity and was therefore selected for the new code. Electrodes must be placed as originally described, because so-called modified Frank leads may not be in agreement with the original Frank lead data.

The availability of a large documented ECG library was significant in selecting the Frank lead system for the new code. Based on standardized, ECG-independent clinical information, this library was developed through a Cooperative Study of the Veterans Administration. Eight hospitals participated.

To reduce coding time and coding errors, the new system was kept as simple and convenient as possible.

Material and Methods

The samples used to develop the code are listed in table 1. The selection criteria have been described in detail, but a brief summary will be given here.

The records from normal subjects were obtained from 1049 adult men and 450 adult women. The age and race distributions of these subjects are shown in figure 1. All patients had a complete history, physical examination and routine laboratory tests. All subjects who had diseases that frequently predispose to cardiovascular disease (diabetes mellitus, pulmonary disease, renal disease, hypertension, anemia and collagen or other types of peripheral vascular disease) were excluded.

For left ventricular hypertrophy, the training set consisted of 440 records from patients with sustained hypertension greater than 150/90 mm Hg. This group was considered to have hypertensive cardiovascular disease (HCVD) of moderate degree with cardiac enlargement but without a history of congestive heart failure. Subjects who had a mild and severe HCVD served as test groups. The mild HCVD group consisted of patients who had normal-size hearts and sustained blood pressure elevation. The severe HCVD group had, in addition, a history of congestive heart failure. An additional test group consisted of 211 records from patients with aortic valvular disease. The group with myocardial infarcts (MI) consisted of 1100 records from patients with a documented history of severe chest pain and typical enzyme elevations. The ECG was not used for case selection, so 44% did not have typical Q-wave abnormalities. This
TABLE 1. Number of Cases

<table>
<thead>
<tr>
<th></th>
<th>White</th>
<th>Black</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal males</td>
<td>690</td>
<td>359</td>
<td>1049</td>
</tr>
<tr>
<td>Normal females</td>
<td>309</td>
<td>141</td>
<td>450</td>
</tr>
<tr>
<td>MI</td>
<td>1043</td>
<td>57</td>
<td>1100</td>
</tr>
<tr>
<td>Left ventricular hypertrophy</td>
<td>822</td>
<td>405</td>
<td>1227</td>
</tr>
<tr>
<td>Mild HCVD</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate HCVD</td>
<td>440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe HCVD</td>
<td>326</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AI</td>
<td>138</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right ventricular hypertrophy</td>
<td>359</td>
<td>18</td>
<td>377</td>
</tr>
<tr>
<td>MS</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate COPD</td>
<td>178</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe COPD</td>
<td>126</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left ventricular conduction defect</td>
<td>487</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With MI</td>
<td>234</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without MI</td>
<td>253</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right ventricular conduction defect</td>
<td>341</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With MI</td>
<td>161</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without MI</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5031</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Breakdown of records used for developing and testing of the code. Except for the 450 normal females, all other records were obtained from males.

Abbreviations: HVCD = hypertensive cardiovascular disease; AS = aortic stenosis; AI = aortic insufficiency; MS = mitral stenosis; COPD = chronic obstructive pulmonary disease; MI = myocardial infarction.

was partially because the majority had old MIs, in which case Q waves might have disappeared. In some other cases, acute MIs were considered to be subendocardial without typical Q wave changes. Because the 481 records without Q-wave abnormalities could not be classified according to infarct location, discriminant-function analysis, as described by Eddleman and Pipberger, was applied to assign MI as anterior, posterodiaphragmatic or lateral. This resulted in 395, 603 and 102 cases, respectively, for the three MI groups.

The group with chronic obstructive pulmonary disease (COPD) consisted of 304 cases. They were considered to have moderate or severe COPD based on their timed vital capacity (TVC). The group with a more severe degree had a TVC of 25–50% and the moderate group had a TVC of 51–75%.

Because right ventricular hypertrophy (RVH) is the most salient feature in the ECG of COPD, particularly in advanced stages, simple ECG criteria that can be measured by hand cannot differentiate efficiently between RVH and COPD. For the purposes of the code, the two groups were combined and labeled RVH-COPD. The RVH group consisted of 73 patients with pure mitral stenosis documented by right-heart catheterization. The mean pulmonary artery pressure was greater than 30 mm Hg.

The sample with ventricular conduction defects (VCD) was selected on the basis of QRS duration. This was the only ECG item used for case selection. Records in which the QRS interval exceeded the normal limit of 0.12 second in males and 0.11 second in females were considered to have VCDs. Although actual normal limits were 10 msec shorter, these limits were extended because some patients with ventricular hypertrophy show a certain degree of QRS prolongation without representing true conduction defects of the bundle branch block type. The longest QRS complex in any one of the three leads is used for measurements. The VCD sample was subdivided according to the direction of the terminal QRS forces. Those with an anterior and rightward direction were considered to have a right ventricular conduction defect (RVCD) and those with mainly leftward and posterior direction, a left ventricular conduction defect (LVCD).

ECG measurements for the classification code were selected on the basis of their efficiency in discrimination between normal and abnormal and for their practicality. The performance of the ECG criteria was measured by their sensitivity and specificity.

Only ECG items that can be easily obtained by hand were tested. This limits the selection of measurements to time intervals, wave amplitudes and some derived measurements such as amplitude ratios, sums of various amplitudes and similar simple combinations. All items were tested by computer, following the measurement rules and recommendations of the American Heart Association. (fig. 2). Sometimes, more complex variables were more efficient in terms of performance, but for the sake of practicality, they were not included.

Sensitivity for several measurements was always determined cumulatively. For LVH, for instance, a

![Figure 1. The age distribution of 1049 normal males and 450 females as a percentage of the total of each sex.](http://circ.ahajournals.org/)}
limit of 1.9 mV for $R_x$ amplitude was used as the first criterion for white males. In 25% of moderately hypertensive white males, this limit was exceeded, indicating the sensitivity for this single measurement (table 2). At the same time, 4% of the normal control of white males exceeded this limit, representing the false-positive rate (FP). The reciprocal of the FP rate indicates the specificity, which was therefore 96%. The second criterion selected for LVH was the sum of the amplitudes of $R_x$ and $R_z$ with a limit of normal of 2.9 mV. The percentage of LVH cases recognized in addition to the first criterion was 16%, resulting in a cumulative sensitivity for the two criteria of 41%. The FP rate increased at the same time to 6%, leading to a combined specificity of 94%. A third criterion, the duration of the R wave in lead Z, increased the percentage of cases recognized as LVH from 41% to 55%, with a concomitant increase of the FP rate from 6% to 7%, resulting in a cumulative specificity of 93%.

Diagnostic criteria with specified levels of sensitivity and specificity were determined separately for white males, white females, black males and black females.

Not enough cases were available for all abnormal categories (none for females and some small samples for black males), so we assumed that at identical levels of specificity, comparable levels of sensitivity can be expected. Because there were enough records from normal subjects, specificity rates could be shown to be stable. The same stability was found for the large series of abnormal white males.

Atrioventricular (AV) conduction abnormalities and atrial and ventricular arrhythmias are coded in the same fashion for both sexes and races. This part of the code is similar to the MC.

QRS-axis deviations are coded on the basis of R/S ratios in leads X and Y. Normal ranges of QRS-axis direction in orthogonal leads differ from those of the standard 12-lead ECG. For both sexes and races, the normal QRS axes are located in the lower left quadrant (0° to +90°).

Criteria for the most common problems in differential diagnosis are also included. Because these criteria were developed from a population of white males and black males, further testing in females is recommended before they are applied routinely. The first differentiation is between LVH and AMI (code 21), which applies to all cases with reduction or loss of anterior QRS forces (abnormally low Q/R_x ratio or loss of Q_s).

The second differentiation (code 22) applies to patients with an abnormal QRS shift in anterior direction, which may be due to high posterior MI or RVH. Left septal fascicular block might also have to be considered in this context.

Differentiation between COPD and MI is a frequent problem because COPD can mimic MI with typical Q-wave or Q/R-ratio abnormalities. Criteria were developed for all infarct locations.

One of the most difficult problems is the recognition of MI in the presence of VCDs. Criteria are given both for MI with LVCD and MI with RVCD. They should be applied routinely in all cases with VCD in age groups prone to coronary artery disease.

### Results

The ECG abnormalities included in the code are listed at the beginning of the appendix. A complete listing of the code follows. The normal ECG is characterized by limits of normal for QRS duration and by exclusion of all other codable abnormalities.

Code numbers 2-1 to 2-4 indicate criteria for the
diagnosis of MI with different MI locations. In this and all subsequent listings, criteria A and B represent a relatively higher and lower specificity, respectively. Columns 1 to 4 indicate normal limits for race and sex. There are substantial differences between the two races and somewhat smaller differences between the sexes. When all four criteria were applied to normal subjects older than age 40 years and stratified according to sex and race, cumulative FP rates varied for criteria A from 6–8% and for criteria B from 12–18%. This corresponds to a specificity of 92–94% for criteria A and of 82–88% for criteria B. Sensitivity rates for the various diagnostic criteria will be given in a separate section below.

For the diagnosis of LVH, three criteria were most efficient. The difference between sex and race groups was even more striking, with highest amplitude limits for black males and lowest limits for white females. The second criterion, \( R_x + R_y \), corresponds closely to the Sokolow-Lyon criterion for LVH, in which leftward and posteriorly directed forces are summed. The cumulative FP rate for LVH varies from 6–8% for criteria A and from 14–18% for criteria B, depending on sex and race. These rates were determined in normal adults of all ages.

The criteria for RVH and COPD were combined. The first four measurements are indicators for both RVH and COPD and the fifth one is more common in COPD. FP rates for the combined RVH-COPD code were 5–8% for criteria A and 11–16% for criteria B.

Codes 5 to 7, dealing with QRS-axis deviations and ST-T abnormalities, are self-explanatory. ST-T changes, similar to other measurements, are classified according to two levels of sensitivity and specificity. Because of the limits of visual resolution and based on tests of reproducibility of hand measurement, accuracy does not appear to exceed 0.5 mm. Therefore, the ST criteria have increments of 0.5 mm.

Code 8 covers VCDs and left ventricular fascicular blocks. For the former, all records with a QRS prolongation are included. Because the normal QRS complex is shorter in women than in men, different limits were used for the two sexes.

The criteria for left ventricular fascicular blocks differ somewhat from those used in the conventional 12-lead ECG because normal ranges for QRS direction are not the same. Left septal fascicular block is also included as an optional code because it is believed to represent a distinct diagnostic entity.

Codes 10 to 12 deal with AV conduction abnormalities, atrial and ventricular rhythms. The various categories were kept relatively simple and are self-explanatory.

Codes 21 to 24 deal with the most common problems in differential diagnosis from the ECG. This part of the code is optional. In most epidemiologic applications, there is probably no need for a detailed differential diagnosis, but in routine clinical applications, this part of the code is useful. It was developed on the basis of many record samples obtained from adult males, both white and black. Limits of the various criteria may need modification for application to females.

Criteria Performance

Because we had many record samples from patients with documentation of the medical diagnosis by non-ECG means, we could test the sensitivity of the criteria for a variety of abnormalities with different degrees of severity. Results of these tests are given in tables 3–5. These data are shown to give some insight into the interdependence of sensitivity and specificity.

The criteria for MI in table 3 cover different MI locations, which occur with different frequencies. The first one, \( Q/R_x \), for instance, will be found abnormal mostly with lateral MIs. Because this MI location is less common than anterior or diaphragmatic locations, the sensitivity of this criterion is relatively low (7–9% in our series). It is needed, however, to include

<table>
<thead>
<tr>
<th>Table 3. Myocardial Infarction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of cases</strong></td>
</tr>
<tr>
<td>WM 1043</td>
</tr>
<tr>
<td>BM 57</td>
</tr>
</tbody>
</table>

Sensitivity and specificity for criteria A and B are shown for 1100 patients with myocardial infarction. Sensitivity for black patients is lower than that for whites, but the number of cases is too low to be truly representative.

Abbreviations: WM = white males; WF = white females; BM = black males; BF = black females.

<table>
<thead>
<tr>
<th>Table 4. Left Ventricular Hypertrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
</tr>
<tr>
<td><strong>No. of cases</strong></td>
</tr>
<tr>
<td>Hypertensive cardiovascular disease</td>
</tr>
<tr>
<td>Group 1 (mild)</td>
</tr>
<tr>
<td>Group 2 (moderate)</td>
</tr>
<tr>
<td>Group 3 (severe)</td>
</tr>
<tr>
<td>Aortic valve disease</td>
</tr>
<tr>
<td>Aortic stenosis</td>
</tr>
<tr>
<td>Aortic regurgitation</td>
</tr>
<tr>
<td>BM 43</td>
</tr>
</tbody>
</table>

Sensitivity of various criteria for left ventricular hypertrophy is shown for patients with hypertensive cardiovascular disease and aortic valvular disease. Specificity for criteria A was 92–94% and for criteria B, 82–86%.
lateral MIs in the code. A similar situation prevails for the fourth criterion, the upper limit of the Q/R ratio, which applies to so-called high posterior MIs, which are also not very common. When all four criteria are tested on new patients, the total cumulative sensitivity depends largely on the frequency distribution of infarct locations. In the training set of 1100 records from patients with MI, there were 9% with lateral MI, 55% with posterodiaphragmatic MI and 36% with anterior and anteroseptal MI. The total sensitivity for infarcts of all locations in white patients was 71% for criteria A and 75% for criteria B. The specificity was 93% and 87%, respectively. The sensitivity for MI in black patients was lower with 60% and 63% for criteria A and B. The specificity was 92% and 88%, respectively. Whether there is a true difference in sensitivity between white and black patients needs further testing on larger series of blacks. In the present series, there were 95% white and only 5% black MI patients.

Results on sensitivity for LVH are shown in table 4. The sensitivity for the three groups with HCVD was 23%, 55% and 67%, respectively, in white patients with criteria A, and 32%, 52% and 67% in blacks. Using criteria B, the corresponding figures were 43%, 70% and 77% in whites and 38%, 59% and 74% in blacks. LVH criteria were also tested on a record sample with aortic valvular disease (table 4). All of these patients had left-heart catheterization. Records from white patients with aortic stenosis showed a sensitivity of 66% with criteria A and 74% with criteria B. Corresponding figures for white patients with aortic regurgitation were 88% and 92%. Blacks with the same lesion showed a sensitivity of 74% and 84%, respectively.

Sensitivity for RVH was tested first on a sample of white patients with pure mitral stenosis described earlier (table 5). Sensitivity for criteria A was 53% and for criteria B, 65%.

A record sample from patients with COPD was divided into a moderate and a severe group, which were also described earlier. The sensitivity for white patients in the moderate category was 52% with criteria A and 68% with criteria B. The corresponding figures in the severe group were 58% and 79%, respectively. The number of records available from black patients was too small to be tested.

**Comparisons of the Minnesota Code and the Washington D.C. Code**

A comparison between the new code and the MC was performed on two large record samples from patients with MI and LVH (tables 6 and 7). Because there is no stratification in the MC according to race or sex, records from white and black males had to be pooled in this comparison. At a specificity of 94% with MC 1-1, the sensitivity for the diagnosis of MI was 49% (table 6). At a similar specificity level of 93%, the Washington D.C. code (WC) gave a sensitivity of 70% (criteria A).

When code 1-2 of the MC is used for MI diagnosis, the specificity decreases to 87%. Criteria B of the new code show the same specificity. With these criteria, a sensitivity of 70% was obtained for the MC, with 75% for the WC. Specificity rates for the MC were reported by Kurihara et al.\textsuperscript{a} based on 615 autopsy cases without MI.

In the comparison of the performance of the MC and WC codes in patients with LVH, records from mild, moderate and severe groups of hypertensive patients were used. The sensitivity of the WC exceeded that of the MC by almost 20% (table 7). The specificity was approximately equal (94% and 93% for MC and WC, respectively). Only voltage criteria were used in this comparison.

**Discussion**

The most important feature of the new code is that it is largely based on actual data distributions of normal and abnormal electrocardiograms and not on generally accepted criteria, which have rarely been tested on sufficiently large and controlled record samples. As in the MC, more than one set of criteria are provided for each diagnostic entity. This feature enhances the code's value, particularly in epidemiologic investigations where different applications may require different levels of specificity.

Major considerations in the development of the new code have been efficiency and ease of application. Compared with the MC, the number of codable items could be considerably reduced, which thereby reduces

**Table 5. Right Ventricular Hypertrophy**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>No. of cases</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral stenosis</td>
<td>WM</td>
<td>93</td>
<td>53%</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>Group 1 (moderate) (TVC 51–75%)</td>
<td>WM</td>
<td>126</td>
</tr>
<tr>
<td>Group 2 (severe) (TVC 25–50%)</td>
<td>WM</td>
<td>160</td>
<td>58%</td>
</tr>
</tbody>
</table>

Sensitivity for various criteria for right ventricular hypertrophy is shown for patients with mitral stenosis and chronic obstructive pulmonary disease. Specificity for criteria A was 92–96% and 84–89% for criteria B.

Abbreviations: TVC = timed vital capacity; WM = white males.

**Table 6. Comparison of Minnesota Code with Washington D.C. Code: Myocardial Infarction**

<table>
<thead>
<tr>
<th>No. of cases</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minnesota Code</td>
<td>1002</td>
<td>1–1</td>
</tr>
<tr>
<td>Washington D.C. Code</td>
<td>1100</td>
<td>A</td>
</tr>
</tbody>
</table>

Comparison of the diagnostic performance of the Minnesota and Washington Codes in records from patients with myocardial infarction. The number of cases tested with the Minnesota Code is slightly lower than that for the new code because new cases were added more recently. At higher specificity levels, the performance of the Washington Code exceeds that of the Minnesota code by a substantial margin.
TABLE 7. Comparison of Minnesota Code with Washington D.C. Code: Hypertensive Cardiovascular Disease

<table>
<thead>
<tr>
<th>MINNESOTA CODE 3-1</th>
<th>WASHINGTON D.C. CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (mild)</td>
<td>A</td>
</tr>
<tr>
<td>Group 2 (moderate)</td>
<td>B</td>
</tr>
<tr>
<td>Group 3 (severe)</td>
<td>C</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>No. of cases</td>
<td>Sensitivity</td>
</tr>
<tr>
<td>394</td>
<td>21%</td>
</tr>
<tr>
<td>242</td>
<td>34%</td>
</tr>
<tr>
<td>303</td>
<td>43%</td>
</tr>
<tr>
<td>939</td>
<td>32%</td>
</tr>
<tr>
<td>250</td>
<td>26%</td>
</tr>
<tr>
<td>440</td>
<td>54%</td>
</tr>
<tr>
<td>326</td>
<td>67%</td>
</tr>
<tr>
<td>1016</td>
<td>51%</td>
</tr>
</tbody>
</table>

Comparison of the diagnostic performance of the Minnesota and Washington Codes in records from hypertensive patients. The number of records tested with the Minnesota Code is somewhat lower than that for the Washington Code because new cases were added more recently. Note that the Washington Code is considerably more sensitive for left ventricular hypertrophy than the Minnesota Code.

Greater differences were encountered in the tests on records from hypertensive patients (table 7). At a constant specificity level, the average sensitivity of the new code exceeded that of the MC by approximately 20%, with the largest differences in patients with severe hypertension. A large part of this improvement seems to be due to the stratification of the LVH criteria according to race. Differences in voltage criteria between races and sexes can amount to more than 1 mV (appendix). Further testing of the new code on newly developed test samples is needed, particularly for abnormal female records, which were not available for the code development.

After stratification of criteria according to sex and race, the influence of age became almost negligible. This was surprising, because age had been found to correlate more strongly with ECGs than any other variable. The constitutional variables, such as age, sex and race, may not exert an independent influence on the ECG, and some of these variables may be interrelated.

Like the MC, the new code is primarily intended for epidemiologic applications in which ECG findings must be documented in uniform, clearly defined terms, usually for large populations. Because the code is rather comprehensive, routine clinical application may also be considered. For such applications, one should use only criteria A, which have a higher degree of specificity. The specificity levels indicated in this report apply only to differentiation between normal and one abnormality at a time. When more abnormalities are considered simultaneously, specificity almost always decreases.

A computer program has been developed to provide all necessary ECG measurements for complete record coding. The output lists all ECG variables that exceed the limits indicated in the appendix with appropriate code numbers. The program is a modification of the computer program developed by the Veterans Administration which has been in routine use for almost 10 years.

Acknowledgment

The authors gratefully acknowledge the help of Vickie Briggs and Shirley Abernathy in preparing this manuscript.

References

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24. Sokolow M, Lyon TP: The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J 37: 161, 1949

Appendix

ECG Abnormalities Included in the Code
1. Normal electrocardiogram
2. Myocardial infarction (MI)
3. Left ventricular hypertrophy (LVH)
4. Right ventricular hypertrophy (RVH) and chronic obstructive pulmonary disease (COPD)
5. QRS-axis deviation
6. ST junction (point J) and ST-segment shifts
7. T-wave and QT-interval abnormalities
8. Ventricular conduction defects (LAVCD and RVCD), including left ventricular fascicular blocks
9. P-wave abnormalities
10. AV conduction abnormalities
11. Atrial rhythm
12. Ventricular rhythm

Differential Diagnosis
21. Anterior MI vs LVH
22. Posterior MI vs RVH
23. COPD vs MI
24. Ventricular conduction defect (VCD) with MI vs VCD without MI

Normal ECG

<table>
<thead>
<tr>
<th>WM</th>
<th>WF</th>
<th>BM</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-1)*</td>
<td>(-2)</td>
<td>(-3)</td>
<td>(-4)</td>
</tr>
<tr>
<td>2-1 Q/Rx amp ratio A†</td>
<td>&gt; 0.21</td>
<td>&gt; 0.20</td>
<td>&gt; 0.15</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 0.19</td>
<td>&gt; 0.15</td>
<td>&gt; 0.12</td>
</tr>
<tr>
<td>2-2 Q/Ry amp ratio A</td>
<td>&gt; 0.22</td>
<td>&gt; 0.20</td>
<td>&gt; 0.17</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 0.20</td>
<td>&gt; 0.17</td>
<td>&gt; 0.15</td>
</tr>
<tr>
<td>2-3 Q/Rz amp ratio A</td>
<td>&lt; 0.10</td>
<td>&lt; 0.05</td>
<td>&lt; 0.09</td>
</tr>
<tr>
<td>B</td>
<td>&lt; 0.12</td>
<td>&lt; 0.10</td>
<td>&lt; 0.10</td>
</tr>
<tr>
<td>2-4 Q/Rz amp ratio A</td>
<td>&gt; 1.5</td>
<td>&gt; 2.0</td>
<td>&gt; 1.4</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 1.2</td>
<td>&gt; 1.4</td>
<td>&gt; 1.8</td>
</tr>
</tbody>
</table>

In this and the following tables: *Code numbers specify race and sex. For example, 2-1-1 indicates the Q/Rx amplitude ratio limits for white males.
†Limits shown under A indicate specificity ≥ 90% associated with relatively low sensitivity. Limits shown under B indicate specificity of 80-90% associated with higher sensitivity.

Abbreviations: WM = white males; WF = white females; BM = black males; BF = black females.

Left Ventricular Hypertrophy (LVH)*

(Do not code in presence of ventricular conduction defects 8-1, 8-2 or 8-3.)

<table>
<thead>
<tr>
<th>WM</th>
<th>WF</th>
<th>BM</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-1)</td>
<td>(-2)</td>
<td>(-3)</td>
<td>(-4)</td>
</tr>
<tr>
<td>3-1 Rx amplitude A</td>
<td>&gt; 1.9</td>
<td>&gt; 1.4</td>
<td>&gt; 2.0</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 1.7</td>
<td>&gt; 1.3</td>
<td>&gt; 1.9</td>
</tr>
<tr>
<td>3-2 Rx + Rz amplitude A</td>
<td>&gt; 2.9</td>
<td>&gt; 2.3</td>
<td>&gt; 3.4</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 2.7</td>
<td>&gt; 2.1</td>
<td>&gt; 3.1</td>
</tr>
<tr>
<td>3-3 Rx duration A</td>
<td>&gt; 0.07</td>
<td>&gt; 0.07</td>
<td>&gt; 0.06</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 0.06</td>
<td>&gt; 0.07</td>
<td>&gt; 0.06</td>
</tr>
</tbody>
</table>

*T-wave abnormalities and ST depression in lead x (codes 7-1-B and 6-1-B) are frequently associated with LVH. If codes 3-1, 3-2 and 3-3 are negative, however, ST and T changes alone are not sufficient for a definite LVH diagnosis, because their specificity is relatively low.
### Table 1: T-wave and QT-Interval Abnormalities

<table>
<thead>
<tr>
<th>T-wave Abnormalities</th>
<th>QT Interval Abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged QT interval</td>
<td>QT interval prolongation</td>
</tr>
<tr>
<td>Abnormal ST-segment</td>
<td>QT interval prolongation</td>
</tr>
<tr>
<td>Abnormal T-wave</td>
<td>QT interval prolongation</td>
</tr>
</tbody>
</table>

**Notes:**
- T-wave abnormalities are classified as follows:
  - **High T waves**: T waves are high and peaked, resembling positive T waves.
  - **Low T waves**: T waves are low and flat, resembling negative T waves.
- QT interval abnormalities are classified as follows:
  - **Prolonged QT interval**: QT interval is greater than 440 ms in males and 460 ms in females.
  - **Short QT interval**: QT interval is less than 350 ms in males and 330 ms in females.

### Table 2: Ventricular Conduction Defects Including Left Ventricular Fascicular Blocks

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left anterior fascicular block</td>
<td>QT interval prolonged</td>
</tr>
<tr>
<td>Right anterior fascicular block</td>
<td>QT interval prolonged</td>
</tr>
<tr>
<td>Left posterior fascicular block</td>
<td>QT interval prolonged</td>
</tr>
<tr>
<td>Right posterior fascicular block</td>
<td>QT interval prolonged</td>
</tr>
</tbody>
</table>

**Notes:**
- QT interval prolongation is defined as a QT interval greater than 440 ms in males and 460 ms in females.
- QT interval is measured from the J-point to the end of the T wave.
P-wave Abnormalities
(Do not code in presence of ectopic rhythms, 11-5 and 11-7 through 11-10.)

<table>
<thead>
<tr>
<th>Left atrial overload</th>
<th>Male, female, white and black (-1, -2, -3 and -4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-1 Sum of positive P_y amplitude and positive P_z amplitude</td>
<td>&gt; 0.15</td>
</tr>
<tr>
<td>Right atrial overload</td>
<td>WM (-1) WF (-2) BM (-3) BF (-4)</td>
</tr>
<tr>
<td>9-2 Positive P_y amplitude</td>
<td>&gt; 0.15</td>
</tr>
<tr>
<td>9-3 Negative P_z amplitude</td>
<td>&lt; -0.05</td>
</tr>
</tbody>
</table>

AV Conduction Abnormalities
Male, female, white and black (-1, -2, -3 and -4)

10-1 First-degree AV block (PR interval > 0.21 second in any lead).

10-2 Type I: progressive PR interval prolongation followed by a dropped beat (Wenckebach).

10-3 Type II: constant PR interval duration (normal or prolonged) with occasional dropped beats.

10-4 Advanced AV block (two or more regular successive P waves are not followed by QRS complex).

10-5 AV dissociation without complete block.

10-6 Complete AV block.

10-7 Preexcitation syndrome, Wolff-Parkinson-White (PR interval < 0.12 second and QRS duration ≥ 0.12 second for male or ≥ 0.11 second for female).

10-8 Short PR interval (< 0.12 second).

Atrial Rhythm
Male, female, white and black (-1, -2, -3 and -4)

11-1 Normal sinus rhythm (≥ 60 and < 100 beats/min).

11-2 Sinus arrhythmia (RR change of > 10% of RR interval of adjacent sinus beats).

11-3 Sinus tachycardia (≥ 100 beats/min).

11-4 Sinus bradycardia (< 60 beats/min).

11-5 Wandering atrial pacemaker.

11-6 Atrial premature complexes.

11-7 Paroxysmal supraventricular tachycardia.

11-8 Atrial flutter.

11-9 Atrial fibrillation.

11-10 AV junctional rhythm.

Ventricular Rhythm
Male, female, white and black (-1, -2, -3 and -4)

12-1 Ventricular premature complexes (occasional).

12-2 Ventricular premature complexes (10% or more of recorded beats).

12-3 Ventricular tachycardia.

12-4 Ventricular fibrillation.

12-5 Accelerated idioventricular rhythm.

12-6 Artificial pacemaker rhythm.

Differential Diagnosis
(Applicable Only to Males)

Anterior MI vs LVH

This differentiation needs to be made when initial anteriorly directed electromotive forces are decreased or absent, i.e., only in presence of code 2-3 A or B. If 21-1 or 21-2 is exceeded, the record is suggestive of LVH and code 2-3 should be deleted. If both measurements are below these limits, the probability of anterior MI is greater and code 2-3 remains unchanged.

21-1 R_x amplitude
≥ 1.2
21-2 R_x + R_y amplitude
≥ 2.5

High Posterior MI vs RVH/COPD

This differentiation needs to be made when there is an abnormal shift of the QRS complex in anterior direction, i.e., only in the presence of codes 2-4 A or B (high posterior MI) and 4-3 A or B (RVH/COPD).

If codes 22-1 and 22-2 are exceeded, the record is suggestive of high posterior MI and code 4-3 should be deleted. When 22-1 is below and 22-2 above the indicated limits, the probability of RVH/COPD is greater, code 4-3 remains unchanged and 2-4 should be deleted.

22-1 Q/R_y amplitude ratio
> 0.25
22-2 T_y amplitude
< 0.0

COPD vs Myocardial Infarction

This differentiation needs to be made when the record is both compatible with MI and COPD, i.e., when any of the codes 2-1 through 2-3 and 4-1 through 4-5 are positive. The differentiation is divided according to infarct location (2-1 = lateral MI; 2-2 = posterodiaphragmatic MI; 2-3 = anterior).

If any of the measurements 23-1 through 23-8 are below the indicated limits, the record is suggestive of COPD and codes 2-1 through 2-3 should be deleted. When the measurements are above the limits, the probability of infarct is greater and COPD and MI may coexist.

COPD vs lateral MI

23-1 R_x peak time
< 0.03
23-2 Q/R_x amplitude ratio
< 0.2

COPD vs posterodiaphragmatic MI

23-3 R_x peak time
< 0.03
23-4 R_x amplitude
< 0.4
23-5 Q/R_x amplitude ratio
< 0.10

COPD vs anterior MI

23-6 R_x + R_y amplitude
< 1.0
23-7 R_y duration
< 0.04
23-8 R/S_y amplitude ratio
< 1.4

Ventricular Conduction Defects (VCD) with MI vs VCD without MI

This differentiation needs to be made in all cases with VCD who are in an age group where coronary artery disease may be expected. If one of the following limits is exceeded, the diagnosis of VCD with MI can be made. Different criteria apply to LVCD and RVCD.

LVCD

24-1 Q/R_x amplitude ratio
> 0.19
24-2 Q/R_y amplitude ratio
> 0.22

RVCD

24-3 Q/R_x amplitude ratio
> 0.19
24-4 Q/R_y amplitude ratio
> 0.22
24-5 Q/R_z amplitude ratio
> 0.10
The electrocardiogram in epidemiologic investigations. A new classification system.
H V Pipberger, E Simonson, E A Lopez, Jr, M A Araoye and H A Pipberger

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