Vectorcardiographic Diagnosis of
Left Ventricular Hypertrophy

By Donald W. Romhilt, M.D., Joseph C. Greenfield, Jr., M.D.,
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SUMMARY
The vectorcardiographic diagnosis of left ventricular hypertrophy, using the Frank
lead system, was evaluated in 93 autopsied male patients (70 with hypertrophy of the
left ventricle and 23 without such hypertrophy). The criterion of the maximal QRS
magnitude in the transverse plane greater than 2.2 mv below the age of 50 years and
1.8 mv at the age of 50 or more was positive in 61% of hypertrophied hearts and
negative for all the nonhypertrophied hearts. The criterion of the T loop vector greater
than H°−70° in the transverse plane was positive in 82% of 49 hypertrophied hearts
and positive in one (7%) of 15 normal hearts for which the T loop was available.

The maximal QRS magnitudes in the frontal and sagittal planes had too low a sensi-
tivity to be of value while the angles of the maximal QRS vector in the transverse and
sagittal planes was too nonspecific to be useful.

By combining the QRS magnitude and the T loop vector in the transverse plane,
the diagnosis of left ventricular hypertrophy was made in 90% of 49 hypertrophied
hearts for which the T loop was available.

Additional Indexing Words:
Electrocardiogram QRS amplitude T-wave angle QRS angle

To date only a limited number of autopsy-controlled studies which evaluate
the vectorcardiographic diagnosis of left ventricular hypertrophy have been published.1–8
However, various criteria for the recognition of this abnormality have been proposed; some
require extensive calculations or computer analysis,4 others require only simple measure-
ments which can be obtained without a computer2,3,5,6 and are thus available in
any vectorcardiographic laboratory. The purpose of this study was to evaluate in a group
of autopsied patients certain of the easily measured vectorcardiographic criteria for left
ventricular hypertrophy; that is, the maximal QRS magnitude, the angle of the maximal
QRS vector, and the angle of the T loop.

Pipberger and associates4 have recently established the QRS magnitude for normal
males by age groups (table 1). We have chosen to use the upper 96th percentile value
which these workers obtained in 518 normal subjects as the magnitude criterion neces-
sary for an interpretation of left ventricular hypertrophy. For a group of patients with
clinical left ventricular hypertrophy, Varriale and associates5 stated that the angle of the
maximal QRS vector was the most sensitive index. These workers found that an angle
either posterior to H°+30° in the transverse plane or to S°+30° or superior in the sagita-
tal plane was consistent with left ventricular hypertrophy.* These values have been used

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Table 1

Normal Magnitude of the QRS Vector by Age Group*

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>96% of maximum*</th>
<th>Mean*</th>
<th>96% of minimum*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>2.41</td>
<td>1.66</td>
<td>1.06</td>
</tr>
<tr>
<td>30-39</td>
<td>2.46</td>
<td>1.62</td>
<td>0.81</td>
</tr>
<tr>
<td>40-49</td>
<td>2.57</td>
<td>1.53</td>
<td>0.80</td>
</tr>
<tr>
<td>50-59</td>
<td>2.07</td>
<td>1.34</td>
<td>0.77</td>
</tr>
<tr>
<td>60+</td>
<td>2.33</td>
<td>1.26</td>
<td>0.63</td>
</tr>
<tr>
<td>Transverse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>2.14</td>
<td>1.41</td>
<td>0.91</td>
</tr>
<tr>
<td>30-39</td>
<td>2.19</td>
<td>1.46</td>
<td>0.81</td>
</tr>
<tr>
<td>40-49</td>
<td>2.19</td>
<td>1.30</td>
<td>0.70</td>
</tr>
<tr>
<td>50-59</td>
<td>1.80</td>
<td>1.17</td>
<td>0.74</td>
</tr>
<tr>
<td>60+</td>
<td>2.05</td>
<td>1.17</td>
<td>0.53</td>
</tr>
<tr>
<td>Sagittal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>2.46</td>
<td>1.56</td>
<td>0.73</td>
</tr>
<tr>
<td>30-39</td>
<td>2.39</td>
<td>1.37</td>
<td>0.72</td>
</tr>
<tr>
<td>40-49</td>
<td>2.25</td>
<td>1.27</td>
<td>0.59</td>
</tr>
<tr>
<td>50-59</td>
<td>2.00</td>
<td>1.12</td>
<td>0.43</td>
</tr>
<tr>
<td>60+</td>
<td>2.03</td>
<td>0.97</td>
<td>0.61</td>
</tr>
</tbody>
</table>

*These measurements given in millivolts were obtained from Pipberger and associates (reference, 4 and also personal communication).

as the maximal QRS angular criteria in our study. Both Murata and co-workers5 and Toyama and associates6 noted that the T loop is directed to the right in left ventricular hypertrophy. We elected to evaluate Toyama and co-workers' criterion6 of a maximal T vector angle greater than H° - 70° in the transverse plane since Murata and associates5 did not define the T angle necessary for the diagnosis of left ventricular hypertrophy.

Methods

All male patients who have been autopsied at the Durham Veterans Administration Hospital between 1961 and 1966 and who had vectorcardiograms recorded within 6 months of death were evaluated. Those with either complete right bundle-branch block or complete heart block were not used; however, seven patients having left bundle-branch block were included. Also excluded were hearts in which the right ventricular thickness was greater than 5 mm and the clinical diagnosis was one leading only to right ventricular hypertrophy. Included were hearts having a right ventricular wall thickness between 5 and 8 mm, if there was a concomitant marked increase in left ventricular thickness and a clinical diagnosis leading one to expect only left ventricular hypertrophy. These hearts were selected because previous observations8 indicate that marked left ventricular hypertrophy may lead to secondary right ventricular hypertrophy. The hearts were then evaluated according to Zeek's5 criteria which define normal heart weight according to body length. The final group consisted of 93 hearts of which 70 were hypertrophied and 23 were not hypertrophied.

The vectorcardiograms were recorded from a Frank lead system having 50,000 ohms as the unit of resistance. The chest electrodes were placed at the level of the fourth intercostal space and recordings were made with the patient in the supine position. The voltages across the X, Y, and Z terminals of the Frank network were amplified by Sanborn Model no. 350-3200 preamplifiers and recorded simultaneously on an Ampex FR-100A magnetic tape recorder at a tape speed of 60 inches per second. The loops were reproduced at a speed of 7.5 inches per second (time expansion factor of 8). The appropriate leads were displayed on a Tektronix Model 502 Dual Beam Oscilloscope as the frontal, transverse, and sagittal plane loops. A Grass Model S4 stimulator was used to modulate the cathode-ray beam every 2 msec in real time. Uninterrupted and interrupted loops of each plane were photographed with a Hewlett-Packard Oscilloscope camera. The vectorcardiographic recording technique used in this laboratory has been described in greater detail elsewhere.10 A standard 12-lead electrocardiogram was also obtained on each patient with either a Sanborn Twin Beam Photographic Recorder or a Sanborn Direct Writing Recorder.

The vectorcardiograms, all of which were obtained in the 6 months prior to death, were evaluated independently as to (1) maximal QRS magnitude in the frontal, transverse, and sagittal planes; (2) angle of maximal QRS vector in the transverse and sagittal planes; and (3) angle of the T vector in the transverse plane. The maximal QRS magnitude was measured as the distance in millivolts from the point of origin to the point of maximal QRS deflection. These values were then compared with the 96th percentile values obtained by Pipberger and co-workers4 for that age group (table 1). The angles of both the maximal QRS vector and the T loop were compared to the established criteria of Varriale and associates5 and Toyama and co-workers,6 respectively, as described above. The

Table 2

Weights of Hypertrophied Hearts

<table>
<thead>
<tr>
<th></th>
<th>No.</th>
<th>Mean (g)</th>
<th>Range (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>70</td>
<td>594</td>
<td>390-850</td>
</tr>
<tr>
<td>T loop present</td>
<td>49</td>
<td>611</td>
<td>400-850</td>
</tr>
</tbody>
</table>

*These measurements given in millivolts were obtained from Pipberger and associates (reference, 4 and also personal communication).
T loop was present on only 64 of the vectorcardiograms and could be interpreted in 63. In one hypertrophied heart the T loop was circular; thus an accurate T vector could not be obtained. The T loop was not present on the remaining 29 vectorcardiograms.

Results

The heart weights in the hypertrophied groups are given in table 2. The maximal QRS magnitude was positive for left ventricular hypertrophy in the frontal plane in 12 (17%) of the 70 hypertrophied hearts evaluated in this manner, in the transverse plane in 43 (61%), and in the sagittal plane in 17 (24%) (table 3). None of the 27 hearts missed by the transverse plane was positive in either of the other planes. There were no false positive diagnoses of the 23 nonhypertrophied hearts in any plane from maximal QRS magnitude (table 4). The angle of the maximal QRS vector determined for 70 hypertrophied hearts was positive for hypertrophy in the transverse plane in 45 (64%) and in the sagittal plane in 53 (76%). However, there were 12 (52%) false positive diagnoses in the transverse plane, and 15 (65%) in the sagittal plane in the 23 nonhypertrophied hearts.

The angle of the T loop was evaluated in 49 hypertrophied hearts and was positive in 40 (82%). A false positive diagnosis of hypertrophy was made in one (7%) of 15 nonhypertrophied hearts. The maximal QRS magnitude in the transverse plane in the 49 hearts in which the T loop was available was positive in 31 (63%). This finding is similar to the 61% found in the overall group of 70 hypertrophied hearts and suggests that the subgroup is not significantly different from the total group. Four of the nine hearts in which a false negative diagnosis was made with T loop criteria were positive for left ventricular hypertrophy on use of the maximal QRS magnitude in the transverse plane. In addition, 13 of the 18 false negative diagnoses attained on use of the maximal QRS magnitude criteria in the transverse plane were found to be positive for hypertrophy with the T loop criteria. Thus the diagnosis was missed for only five (10%) of the 49 hypertrophied hearts when both criteria were used.

The electrocardiographic diagnosis of left ventricular hypertrophy, using a point-score system, described elsewhere,11 was also evaluated and compared with the vectorcardiographic diagnosis. The electrocardiogram was interpreted as diagnostic in 65% of the overall group of 70 hypertrophied hearts and in 70% of the 49 hearts for which the T loop was available. There were no false positive diagnoses made from the electrocardiograms of the 23 normal hearts. Of the 27 hypertrophied hearts which were negative according to the maximal QRS magnitude in the transverse plane, 13 were found to be positive by the electrocardiogram. However, only eight of the electrocardiographic false negatives were found to be positive when the maximal QRS magnitude criteria in the transverse plane was used. Thus 14 (20%) of the 70 hypertrophied hearts were negative with both criteria. Of the nine hypertrophied hearts that were negative on use of the T loop angle index, five were positive according to the electrocardiogram, whereas eight of the electrocardiographic false negative diagnoses were missed.

Table 3
Sensitivity of Vectorcardiographic Criteria in the Evaluation of Hypertrophied Hearts

<table>
<thead>
<tr>
<th>VCG criteria*</th>
<th>Cases evaluated</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal QRS magnitude</td>
<td>70</td>
<td>12 (17%)</td>
</tr>
<tr>
<td>Transverse QRS magnitude</td>
<td>70</td>
<td>43 (61%)</td>
</tr>
<tr>
<td>Sagittal QRS magnitude</td>
<td>70</td>
<td>17 (24%)</td>
</tr>
<tr>
<td>Transverse maximal QRS angle</td>
<td>70</td>
<td>45 (64%)</td>
</tr>
<tr>
<td>Sagittal maximal QRS angle</td>
<td>70</td>
<td>53 (76%)</td>
</tr>
<tr>
<td>T loop angle in transverse plane</td>
<td>49</td>
<td>40 (82%)</td>
</tr>
</tbody>
</table>

*For definition of criteria, see text.

Table 4
Specificity of Vectorcardiographic Criteria in the Evaluation of Nonhypertrophied Hearts

<table>
<thead>
<tr>
<th>VCG criteria*</th>
<th>Cases evaluated</th>
<th>False positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal QRS magnitude</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Transverse QRS magnitude</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Sagittal QRS magnitude</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>Transverse maximal QRS angle</td>
<td>23</td>
<td>12 (52%)</td>
</tr>
<tr>
<td>Sagittal maximal QRS angle</td>
<td>23</td>
<td>15 (65%)</td>
</tr>
<tr>
<td>T loop angle in transverse plane</td>
<td>15</td>
<td>1 (7%)</td>
</tr>
</tbody>
</table>

*For definition of criteria, see text.
cardiographic false negative diagnoses were positive with the T loop criteria. Only three (6%) of the 49 hypertrophied hearts were missed by all three sets of criteria.

Discussion

Pipberger and associates4 have established that the maximal vectorcardiographic QRS voltage, both mean and 96th percentile values, decrease with advancing age in males. An exception to this finding was noted in that the maximal 96th percentile value for the age group of 60 and over was increased over that of the previous decade (Pipberger, personal communication). Despite careful selection, it seems probable that a few hypertrophied hearts may have been included in this group and affected the 96th percentile value, but not the mean. For this reason we have elected to apply the 96th percentile maximal QRS magnitude derived from the 50 to 59 year age group for all males over the age of 60. For these values, the maximal QRS magnitude in the transverse plane is acceptable for the vectorcardiographic diagnosis of left ventricular hypertrophy with an incidence of 61% positive in the hypertrophied group and no false positives, although an incidence of 2% false positives would be statistically expected. In daily practice this criterion can be simplified so that it is positive if the voltage in the transverse plane is greater than 2.2 mv below the age of 50 years and 1.8 mv at age of 50 or more. The maximal QRS magnitude in either the frontal or sagittal plane is of little value because of the low sensitivity. The angle of the maximal QRS vector described by Varriale and co-workers5 for the transverse and sagittal planes is present in too many normal hearts (52% and 65%, respectively) to be clinically useful for the diagnosis of left ventricular hypertrophy. This lack of specificity was also demonstrated by Pipberger and associates5 for the transverse plane.

In our series a T loop direction of greater than H° - 70° in the transverse plane was the most sensitive index of hypertrophy (82%) and included only 7% false positive diagnoses. This finding agrees with the 8% false positive interpretations found by Murata and associates.3 However, it should be noted that Murata and co-workers found false positives in 14% of a separate group of patients having coronary artery disease without hypertrophy. Also our 82% incidence of positive diagnosis is higher than that reported by Murata and co-workers. This discrepancy is most likely due to the larger size of the hearts in our series (table 2).

When the T loop direction is combined with the QRS magnitude in the transverse plane in the 49 hearts in which a T loop was present on the vectorcardiogram, it would appear from our series that 90% of the hearts having left ventricular hypertrophy would be recognized. However, before these criteria can be relied upon as a clinically diagnostic tool, the T loop needs further evaluation in normal hearts, and in nonhypertrophied hearts in which coronary artery disease is present, particularly those with anterior and lateral wall infarction and ischemia.

There is an insignificant difference between the electrocardiographic diagnosis of left ventricular hypertrophy using the point-score system, and the vectorcardiographic diagnosis using QRS magnitude in the transverse plane as a single criterion. The electrocardiogram is less sensitive than the angle of the T loop in the transverse plane as a single criterion. The combination of using the maximal QRS magnitude in the transverse plane, the angle of the T loop in the transverse plane, and the electrocardiographic point-score system will yield a correct diagnosis of left ventricular hypertrophy in 46 of 49 (94%) of the hypertrophied hearts. The number of false positive diagnoses is unchanged, but as discussed further evaluation in a larger series of normal hearts and nonhypertrophied diseased hearts is needed.

References


Parry on Natural History of Angina Pectoris

If the opinion be well founded, which I have endeavoured to support in the preceding pages, that the Syncope Anginosa is primarily owing to induration of the coronary arteries, we have no reason to expect that it will ever suffer a radical cure. But as we have also rendered it probable, that this mal-organization may subsist, without producing violent symptoms, till it meets with the coincidence of other causes, we may, perhaps, in some cases, afford relief by removing or suspending the operation of those causes. And, should that relief continue so long as to allow of the patient's dying of some other disease, the Syncope Anginosa may, in such a case, according to common language, be justly enough said to have been cured.—Caleb Hillier Parry: An Inquiry into the Symptoms and Causes of the Syncope Anginosa, Commonly Called Angina Pectoris. London, Cadell and Davies, 1799, p. 146.
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