Electrocardiographic Differentiation
Between Left Ventricular Hypertrophy and
Anterior Myocardial Infarction

By P. M. Kini, M.D., E. E. Edleman, Jr., M.D., and H. V. Pipberger, M.D.

SUMMARY
Electrocardiograms recorded from patients with uncomplicated left ventricular hypertrophy (LVH) often show loss of initial anteriorly directed QRS forces. An attempt was made to differentiate these records from electrocardiograms showing a similar pattern as a result of anterior myocardial infarction (MI). Orthogonal ECGs (Frank system) obtained from 103 patients with LVH were compared to ECGs obtained from 327 patients with MI. The ECGs were selected on the basis of absence of Q waves in lead Z which in the conventional ECG corresponds to absence of the R wave in right precordial leads. With two simple scalar measurements, namely R amplitude in lead X ≥ 1.2 mv and the sum of amplitudes of R in leads X and Z ≥ 2.5 mv, 66% of LVH cases were recognized. With these criteria, 88% of the MI records were also correctly classified. The same measurements identified 59% of an independent sample of 66 cases of LVH with no Q in lead Z. By utilizing linear discriminant function analysis, 75% of the cases of LVH, 80% of the MI, and 70% of the independent group of LVH were correctly classified.

Classification procedures were also tested on 48 autopsy cases with results slightly inferior to those obtained on clinical samples.

Direction of initial instantaneous QRS vectors in the transverse plane proved to be much less efficient than scalar measurements or multivariate analysis in the separation between LVH and MI.

This study confirms the difficulties concerning the correct interpretation of the significance of loss of anteriorly directed forces in the presence of LVH. However, the error rate in diagnosis can be considerably reduced by the use of criteria proposed on the basis of this investigation.

Additional Indexing Words:
ECG classification
Computer analysis
Scalar measurements
Multivariate analysis

Essentially negative QRS complexes displaying QS configuration in the right precordial leads have been observed relatively frequently in electrocardiograms (ECGs) of patients with uncomplicated left ventricular hypertrophy (LVH). These changes are often indistinguishable from those due to a healed anteroseptal infarction, especially in the absence of a positive clinical history. LVH as a result of hypertension or aortic valve disease and myocardial infarction (MI) due

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to coronary artery disease are most often found in similar age groups, and precise interpretation of electrocardiographic findings for clear separation of the two diagnostic categories is highly desirable in clinical situations as well as in population studies.

Studies on the electrocardiographic differentiation between uncomplicated LVH and anterior MI exhibiting similar ECG patterns have been few. Due to the complexity of the problem, the issue has remained unsolved. The present investigation was performed to select the best possible criteria to differentiate orthogonal ECGs of LVH from those of anterior MI when there was absence of the Q wave in lead Z, which in the conventional ECG corresponds to loss of R waves in the right precordial leads. Large numbers of ECG records drawn from a taped library were used for study. A digital computer was available for record analysis and evaluation of statistical data. Large numbers of diagnostic criteria could be tested for their efficiency with the computer.

Methods

ECG recordings were made on magnetic tape using Frank’s corrected orthogonal lead system, and subsequently converted into digital form for processing by a Control Data Corporation 3200 computer. Recording technic and computer method have been detailed previously.

ECGs were collected from eight VA hospitals in the framework of a cooperative study and classified strictly on the basis of non-electrocardiographic information obtained from patient protocols designed for the study. Records of patients with hypertension (340) and aortic valve disease (490) formed the LVH group; none of the patients had a history compatible with MI. Of the total of 830 records, 114 (14%) were selected for the purpose of the study on the basis of absence of the Q wave in lead Z. This finding is usually interpreted to be the consequence of anteroseptal infarction. Eleven of these 114 cases had detailed autopsy studies, and this group was used as an independent control. The 103 remaining records formed the core sample in the search for optimal discriminators between LVH and MI.

One thousand ninety-five ECGs from patients with well-documented MI were available for study; 365 (33%) of these were found to have no Q in lead Z. Thirty-eight of these cases were again separated as an independent control sample as autopsy had been performed and the remaining 327 were used for comparison with records of LVH without a Q wave in lead Z. In both groups, ECGs with QRS prolongation of 0.126 sec or more indicating ventricular conduction defects were excluded from the study.

Two different sets of diagnostic criteria were chosen to separate the two groups of ECG records. The first set consisted of relatively simple criteria that could easily be measured by hand. Practically all simple measurements used in routine ECG interpretation were tested by the following method: From the MI group a 96 percentile range was computed for each measurement; this procedure was used since ranges for ECG measurements rarely show normal distribution. The number of cases of LVH that were outside this range was then determined for each measurement. Measurements that separated the maximum number of LVH cases from the MI ranges were selected as the best criteria for differentiation between the groups, the false-positive rate being 2% by definition.

The second set of criteria was selected strictly for computer usage without regard to complexity. More than 300 different measurements which comprise practically all spatial and scalar parameters that have been proposed for ECG analysis were computed for each record. Linear discriminant function analysis was used to select a small number of optimal discriminators between LVH and MI, not exceeding the square root of the number of cases available. Previous studies have indicated that use of a greater number of discriminators leads to overly optimistic results. Weight factors indicating the degree of contribution to the separation of the groups were computed for each measurement. Subsequently, a multidimensional vector was formed by the products of measurements and weight factors. The distances of these vectors from the means of the groups determine whether a patient belongs to a particular group. The smaller the difference of the patient’s vector from the mean vector of a group, the greater the probability that the patient belongs to this group.

Besides using the above procedure, we tried to separate the two groups by computing the angle of their instantaneous vectors in the transverse plane taken at 0.01-sec intervals from the beginning of the QRS up to 0.04 sec. Hugenholtz and his associates suggested that the direction of the 0.02-sec vector in this plane is the most useful measurement in separating LVH from anterior MI with or without LVH; this criterion was chosen as the best from a series of measurements they made on QRS vector loops. Measurements made on

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loops are frequently inaccurate as the initial part of QRS is often indistinct because of overlap of the T and P loops; furthermore, time markings perpendicular to the plane of projection of the loop escape detection. To obviate these errors, we computed the instantaneous vectors from the onset of the QRS on the scalar leads which were recorded simultaneously.

To test repeatability and reliability of the criteria, all procedures were performed on a control sample of 66 records of LVH with no Q in lead Z. These records were selected on the basis of absence of Q in Z from an independent group of 696 cases of hypertension with no history suggestive of myocardial ischemia or infarction.

Detailed postmortem information was available on 11 cases of LVH and 37 cases of MI. One additional case of MI was omitted from further analysis because of lack of adequate autopsy information. As the autopsies were performed at different centers, some variation in the technic of study was unavoidable. Information with regard to the LV size and the presence or absence of infarction or fibrosis was, however, available in each case. ECG records of these patients were then subjected to analysis by sets of measurements already obtained from clinically diagnosed cases and were classified into one of two groups, LVH or MI.

### Results

The mean configurations of the scalar X, Y, and Z leads and the vector loop projections in the frontal, left sagittal, and transverse planes are shown in figure 1. The only significant difference between the LVH and MI loops is in the amplitudes, especially in the frontal and sagittal planes, and not in direction. The difference is represented on the scalar leads by the higher amplitudes of the R waves in cases of LVH on leads X and Z. Two measurements that can easily be obtained by hand from an ECG record, namely the amplitude of R in lead X and the sum of the amplitudes of R in leads X and Z, proved most efficient in separation of the groups (table 1).

When R amplitude in lead X of 1.2 millivolt (mv) was used as limit, 56% of the LVH cases were correctly classified, but 10% of MI records were erroneously diagnosed as LVH (false positives). Lowering the limit of R amplitude in lead X to 1.0 mv improved

### Table 1

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Results of the Use of Measurements That Could Easily Be Obtained from a Scalar ECG in the Differentiation Between LVH and Anterior MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECG measurement</td>
<td>Diagnosis of LVH correct (cumulative) (%)</td>
</tr>
<tr>
<td>1. R amplitude in X ≥ 1.2 mv</td>
<td>56</td>
</tr>
<tr>
<td>2. R amplitude in X + R amplitude in Z ≥ 2.5 mv</td>
<td>66</td>
</tr>
</tbody>
</table>
recognition rate of LVH to 72%, but the false positives increased to 23%. The histogram in figure 2 illustrates the overlap between the groups and shows how any improvement in correct classifications by shifting the limits will be accompanied by an increase in false positives. If, on the other hand, the percentage of false positives is kept too low, very few cases are correctly diagnosed. It should be clear from the histogram that complete separation of the two groups by this measurement is not possible. The second measurement improved separation of the LVH cases by 10% with an increase in the false positives by 2%. Only records that were not separated by the first criterion were subjected to analysis by the second to make the classification cumulative.

Several other scalar and vector measurements did not improve separation of the groups. The ST and T amplitudes failed to contribute to any extent to the differentiation between the two categories. Cases that could be separated on the basis of T measurements were already correctly classified by the R amplitude in leads X and Z. Thus, by the use of two simple and easily measurable criteria, we were able to diagnose LVH from two thirds of the records with 12% of the MI records being interpreted as LVH.

Computer Classification

Measurements that were found by linear discriminant function analysis to be of greatest value in separation of the two categories are shown in table 2. Discriminant function coefficients shown in column 1 indicate weight factors or the relative importance of each of the variables for the discrimination. Each coefficient is multiplied by the magnitude of the corresponding ECG measurement, and the products are shown in column 2. The product of the coefficient with the magnitude

<table>
<thead>
<tr>
<th>ECG measurements</th>
<th>Coefficients of discriminant functions (column 1)</th>
<th>Products of means and discriminant function coefficient (column 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximal spatial QRS vector</td>
<td>1.00</td>
<td>1618</td>
</tr>
<tr>
<td>2. Magnitude of 4/8 QRS transverse plane</td>
<td>-0.82</td>
<td>1084</td>
</tr>
<tr>
<td>3. Spatial magnitude of 4/8 QRS</td>
<td>0.59</td>
<td>846</td>
</tr>
<tr>
<td>4. Spatial magnitude of 3/8 QRS</td>
<td>-0.68</td>
<td>815</td>
</tr>
<tr>
<td>5. R amplitude</td>
<td>-0.72</td>
<td>745</td>
</tr>
<tr>
<td>6. Maximum QRS magnitude, sagittal plane</td>
<td>-0.59</td>
<td>738</td>
</tr>
<tr>
<td>7. Magnitude of 3/8 QRS, transverse plane</td>
<td>0.54</td>
<td>604</td>
</tr>
<tr>
<td>8. Maximum QRS magnitude, transverse plane</td>
<td>-0.36</td>
<td>541</td>
</tr>
<tr>
<td>9. Magnitude of 5/8 QRS, sagittal plane</td>
<td>-0.47</td>
<td>394</td>
</tr>
<tr>
<td>10. 5/8 QRS</td>
<td>0.28</td>
<td>182</td>
</tr>
</tbody>
</table>
Table 3
Classification of LVH (103 Cases) and MI (327 Cases) by Discriminant Function Analysis

<table>
<thead>
<tr>
<th></th>
<th>LVH (%)</th>
<th>MI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVH</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>MI</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

determines the true weight of the parameter. Note that vector measurements exceed the scalar variables in their contribution to differentiation.

When these measurements were combined to form a 10-dimensional vector and a likelihood ratio test applied for classification of records, 75% of the cases of LVH and 80% of those of MI were correctly recognized (table 3). The error ratio of classification was kept nearly equal for both categories.

Angular Measurements

Instantaneous vectors computed at 0.01-sec intervals from the onset of the QRS up to 0.04 sec were not useful in the separation of the groups. The most efficient discriminator was the 0.03-sec vector in the transverse plane, but only 17% of cases of MI could be separated from the LVH ranges. Figure 3 shows the scatter of the ranges for instantaneous vectors of the initial part of QRS in LVH.

![Image of vectors](image.png)

Figure 3
Distribution of initial instantaneous vectors of the QRS in the transverse plane in LVH. These were computed at 0.01-sec intervals from the onset of the QRS in 103 records of LVH without a Q in lead Z.

Repeatability of Results

Testing the initial results with new and independent control samples is essential to confirm the reliability of diagnostic criteria. Of 66 new and independent cases of LVH without a Q in Z studied, 59% (39) were correctly diagnosed as LVH when tested by criteria used for hand measurements; this is close to the 66% rate of recognition obtained for the original series of LVH cases. The closeness of the results confirms the efficiency and consistency of the criteria in the diagnosis of LVH, keeping the false-positive rate constant at 12%.

Using the computer measurements listed in table 2, 70% of these LVH cases were correctly classified.

Autopsy Data

Six out of the 11 cases of LVH (55%) were correctly classified by hand measurements; five of the 37 MI cases (13%) were, however, erroneously diagnosed as LVH. When the diagnostic matrix in table 2 was used, the computer identified 55% of the LVH cases and 71% of MI cases correctly. The small number of the LVH cases makes any meaningful conclusions on the basis of these results difficult. However, the closeness of the figures to those obtained by analysis of the clinical material tends to confirm the reliability of the criteria used for analysis.

The 0.03-sec vector in the transverse plane was found to be the most useful angular measurement computed to differentiate between the groups. However, only 32% of the MI cases could be separated from the LVH group by this measurement.

Discussion

An abnormal QS pattern in right-sided precordial leads was clearly shown by Wilson and associates in their classic paper of 1944, to be a finding in patients with LVH. Although several reports of this electrocardiographic pattern in LVH have appeared since that time in the literature, the authors presented no specific data on differentiation of MI from LVH. Most investigators believed that in the presence of electrocardiographic
evidence of LVH, these changes did not warrant an additional diagnosis of MI. Master and his associates\textsuperscript{4} thought that there was no way of deciding whether coronary occlusion had occurred in such cases other than by a reliable history and a careful study of serial ECG tracings.

The problem of differentiation of LVH and MI confronts the clinician often enough to make a fresh approach to resolve the dilemma worthwhile. The present study demonstrates that by the use of two simple measurements from an orthogonal ECG, two thirds of the problem LVH cases are correctly classified. It should, however, be realized that these criteria based on QRS voltage have some disadvantages. It is well known that following a MI, varying degrees of LVH occur in the great majority of patients. This post-infarction hypertrophy of the LV contributes to increasing QRS voltage in cases of MI and these may be erroneously diagnosed as LVH by criteria based on R amplitude.

Conversely, voltage of the QRS complexes in LVH may be reduced considerably following the development of congestive heart failure and consequent biventricular hypertrophy.\textsuperscript{5} These criteria will, therefore, be less useful in the presence of severe LVH with progressive heart failure. In such cases it would be virtually impossible to decide whether MI had occurred or not when the ECG pattern suggests loss of anterior wall forces. In spite of these limitations, it is worthy of note that the proposed criteria correctly classified more than half the LVH cases and more than 85\% of MI cases that were autopsied.

The reliability and consistency of performance of the criteria were further proved by the recognition of almost 60\% of an independent sample of cases of LVH with loss of initial anterior wall forces. Of the total 1,526 cases (including the original 830 and the control of 696) 11\% (169) records had no Q in lead Z, and these could have been erroneously interpreted as MI; with simple hand measurements, this error rate was reduced to 4\% (62 cases).

Multivariate analysis using 10 measurements, identified correctly 75\% of LVH cases and 80\% of MI cases with the error rate in diagnosis being kept nearly equal on both sides. The identification rate of either one of the diagnostic categories could be increased progressively, but only with an associated rise in error rate: Gain in sensitivity was offset by a concomitant loss of specificity. The computer criteria that we have suggested give probably the best and most realistic recognition rate for both LVH and MI groups. The number of incorrect diagnoses is relatively high, but this is tolerable in a clinical situation when there are no better means of differentiation.

In a study on vectorcardiographic differentiation between LVH and anterior myocardial infarction, Hugenholtz and associates\textsuperscript{7} reported that the direction of the 0.02-sec QRS vector in the transverse plane allowed complete separation of the infarct group from the LVH group. Analyzing records of a group of 36 patients with LVH, Estes\textsuperscript{8} found 11 in which the posterior direction of the 0.02-sec vector was suggestive of MI according to the Hugenholtz criteria. However, coronary artery studies by angiography in four patients and autopsy in three showed evidence of coronary occlusive disease in only one patient. Estes concluded that when the 20-msec vector is posteriorly directed, the probability of MI is distinctly reduced in the presence of LVH and especially if CHF is present. The present investigation confirms the inefficiency of angular measurements in the transverse plane for separation of the groups. Only 17\% of the clinically documented cases and 32\% of the autopsied cases of MI could be separated from LVH cases by the 0.03-sec vector.

It must be emphasized that we have used large numbers of records to offset the shortcomings of drawing conclusions on the basis of smaller numbers of cases and controls.\textsuperscript{10} Again, for each ECG 333 measurements were analyzed which included practically all scalar and vector measurements suggested in electrocardiography. In addition, a large number of records was tested for
repeatability of results. By using the criteria we have suggested, it is possible to classify correctly a large percentage of the records into the LVH or MI groups. The failure to obtain even better separation only emphasizes the inherent difficulty in diagnosing or excluding the presence of anteroseptal infarction in LVH when the ECG shows loss of initial anterior forces.

Acknowledgment

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