Vectorcardiographic Criteria for the Diagnosis of Inferior Myocardial Infarction

By John W. Starr, M.D., Galen S. Wagner, M.D., Victor S. Behar, M.D., Abe Walston, II, M.D., and Joseph C. Greenfield, Jr., M.D.

SUMMARY

Vectorcardiograms (VCG) from two patient groups were analyzed to develop and test quantitative criteria for the diagnosis of inferior myocardial infarction. The first group (219 patients) consisted of four subgroups and was used to develop the criteria. Patients were placed in the normal and infarct subgroups by clinical descriptors including history, course in the coronary care unit, and cardiac catheterization findings. The criteria which were found to give the fewest false positive results with acceptable sensitivity were as follows:

In the frontal plane, generally clockwise early superior QRS forces must be present, i.e., forces which are initially either a) superior (rightward or leftward) or b) inferior and completely rightward for not more than 10 msec prior to becoming superior, and which subsequently cross the X axis to the left of the 0 point (or less commonly, the entire efferent limb remaining superior to the X axis). One of the following conditions must also be present: 1) Time from the 0 point to leftward X intercept of at least 25 msec and distance from the 0 point to leftward X intercept of at least 0.30 mV; 2) A maximal frontal plane QRS vector less than 15°; 3) A maximal superior deviation of at least 0.1 mV and a ratio of maximal superior deviation to maximal inferior deviation of at least 1:5.

The performance of these proposed criteria were then tested prospectively using a second group (255 patients) which was similar to the criteria group. The proposed criteria were found to be statistically superior to both ECG Q wave criteria and to the VCG initial force criteria of Young and Williams. The incidence of false positive diagnosis in the test group was less than 3%.

Additional Indexing Words:

Ventriculography Coronary Artery Disease Electrocardiogram

Early QRS forces

In recent years, considerable effort has been directed toward the improvement of electrocardiographic (ECG) and vectorcardiographic (VCG) criteria for the identification of myocardial infarction. Utilizing the independent judgments of a group of prominent cardiologists, the cooperative study by Simonson et al. in 1966 showed that the VCG had no diagnostic advantage over the ECG. More recently, specific quantitative VCG criteria for inferior myocardial infarction were developed by Young and Williams. Similar criteria were examined by McConahay et al. who used cardiac catheterization data to define infarct and normal groups. These investigators concluded that "a quantitative analysis of the corrected orthogonal VCG is an improvement over conventional analysis of the ECG."

The present study was performed to further quantify the characteristics of the QRS complex as recorded by the Frank orthogonal VCG which best define or exclude the diagnosis of inferior myocardial infarction. Special emphasis was placed on minimizing the number of false positive diagnoses.

Methods

Patient Selection

Ideally, the patients should be classified by postmortem examination, since this is the only certain method of distinguishing between the normal and infarcted myocardium and of determining the size and location of an infarcted area. This is not practical, however, since in the usual case, several episodes of infarction have occurred prior to death, and precise identification of QRS descriptors for a specific location of infarction cannot be made. In another group of patients, death due to an arrhythmia may occur before the anatomic changes can be clearly identified. Thus, it is difficult to collect a large series of patients with discrete infarction proven by postmortem examination. Our purpose was to evaluate the quantitative descriptors of the QRS com-
plex in patients who had discrete inferior myocardial infarction and in subjects who had a normal myocardium by clinical criteria. Patients were divided into two groups. Data from the first were used to develop the criteria (criteria group) and from the second to test these criteria (test group).

The criteria group included two subgroups (A and B) in which the diagnosis of inferior myocardial infarction was most unlikely and two subgroups (C and D) in which the diagnosis of inferior myocardial infarction was established without regard to descriptors of the QRS except to exclude patients in whom coincidental pathological conditions might make accurate diagnosis difficult. The criteria for exclusion are given below, after the description of subgroup D. Subgroup A was composed of 100 healthy volunteers, collected in 1971, aged 20-29, without history of heart disease or hypertension. Subgroup B was composed of 47 patients who had undergone coronary arteriography during 1971 because of chest pain suggestive of angina and in whom both normal ventricular contraction and normal coronary arterial anatomy were proven.

Subgroup C was composed of 47 patients admitted to the coronary care unit of the Duke University Medical Center during 1971 with a history compatible with an acute myocardial infarction and with evolutionary ECG changes of repolarization in leads II, III, and aVF consisting of both ST elevation and T wave inversion. The presence or absence of Q waves did not influence the inclusion in this subgroup. All patients in subgroup C also had to have shown transient findings of 1) serum CPK-MB and 2) LDH, greater than LDH₃. CPK-MB is a myocardial specific creatine phosphokinase isoenzyme⁴ and LDH₃ (lactate dehydrogenase) greater than LDH₃ is a finding consistent with acute myocardial infarction.⁵

Subgroup D was composed of 25 patients who had coronary arteriography during 1971 because of clinical symptoms and in whom the presence of a 95 to 100% occlusion of the right coronary artery and localized asynergy of the inferior left ventricular myocardium were proven. Inclusion in this subgroup was not dependent on the presence or absence of Q waves. Patients were excluded from subgroup C or D if any one of the following was observed: a) QRS or ventriculographic evidence of anterior or lateral infarction, b) QRS duration of 120 msec or greater, c) evidence of left ventricular hypertrophy as indicated by the maximal QRS magnitude in the horizontal plane of 1.8 mV or greater in patients over 50 years of age or 2.2 mV or greater in patients less than 50 years of age,⁶ or d) evidence of right ventricular hypertrophy as indicated by the QRS criteria of Chou and Helm.⁷

The test group was also made up of two subgroups of normal subjects and two subgroups with infarctions. Subgroup A' (100 volunteers), B' (98 patients), C' (32 patients), and D' (25 patients) were composed of persons meeting the same selection criteria as subgroups A, B, C, and D. In addition, two other subgroups (E' and F') were investigated. Persons in these two subgroups were very unlikely to have myocardial infarction but because of elevated diaphragmatic ECG changes could yield false positive diagnosis of myocardial infarction. Subgroup E' consisted of 19 patients aged 20 to 29, weighing between 275 and 360 pounds with no history of heart disease. Subgroup F' was composed of 23 women, 33 to 39 weeks pregnant, who were less than 30 years of age and had no history of heart disease or hypertension.

Data Collection

In the appropriate subgroups (B, B', D and D'), right and left heart catheterization was performed using standard techniques. Cineangiographic evaluation was performed using a single plane or biplane system at a filming speed of 60 frames/second. The patients were positioned in a 15° right anterior oblique projection for the left ventriculogram while multiple views were obtained for the selective coronary arteriograms. The latter were performed using the Judkins technique.⁸ The angiographic studies were evaluated for the presence of ventricular asynergy⁹ and the severity of coronary artery disease. In each case, the left ventriculogram was analyzed before the coronary arteriograms were visualized. This analysis was done by an independent observer without knowledge of the VCG data.

Standard 12 lead ECGs were recorded in the supine position using a Hewlett-Packard automatic cardiograph (1515B). Q wave duration in leads II, III, and aVF were measured in all ECGs. The VCGs were recorded using the Frank lead system on a Hewlett-Packard model 1507A vectorcardiograph and photographs of the frontal, horizontal, and left sagittal planes were taken from the oscilloscope screen on Polaroid type 107 film. Chest electrodes (A, C, E, and I) were placed at the fourth intercostal space, as recommended for the supine position.¹⁰ A calibration of 1 mV per 2 to 4 cm deflection was used depending on the size of the total VCG loop. The initial QRS forces were enlarged with a calibration of 1 mV per 10 cm deflection and photographed with the P and T loops excluded. The VCG trace was interrupted each 2.5 msec. VCGs were recorded within two weeks after the acute infarction (subgroups C and D) and within one week of cardiac catheterizations (subgroups B, D, B', and D'). Manual measurements were made from the polaroid prints of the VCG loops.

The characteristics of early superior forces in the frontal plane were noted. These were classified using the Young and Williams definition: completely clockwise with contour A or B, almost clockwise, or figure eight.² The presence of generally clockwise early superior forces was identified when forces were initially either inferior and rightward or superior (leftward or rightward) and subsequent superior forces crossed the X axis to the left of the origin. The contour of the loop described by the early superior forces was disregarded in this definition. Figure 1 shows examples of different types of early superior forces. It should be clearly understood that if initial forces are inferior, they must be completely rightward, i.e., these forces must not cross the Y axis inferior to the 0 point.

The following parameters were measured in the frontal plane (fig. 1e): a) time (msec) from the 0 point to the point at which early superior forces cross the X axis, b) distance (mV) from the 0 point at which the early superior clockwise forces cross the X axis (XL), c) orientation of the maximal QRS vector (AM), and d) magnitude of maximal superior clockwise forces (SD) and the ratio of maximal superior to maximal inferior forces (SD-ID). The presence or absence of clockwise early superior forces crossing the Y axis superior to the 0 point was noted in the left sagittal plane.¹¹ No measurements were made in the transverse plane except maximal QRS magnitude. Therefore, no conclusions were attempted concerning true posterior myocardial infarction.

Data Evaluation

If an ECG or VCG criterion did not indicate inferior
myocardial infarction when applied to a member of the normal criteria subgroups (A and B), a true negative result was recorded. If an ECG or VCG criterion indicated inferior myocardial infarction when applied to a member of the infarct criteria subgroups (C or D), a true positive result was recorded.

Optimal criteria were identified by determining the value of each descriptor which yielded a maximum of both true negative and true positive results. True negative results were felt to be more important than true positive results. For example, figure 2A demonstrates that when the criterion of 30 msec generally clockwise early superior forces is applied to the criterion group 100% true negative results are obtained in both subgroups A and B (upper graph) with 53% incidence of true positive results in subgroup C and 44% in subgroup D (lower graph). A set of criteria for VCG diagnosis of inferior myocardial infarction was formulated using this method of analysis.

The performance of the proposed VCG criteria was compared to ECG Q wave criteria (presence of 0.03 sec Q waves in leads II, III, and aVF) and to established VCG criteria for inferior myocardial infarction. The following frontal plane criteria proposed by Young and Williams were chosen because they appeared to be the most sensitive for the diagnosis of inferior myocardial infarction.

**Group 1** (initial superior forces)

1) Early superior forces must be completely clockwise in rotation, contour B in shape (early superior forces forming an upward convexity located more leftward than the initial superior forces), 0.02 sec or more in duration, and more than 0.25 mV leftward deviation.

2) In some unusual cases of inferior and associated anterior infarction, criterion 1 applies even if early superior forces are almost completely clockwise in rotation. However, in these cases, early superior vectors must be 0.025 sec or longer.

3) Completely clockwise early superior forces, regardless of their contour, duration, or the magnitude of their leftward deviation, are diagnostic provided they are associated with a maximal QRS vector above +10° (less than +10°).

**Group 2** (early superior forces preceded by initial inferior forces)

4) Criterion 1 applies only if the preceding initial inferior forces are to the right and completely clockwise. Moreover, in these cases, subsequent early superior forces must be 0.025 sec or longer and must also fulfill the other requirements listed under criterion 1 (the

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**Figure 1**

Different types of initial forces and measurements performed on the frontal plane. Panel A shows initially completely clockwise forces forming an upward convexity located more leftward than initial forces as specified by Young and Williams' contour B. Panel B shows an example of initial inferior forces which are not completely rightward, and therefore, are not acceptable as generally clockwise early superior forces. Panels C, D, and E show various types of early forces acceptable as generally clockwise early superior forces. These are shown to emphasize that no specific contour is necessary as long as the early superior forces cross the X axis to the left of the 0 point and that initial inferior forces, if present, must be completely rightward as in panel E. Panel E also defines measurements performed on the frontal plane QRS loop.

**Figure 2**

Determination of the value for each descriptor which yields a maximum of true negatives and true positive results. Symbols: open squares = subgroup A; filled circles = subgroup B; open circles = subgroup C; filled triangles = subgroup D. The abscissa shows the value of the descriptor used as a criterion for inferior myocardial infarction to obtain the incidence of correct results shown on the ordinate, i.e., true negative results for subgroups A and B (upper graph) and true positives for subgroups C and D (lower graph). The solid vertical line in each graph indicates the value for that descriptor found to give the best results as explained in the methods. Figure 2A shows the effect of varying the time from the 0 point to the point at which generally clockwise early superior forces cross the X axis. Figure 2B shows the effect of varying distance from 0 at which early superior forces cross the X axis to the left in the presence of a 25 msec time requirement as derived in figure 2A and as explained in the text.
analysis of this group suggests that if the maximum QRS vector lies above +10° [less than +10°] the early superior forces may be less than 0.025 sec in duration, or less than 0.25 mV in leftward deviation or both.

5) In some unusual cases of inferior and associated anterior infarction, criterion 4 may be modified as follows: (a) Initial inferior forces may be to the left and counterclockwise or superimposed, or both. (b) The subsequent early superior forces may be almost completely clockwise.

Using the test group, the equivalence of the proposed criteria and the Young and Williams criteria and the equivalence of the proposed criteria and ECG Q wave criteria were evaluated using McNamar’s test for equality of correlated proportions.13 When any two sets of criteria are evaluated, this test can be used to compare the number of occasions when each is exclusively in error. This test ignores those occasions when both sets of criteria are correct and when both are in error. To estimate these classification errors, "two by two" frequency tables were constructed for both the normal test subgroups A' and B' and the infarct test subgroups C' and D'. The prerequisite for equivalence of two sets of criteria would be equal proportions of exclusive errors by both sets of criteria.

Results

Criteria Group

The analysis of the frontal plane VCG measurements is shown in figures 2-4. Figure 2A shows the effect of varying the time from the 0 point at which generally clockwise early superior forces cross the X axis in the frontal plane. When 20 msec is used, as in the Young and Williams criteria, 87% of subgroup A and 76% of subgroup B are truly negative while 87% of subgroup C and 92% of subgroup D are truly positive. When 25 msec is used, however, true negative results in both subgroups A and B improve to 98% while true positive results fall to 79% in subgroup C and 68% in subgroup D.

An increase in true negative results could be achieved by increasing the time requirement to 30 msec but only at the expense of a significant decrease in true positive results. However, when the more liberal time requirement (25 msec) is combined with a required distance (0.30 mV) between the origin and the leftward X intercept (fig. 2B), additional true negatives (100%) are identified without sacrificing significant numbers of true positives.

Figure 3 shows the results of using different locations of the maximal QRS vector in the frontal plane in the presence of generally clockwise early superior forces. By using less than 10° (Young and Williams), there is a 100% incidence of true negatives in subgroups A and B, while true positives in subgroup C are only 66% and 44% in subgroup D. Changing to less than 15° results in no sacrifice of true negative results (still 100% in subgroups A and B) while increasing true positives to 70% in subgroup C and 56% in subgroup D. Since using less than 20°, however, would cause a decrease in true negatives determined in subgroup B, 15° appears to be the optimal criteria.

Figure 4 shows the differing results obtained in the presence of generally clockwise early superior forces in the frontal plane and maximal early superior forces greater than or equal to 0.1 mV by varying the ratio of maximal superior to maximal inferior forces. Use of a 1:5 ratio provides 99% true negative results in subgroup A and 100% in subgroup B with 83% true positives in subgroup C and 68% in subgroup D.

There are only three patients in subgroups C and D in whom initial rightward inferior forces precede generally clockwise early superior forces. The duration of these initial inferior forces is no more than 10 msec. In subgroups A and B there were no patients with these findings who also meet criteria for inferior myocardial infarction as detailed below.

The criterion of clockwise early superior forces

![Figure 3](http://circ.ahajournals.org/Download/1974/41/1064/Figure3.jpg)

**Figure 3**

Effect of varying orientation of maximal frontal plane vector in the presence of generally clockwise early superior forces. Symbols and explanation of method same as in figure 2.

![Figure 4](http://circ.ahajournals.org/Download/1974/41/1064/Figure4.jpg)

**Figure 4**

Effect of varying the ratio of maximal superior to maximal inferior deviation in the presence of both generally clockwise early superior forces and a maximal superior deviation of at least 0.1 mV. Symbols and methods explained in figure 2.
crossing the Y axis superior to the 0 point in the left sagittal plane\(^1\) is never met in subgroups A and B (100% true negative) but results in only 38% and 36% true positives in subgroups C and D, respectively. Furthermore, all the VCGs which meet this criterion meet at least one of the other proposed criteria so that no additional information is gained by using sagittal plane measurements.

The three criteria which best discriminate between normal subjects and patients with inferior myocardial infarction were identified and are shown in table 1. It should be emphasized that any one of these criteria is sufficient for the VCG diagnosis of inferior myocardial infarction.

Test Group

A comparison of the Young and Williams and the proposed criteria applied to the test group is shown in table 2. This can be broken down further as shown in table 3. In 3A, the normal subgroups A' and B' are analyzed in a two-by-two frequency table which shows how each individual VCG was classified by the proposed and by the Young and Williams criteria. Obviously, there are only four possibilities: 1) both can be positive (cell a); 2) both negative (cell d); 3) proposed positive, with Young and Williams negative (cell b), or 4) proposed negative, with Young and Williams positive (cell c). If the data are analyzed in this manner, then only cells b and c (exclusive errors) are important in determining the difference in performance of the two methods, and statistical significance of this difference can be determined by the McNemar test.\(^12\) As shown in table 3A, the results from the two methods are significantly different \((P < 0.005)\) in defining the normal subgroups. In addition, all eight of the exclusive errors are Young and Williams errors (cell c) while all of the errors made by the proposed criteria are also found when the Young and Williams criteria are used (cell a). Therefore the proposed criteria are more specific than the Young and Williams criteria.

In table 3B, the infarct subgroups C' and D' are analyzed by the same method. In this case, however, there is no significant difference between the diagnoses determined by each method and thus no statistical difference in sensitivity between the methods.

Subgroups E' and F' were not analyzed by this method since they constitute special cases which are not applicable to the usual patient suspected of acute infarction. Nevertheless, as illustrated in table 2, the proposed criteria are more specific than the Young and Williams criteria when applied to these two subgroups.

A comparison of the proposed criteria and ECG Q wave measurements is shown in table 4. The criterion of a 0.03 sec Q wave in lead aVF does not necessarily

### Table 1

**Proposed VCG Criteria for the Diagnosis of Inferior Myocardial Infarction**

In the frontal plane, generally clockwise early superior forces must be present. These are defined as forces which are initially either a) superior (rightward or leftward) or b) inferior and completely rightward for not more than 10 msec prior to becoming superior and which subsequently cross the X axis to the left of the 0 point (or less commonly the entire efferent limb remaining superior to the X axis.) At least one of the following must also be present:

1. Time from the 0 point to leftward X intercept of at least 25 msec and distance from 0 point to leftward X intercept of at least 0.30 mV.
2. A maximal frontal plane QRS vector above 15° (less than 15°).
3. A maximal superior deviation of at least 0.1 mV and a ratio of maximal superior deviation to maximal inferior deviation of at least 1.5.

### Table 2

**Comparison of VCG Criteria**

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>n</th>
<th>Young and Williams(^\circ) criteria</th>
<th>Proposed criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>A'</td>
<td>100</td>
<td>95 (95%)</td>
<td>98 (98%)</td>
</tr>
<tr>
<td>B'</td>
<td>98</td>
<td>90 (92%)</td>
<td>95 (97%)</td>
</tr>
<tr>
<td>C'</td>
<td>32</td>
<td>28 (87%)</td>
<td>30 (93%)</td>
</tr>
<tr>
<td>D'</td>
<td>25</td>
<td>22 (88%)</td>
<td>21 (84%)</td>
</tr>
<tr>
<td>E'</td>
<td>19</td>
<td>17 (89%)</td>
<td>18 (95%)</td>
</tr>
<tr>
<td>F'</td>
<td>23</td>
<td>16 (70%)</td>
<td>22 (96%)</td>
</tr>
</tbody>
</table>

The percentages indicate incidence of true negative results for the normal subgroups (A' and B') and true positive results for the infarct subgroups (C' and D'). True negative results for subgroups E' and F', which were analyzed separately, are also shown.

### Table 3

**Comparison of Performance of Young and Williams Criteria and Proposed Criteria**

<table>
<thead>
<tr>
<th>Normal Subgroups A' and B'</th>
<th>Infarct Subgroups C' and D'</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Young and Williams</td>
<td>B. Young and Williams</td>
</tr>
<tr>
<td>Proposed Criteria</td>
<td>Proposed Criteria</td>
</tr>
</tbody>
</table>

Panel A shows results using normal subgroups with mutual errors in cell a and exclusive errors in cells b and c. Panel B shows results using infarct subgroups with mutual errors in cell d and exclusive errors in cells b and c.
Table 4
Comparison of Proposed VCG Criteria and ECG Q Wave Measurements

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>N</th>
<th>Proposed VCG criteria</th>
<th>0.03 Q waves in leads II, III, aVF</th>
<th>0.03 Q in aVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>A'</td>
<td>100</td>
<td>98 (98%)</td>
<td>100 (100%)</td>
<td>98 (98%)</td>
</tr>
<tr>
<td>B'</td>
<td>98</td>
<td>95 (97%)</td>
<td>98 (100%)</td>
<td>98 (100%)</td>
</tr>
<tr>
<td>C'</td>
<td>32</td>
<td>30 (93%)</td>
<td>14 (44%)</td>
<td>24 (75%)</td>
</tr>
<tr>
<td>D'</td>
<td>25</td>
<td>21 (84%)</td>
<td>7 (28%)</td>
<td>15 (60%)</td>
</tr>
<tr>
<td>E'</td>
<td>19</td>
<td>18 (95%)</td>
<td>19 (100%)</td>
<td>19 (100%)</td>
</tr>
<tr>
<td>F'</td>
<td>23</td>
<td>22 (96%)</td>
<td>23 (100%)</td>
<td>22 (96%)</td>
</tr>
</tbody>
</table>

The percentages indicate incidence of true negative results for the normal subgroups (A', B', E', F') and true positive results for the infarct subgroups (C', D').

include a 0.03 sec Q wave in lead III, i.e., if initial forces are superior and between 180° and 209° in orientation, an initial Q wave will be recorded in lead aVF but there will be an initial R wave in lead III. This occurred in about 10% of the patients in test infarct subgroups C' and D'. These data are further analyzed in table 5 by the same method used in table 3. In table 5A, the diagnostic performance of 0.03 sec Q waves in ECG leads II, III, and aVF (upper two-by-two frequency table) and of 0.03 sec Q waves in lead aVF alone (lower two-by-two frequency table) are compared with the performance of the proposed criteria in the normal test subgroups A' and B'. This clearly shows no significant difference in specificity between the methods. In table 5B, the same methods are analyzed for their performance in infarct test subgroups C' and D'. The proposed VCG criteria are significantly different (P < 0.01) from ECG Q wave criteria derived from either one or three leads. Furthermore, this method of analysis shows that the proposed criteria are more sensitive since all of the exclusive errors came out of ECG Q wave criteria (cell b).

Table 5
Comparison of ECG Q Wave Measurements and Proposed VCG Criteria

<table>
<thead>
<tr>
<th>Normal Subgroups A' and B'</th>
<th>Infarct Subgroups C' and D'</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>B.</td>
</tr>
<tr>
<td>Proposed Criteria</td>
<td>Proposed Criteria</td>
</tr>
<tr>
<td>0.03 Q waves in II, III, and aVF</td>
<td>0.03 Q waves in II, III, and aVF</td>
</tr>
<tr>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>P: NS</td>
<td>P: (D)</td>
</tr>
<tr>
<td>0.03 Q wave in aVF</td>
<td>0.03 Q wave in aVF</td>
</tr>
<tr>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>P: NS</td>
<td>P: NS</td>
</tr>
</tbody>
</table>

Panel A shows results in normal subgroups with mutual errors in cell a and exclusive errors in cells b and c. Panel B shows results in infarct subgroups with mutual errors in cell d and exclusive errors in cells b and c.

Discussion

Several recent technical advances have facilitated the development of quantitative VCG criteria for myocardial infarction. Improved VCG recording apparatus has made accurate enlargements of initial forces routinely possible so that more precise measurements can be performed on the QRS loop. In addition, the QRS loops can be recorded with the P and T loops excluded to improve definition of the initial forces. Cineangiographic techniques both for identification of coronary artery lesions and for location of functionally abnormal myocardium have been developed and are used in a large number of patients. These data have allowed comparison of diagnoses by ECG and VCG descriptors with anatomical findings in living patients. Finally, the development of more specific isoenzymes for the identification of acute myocardial infarction, i.e., LDH₄⁵ and CPK-MB⁶ have added additional reliable descriptors which may be used for correlation with electrocardiographic findings.

In the design of this study, normal subjects were selected (subgroups A, A', B, and B') in whom myocardial infarction was most unlikely since those under 30 years of age were healthy volunteers and those over 30 were shown to have normal coronary arteries and normal ventricular contraction pattern by cineangiographic methods. In contrast, some previous studies have included many "normals" over the age of 40 with no cineangiographic confirmation of the absence of cardiac pathology.⁶,¹³ It is certainly possible that a significant number of unsuspected infarctions could have been present among these patients.

In addition, use of strict ECG criteria for defining patients with inferior myocardial infarction is a quite insensitive method. As can be seen from this study, only 44% of patients with positive enzymes and evolution of ECG changes of repolarization in II, III, and aVF (subgroup C') develop 0.03 sec Q waves in all of the inferior leads, while 93% of this subgroup met the proposed VCG criteria for inferior myocardial infarc-
A change in the ECG criteria to appearance of a 0.03 sec Q wave in aVF alone will only increase predictability by ECG to 75%.

Most importantly, the proposed criteria were developed not only using strictly selected normal and infarct subgroups, but they were also tested prospectively using similarly selected patient subgroups and additional noninfarct patient subgroups. This prospective evaluation shows that the proposed criteria are significantly more sensitive than ECG Q wave measurements and more specific than the Young and Williams criteria.

Other studies\(^1\) to 15 have evaluated the use of VCG criteria for inferior myocardial infarction. However, these studies do not attempt to determine the best criteria, but simply test the performance of criteria which have been developed by other investigators. Also, in those studies,\(^1\) to 18 which use coronary lesions of at least 75% without reference to ventricular contraction patterns to define normal and abnormal groups, it is difficult to determine the sensitivity of the VCG criteria. For these reasons, it was decided to select from the literature the criteria which seemed to be the most sensitive (Young and Williams\(^2\)), and to compare these criteria with the proposed criteria using the test group. The graphs shown in figures 2-4 can be used to estimate the performance of other criteria.

Although the sensitivity of the proposed criteria when applied to subgroup D’ was 84%, it should be pointed out that the sensitivity of these criteria when applied to the diagnosis of old inferior myocardial infarction in the general population may be somewhat less. The selection criteria for subgroup D’ may have included only patients with a relatively large inferior myocardial infarction. In a recent follow-up study of patients with myocardial infarction, only 93% showed asynergy by ventriculogram.\(^18\)

The proposed criteria were designed to minimize the incidence of false positive results. Indeed, each individual criterion falsely indicated infarction in less than 1% of “normals” in the criteria group. This high level of specificity was verified using the test group. The use of obese patients (subgroup E’) and women in the third trimester of pregnancy (subgroup F’) further documents the specificity of the proposed criteria and shows the susceptibility of the Young and Williams criteria for false positive diagnoses.

The Young and Williams requirements for the VCG diagnosis of infarction vary depending on the contour of initial clockwise forces in the frontal plane and whether they are inferior or superior.\(^8\) In practice, discrimination among these contours is often difficult. The requirement of generally clockwise early superior forces (early superior forces must cross the X axis to the left of the 0 point) eliminates this confusion and also results in consolidation of four of the original Young and Williams criteria into one criterion. It is important to understand that if initial forces are inferior, the Young and Williams criteria require that these inferior forces be followed by early superior forces 25 msec or more in duration. In the proposed criteria, however, the time from the 0 point to the point at which early superior forces cross the X axis is used provided initial inferior forces are not more than 10 msec in duration and are completely rightward.

The necessity of including a distance requirement in proposed criterion 1 to eliminate the false indication of infarction by a time requirement alone was examined. This occurred in only 2% of the criteria group when 25 msec was required (fig. 2A). However, in test subgroup A’ the incidence was 6%. This was an unacceptable result indicating the need for combined criteria. The addition of a 0.3 mV distance requirement in the presence of 25 msec duration reduced the incidence of false positives in this subgroup to 2%. This complementary use of time and distance measurements is not possible from the ECG reading, and this fact represents an important limitation of its performance.

Others have investigated the diagnostic significance of the ratio of superior to inferior maximal forces in the cube system\(^19\) and in the Frank system for normal males.\(^19\) No correlation with direction of rotation of early superior forces in the frontal plane, however, was included. Use of proposed criterion 3 (table 1) adds this dimension and results in a significant increase in sensitivity when compared to the use of proposed criteria 1 and 2 alone. Although figure 4 shows that in subgroup C use of a 1:3 ratio does as well as a 1.5 ratio, this is not true in subgroup D. Since the use of a 1.5 ratio did not result in a significant number of false positive diagnoses, the more sensitive ratio was chosen.

It should be reemphasized that all patients in this study had no clinical or VCG evidence of left ventricular hypertrophy, right ventricular hypertrophy, or bundle branch block. We have observed an increased incidence of false positive VCG diagnosis of inferior myocardial infarction as documented by cineangiography (normal contraction and coronary anatomy) in patients with left ventricular hypertrophy. In addition, we have noted that development of left anterior hemiblock may obscure the changes of documented inferior infarction. Studies are underway in our laboratory to further evaluate these problems.

This study was directed toward developing improved VCG criteria for the definite diagnosis of inferior myocardial infarction. However, some car-
diologists may wish to include criteria for possible infarction which would be more sensitive but less specific. From the criteria data it would seem reasonable to add criteria for possible infarction as follows:

1. Generally clockwise early superior forces must be present in the frontal plane (as defined in table 1) which cross the X axis at least 20 mV from the 0 point and at least 0.25 mV to the left.
2. Generally clockwise early superior forces must be present in the frontal plane with a maximal frontal plane QRS vector above 20 degrees (less than 20 degrees).

It should be kept in mind, however, that use of these additional criteria will result in a 10% or more incidence of false positive results as well as increase true positive results by 5 to 10%.

Acknowledgments

The authors wish to express their appreciation to Dr. Frank Starmer for his contribution to analysis of the data; Mrs. Dorothy Jones and Mrs. Patricia Nichols for technical assistance; Mrs. Virginia Utley for typing the manuscript and Miss Bettie Gawthorne for assisting in the preparation of the manuscript.

The authors are grateful to the Cardiology Staff of Duke University Medical Center for permission to utilize their patients in these studies. Special gratitude is due Dr. Walter Kempner and Dr. Barbara Newborg for allowing us access to the patients in subgroup E'.

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Circulation. 1974;49:829-836
doi: 10.1161/01.CIR.49.5.829
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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the World Wide Web at:
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