The Normal Orthogonal Electrocardiogram and Vectorcardiogram
With a Critique of Some Commonly Used Analytic Criteria

By Hubert V. Pipberger, M.D.

Preliminary standards for the normal orthogonal electrocardiogram and vectorcardiogram were established as a basis for further studies on pathologic series. Schmitt’s corrected lead system (SVEC III) was used. The statistical analysis of electrocardiographic and vectorcardiographic data revealed some intrinsic shortcomings of commonly used analytic criteria. As the orthogonal electrocardiogram and vectorcardiogram are interchangeable, inherent advantages and disadvantages of the 2 methods of display could be evaluated in a quantitative fashion.

A previous study from this laboratory demonstrated in man an enhanced accuracy in the performance of corrected orthogonal electrocardiographic leads as compared to conventional lead systems. In the present investigation, Schmitt’s corrected SVEC III leads were applied to 100 normal subjects in order to establish normal standards. Its purpose is to provide at least preliminary data concerning the extent of normal ranges that logically should precede extensive application of the corrected leads to pathologic cases. The results of the present study apply to a great extent also to any other orthogonal lead system with appropriate lead corrections, since it has been shown that the performance of such systems is relatively similar.

Scalar and vectorial display was used for the collection of data. Both methods of recording are interchangeable with an orthogonal lead system. Thus, it was possible for the first time to evaluate quantitatively some of the inherent advantages and disadvantages of the display methods. Statistical data were

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Table 1.—Age Distribution of the Subjects Studied

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>15–20</td>
<td>2</td>
</tr>
<tr>
<td>21–30</td>
<td>31</td>
</tr>
<tr>
<td>31–40</td>
<td>16</td>
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<tr>
<td>41–50</td>
<td>7</td>
</tr>
<tr>
<td>51–60</td>
<td>5</td>
</tr>
<tr>
<td>61–69</td>
<td>4</td>
</tr>
</tbody>
</table>

Fig. 1. Reference frame for angular measurements of vector loops in the frontal, right sagittal, and horizontal planes. Plus and minus indicate the polarity of the 3 leads X, Y, and Z as they were used in scalar recordings.

analyzed to evaluate the adequacy of some commonly used electrocardiographic and vectorcardiographic criteria.
MATERIAL AND METHODS

The SVEC III lead system was applied to 100 normal subjects, 71 of whom were patients admitted to Georgetown University Hospital for reasons other than heart disease. History, physical examination, chest x-ray, and the 12-lead electrocardiogram did not reveal any evidence for past or present heart disease. The remainder of the subjects were members of the housestaff or medical students without evidence of heart disease. The age and sex distribution of the subjects is shown in Table 1.

The scalar leads X, Y, and Z were recorded simultaneously from a cathode-ray oscilloscope with a film speed of 118 mm. per second. Vector loops were photographed in the frontal, right sagittal, and horizontal planes, both by single exposures and on running film. The latter method was used for the identification of time-markings in the vicinity of point E, which are frequently hidden by P and T loops. No measurements were made from these records as the loops become grossly distorted by this method. Due to the previously mentioned difficulties around point E, P loops could not be measured in all subjects.

The electronic characteristics of the recording apparatus have been reported previously. The reference frame used for measurements of loops is given in Figure 1. Figure 2 shows a representative record.

Great care was taken to identify accurately instantaneous vectors in loops. A new method was used for this purpose. Time relations are determined more reliably on time-based scalar leads than on any type of loop recordings. Therefore, the incidence in time of the peaks of RX and RV and the nadir of Sz were measured from the beginning of the QRS complex in simultaneously recorded scalar leads. The corresponding maximal X, Y, and Z vectors of the loops were then marked according to the time measurements from the scalar tracings. As all maximal X, Y, and Z deflections appear twice in vector loops of 3 planes, their incidence in time could be double-checked. When differences were found, a mean value was taken. The error in time could so be reduced to half the interval between time-markings, or 0.00125 second. The described method of identifying instantaneous vectors takes full advantage of the electronic lead integration through vector loops. Vector directions are therefore more accurate than those plotted from scalar deflections.

The different items measured from vector loops are indicated in Figure 3. Maximal QRS, T, and P vectors are those of largest magnitude in each planar projection.

The quantitative analysis of the terminal QRS forces posed several problems. One approach would be the consecutive determination of instantaneous vectors at successive time intervals from
TABLE 2.—Tabulation of Mean Results and Standard Deviations for the Normal Orthogonal Vectorcardiogram

<table>
<thead>
<tr>
<th>Rotation of QRS-loops (number of cases)</th>
<th>Frontal*</th>
<th>Sagittal</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal QRS vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Length to width ratio of QRS-loops:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direction of terminal QRS forces (for method of determination see text):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01 sec. QRS vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.02 sec. QRS vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.03 sec. QRS vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.04 sec. QRS vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal T vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QRS-T-angle (measured between maximal QRS and maximal T vectors):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal P vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. direction:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. magnitude:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* SE = standard error. For measured items and methods of determination see figure 3. Measurements which appeared unreliable for technical reasons were not included in the tabulation. This occurred frequently in P-loops, which were partially or totally hidden by other loops. The number of subjects for each measured item is given in parenthesis. Ranges between lowest and highest values were indicated only when the distribution appeared asymmetric or when the range could not be defined properly by the mean and standard deviations.
ORTHOGONAL ELECTROCARDIOGRAM AND VECTORCARDIOGRAM

![Figure 4: Distribution curves of maximal QRS vectors in the frontal, right sagittal, and horizontal planes.](image)

The vectors were grouped in sectors of 15 degrees. The number of cases is given on the ordinate, the sectors on the abscissa. Curves were arranged to show the main peaks on top of each other. Note the small range and symmetric distribution in the frontal plane in contrast to the large scatter and asymmetry of distribution in the other planes. The cases with $R_x > S_z$ are distributed around the larger peak in the horizontal plane. Cases with $S_z > R_x$ form the smaller peak at the left.

The beginning of QRS to the end. Due to differences in QRS duration, the end of the complex would then fall in different time categories. Time measurements backward from the end of QRS lead to similar discrepancies with measurements started from the QRS onset. In this case, the discrepancy is shifted to the midportion of QRS. The attempt to time the terminal QRS forces was therefore abandoned. A tangent to the terminal part of the QRS loop arising from point E was plotted and its direction measured (fig. 3). This method appeared more satisfactory than the arbitrary choice of a point preceding the end of QRS.

**RESULTS**

A statistical analysis of the QRS, T, and P loops is given in table 2. Most of the listed

<table>
<thead>
<tr>
<th>Items measured</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Magnitude of $Q_x$:</td>
<td>$0.11 \pm 0.08$ mV, SE $\ast 0.01$ mV range: $0.015 - 0.36$ mV (62)</td>
</tr>
<tr>
<td></td>
<td>of $Q_y$:</td>
</tr>
<tr>
<td></td>
<td>of $R_x$:</td>
</tr>
<tr>
<td>II Magnitude of $R_x$:</td>
<td>$1.70 \pm 0.49$ mV, SE $0.05$ mV range: $0.64 - 2.85$ mV (100)</td>
</tr>
<tr>
<td></td>
<td>of $R_y$:</td>
</tr>
<tr>
<td></td>
<td>of $S_z$:</td>
</tr>
<tr>
<td>III Magnitude of $S_x$:</td>
<td>$0.31 \pm 0.24$ mV, SE $0.03$ mV range: $0.03 - 1.17$ mV (82)</td>
</tr>
<tr>
<td></td>
<td>of $S_y$:</td>
</tr>
<tr>
<td>IV $Q/R$ ratio in lead X:</td>
<td>$0.06 \pm 0.04$, SE $0.01$ range: $0.01 - 0.15$ (62)</td>
</tr>
<tr>
<td></td>
<td>in lead Y:</td>
</tr>
<tr>
<td>V $R/S$ ratio in lead X:</td>
<td>$10.44 \pm 10.25$, SE $1.13$ range: $1.03 - 47.50$ (82)</td>
</tr>
<tr>
<td></td>
<td>in lead Y:</td>
</tr>
<tr>
<td></td>
<td>in lead Z:</td>
</tr>
<tr>
<td>VI QRS duration (measured from simultaneously recorded scalar leads; see text):</td>
<td>$0.093 \pm 0.010$ sec., SE $0.001$ sec. range: $0.074 - 0.113$ sec. (100)</td>
</tr>
<tr>
<td>VII Time interval between beginning of QRS and beginning of $R_x$:</td>
<td>$0.017 \pm 0.008$ sec., SE $0.0008$ sec. (100)</td>
</tr>
<tr>
<td></td>
<td>of $R_y$:</td>
</tr>
<tr>
<td></td>
<td>of $S_z$:</td>
</tr>
</tbody>
</table>

(continued)
### Table 3—Continued

<table>
<thead>
<tr>
<th>Items measured</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII Time interval between beginning of QRS and beginning of $R_x$: $R_y$: (only cases where a Q-wave was present)</td>
<td>0.021±0.005 sec., SE 0.0006 sec. (67) 0.020±0.006 sec., SE 0.0007 sec. (72)</td>
</tr>
<tr>
<td>IX Duration of $Q_x$: of $Q_y$: of $R_z$: (measured from the beginning of these waves to the beginning of the R or S-waves respectively; not from the beginning of the QRS-complex)</td>
<td>0.018±0.006 sec., SE 0.0008 sec. (67) 0.019±0.006 sec., SE 0.0007 sec. (72) 0.038±0.008 sec., SE 0.0008 sec. (100)</td>
</tr>
<tr>
<td>X Number of cases without Q-wave in lead X: without Q-wave in lead Y: without R-wave in lead Z:</td>
<td>33 28 0</td>
</tr>
<tr>
<td>XI Number of cases with</td>
<td>10 23</td>
</tr>
<tr>
<td>1. leftward direction of initial forces in lead X:</td>
<td></td>
</tr>
<tr>
<td>2. isoelectric interval between beginning of QRS and beginning of R-wave but without Q-wave in lead X: duration of this isoelectric interval:</td>
<td>0.013±0.005 sec., SE 0.001 sec. (23)</td>
</tr>
<tr>
<td>3. Downward direction of initial forces in lead Y:</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3—Continued</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4. Isoelectric interval between beginning of QRS and beginning of R-wave but without Q-wave in lead Y:</strong></td>
</tr>
<tr>
<td>Duration of this isoelectric interval:</td>
</tr>
<tr>
<td><strong>5. Isoelectric interval between beginning of QRS and beginning of R-wave in lead Z:</strong></td>
</tr>
<tr>
<td>Duration of this isoelectric interval:</td>
</tr>
<tr>
<td><strong>XII Time interval between beginning of QRS and peak of $R_x$: $R_y$: $S_x$: $S_y$:</strong></td>
</tr>
<tr>
<td>0.044±0.006 sec., SE 0.0006 sec. (100) 0.045±0.006 sec., SE 0.0006 sec. (100) 0.057±0.007 sec., SE 0.0007 sec. (100) 0.026±0.009 sec., SE 0.001 sec. (82) 0.023±0.011 sec., SE 0.001 sec. (76)</td>
</tr>
</tbody>
</table>

*SE = standard error. For polarity of the scalar leads and methods of measurements see figure 1 and text. Results which appeared unreliable for technical reasons are not included in the tabulation. The number of subjects is therefore given for each item in parenthesis. Ranges between highest and lowest values were indicated only when the range was not properly defined by the mean and standard deviation.

Data are self-explanatory. The range for the direction of maximal QRS vectors in the frontal plane was relatively small. The distribution of results followed a symmetric Gaussian curve. In the sagittal and horizontal planes, no normal distribution was found (fig. 4). In the latter plane the maximal QRS vectors were distributed around 2 different peaks. This was found to be due
TABLE 4.—Grouping of 0.01-sec. QRS Vectors of the Frontal Plane According to the Direction of Their Maximal QRS Vectors in This Plane

<table>
<thead>
<tr>
<th>Group no.</th>
<th>Sectors of 15° in the frontal plane for grouping of maximal QRS vectors</th>
<th>Mean direction of 0.01-sec. QRS vectors in the frontal plane grouped according to the direction of their maximal QRS vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0—15°</td>
<td>151±30°, SE 13.4° (5)</td>
</tr>
<tr>
<td>2</td>
<td>16—30°</td>
<td>190±87°, SE 21.2° (17)</td>
</tr>
<tr>
<td>3</td>
<td>31—45°</td>
<td>243±69°, SE 13° (28)</td>
</tr>
<tr>
<td>4</td>
<td>46—60°</td>
<td>258±44°, SE 9.4° (22)</td>
</tr>
<tr>
<td>5</td>
<td>61—75°</td>
<td>275±23°, SE 7.8° (9)</td>
</tr>
</tbody>
</table>

Significant differences between the groups (t test): Group 1 and 3, 1 and 4, 2 and 4: p < 0.01
Group 1 and 5, 2 and 5: p < 0.001
Group 2 and 3, 3 and 5: p < 0.05

These initial vectors were scattered around the whole angular reference frame. Means and standard deviations could be obtained only after grouping. Note the relatively fixed relationship between the direction of 0.01 sec. and maximal QRS vectors. In spite of grouping ranges for the initial vectors exceed those of the maximal vectors.

to a time interval between the peak of $R_X$ and the nadir of $S_Z$. In the majority of cases, the magnitude of $R_X$ exceeded that of $S_Z$. In these instances the maximal QRS vector was identical or close to the maximal X vector. In the remainder of the cases the maximal QRS vector coincided closely with the maximal Z vector. A mean time interval of 0.012 second separated the peak of $R_X$ and the nadir of $S_Z$ (table 3, XII). This led to an angular discrepancy of the 2 peaks for maximal QRS vectors of 90° (fig. 4).

The direction of the 0.01- and 0.02-second QRS vectors in the frontal plane varied extremely with a range covering the entire angular scale. A mean direction could therefore not be determined. When the 0.01-second QRS vectors of the frontal plane were separated according to the direction of their maximal QRS vectors, a better grouping was obtained. Most of the subgroups differed significantly (table 4). It was obvious that maximal and 0.01-second QRS vectors were related to each other through their direction. Grouping of 0.02-second QRS vectors in the frontal plane in the same fashion did not lead to significant differences of the subgroups. Ranges of direction for the 0.03 and 0.04-second QRS vectors were considerably smaller, especially the latter.

Directions of maximal, 0.01-second and terminal QRS vectors were correlated with age, relative body weight, and height of the subjects. No correlation was found for any of these comparisons. In the age group beyond 50 years (14 subjects) all maximal QRS vectors of the frontal plane showed an angle of less than 50° with the X axis. Below this age limit a large scatter of QRS directions was found.

A uniform rotation of the QRS loops was found for all cases in the horizontal and sagittal planes. In the frontal plane the rotation was clockwise in 61 per cent, counterclockwise or figure 8 in the remainder of the cases (table 2). No correlation was found between the QRS rotation in the frontal plane and age or relative body weight. A relation, however, existed between rotation of QRS and the direction of maximal QRS vectors. The cases with clockwise rotation showed a mean direction of the maximal QRS vectors of $45 \pm 13°$ and those with counterclockwise rotation of $27 \pm 15°$. The angular difference between the 2 groups proved significant ($p < 0.001$).

The pertinent data for the orthogonal electrocardiogram are given in table 3. The magnitude of all measured items was higher than for conventional bipolar or unipolar leads. The QRS duration determined from simultaneously recorded leads was $0.093 \pm 0.010$ second. In many cases, an initial QRS deflection was found only in 1 or 2 leads, whereas other leads showed an initial isoelectric interval. The duration of Q waves in lead X and Y, and of R waves in lead Z, differed therefore as to whether they were measured from the beginning of the QRS complex to the end of the wave, or from the beginning of the wave proper to its end. Both types of measurements have been made (table 3, VII, VIII, IX) in order to demonstrate the discrepancies in results of the 2 methods.

**DISCUSSION**

The most cumbersome feature of the conventional electrocardiogram and vectorcardiogram is the large normal range for almost all analytic criteria commonly used. A wide
overlap between normal and pathologic obviously is undesirable. Part of the variability of the normal electrocardiogram has been attributed to the inconstancy in direction and strength of conventional effective lead axes. The SVEC III lead system used in this study has been shown in torso models and in man to have relatively constant lead characteristics regardless of positional dipole variations and differences in body build. If a reduction of normal ranges is found with such a corrected lead system, it can be concluded that the large variability of the conventional normal electrocardiogram is indeed due to variations in direction and strength of their effective lead axes. On the other hand, large normal ranges from the use of corrected lead systems would indicate a great intrinsic variability. The extension of normal ranges for corrected lead systems has therefore to be compared with that of conventional lead systems.

1. Configuration of Vector Loops. The configuration of vector loops is difficult to quantitate and remains a descriptive criterion. In the present study, a striking uniformity in configuration of the tracings was found (fig. 2). It was not possible to separate different types of QRS loop configurations, as have been described by Burch and associates for the tetrahedron lead system. Ablidskov and Pence reported a similar uniformity in their tracings of a younger age group. From the present study of a relatively small number of subjects in the older age groups it appears that this uniformity is maintained to a considerable extent throughout life. No significant correlations between age and directions of maximal and initial QRS vectors were found. This negative finding, however, needs to be corroborated by larger series.

2. Directions of Maximal QRS and T Vectors in the Frontal Plane. The normal range for the maximal QRS and T vectors in the frontal plane was relatively small. Ranges for QRS up to 140° were found when bipolar and unipolar extremity leads were used. The relatively small range of 75° for QRS and 63° for T as found in this study, strongly suggests that the extreme horizontal and vertical QRS axes of conventional electrocardiographic leads are due to the varying characteristics of these leads in direction and strength.

Comparable small ranges for maximal QRS vectors in the frontal plane have been reported for the 2 cube vectorcardiographic lead systems (Duchosal and Grishman). The main disadvantage of these systems is the weak and variable representation of sagittal forces. Frank’s corrected lead system whose performance is very close to the SVEC III showed also a relatively small range for maximal QRS vectors in the frontal plane. The range can be approximated from the elevation angle of the “QRS plane” as reported by Seiden. The narrow range for the main direction of the heart’s electromotive forces is surprising, considering the complex muscular structure of this organ. These findings lead to the conclusion that discrepancies between anatomic and electric heart axes must be considerably smaller when corrected instead of conventional electrocardiographic leads are used.

3. Ranges for Other Scalar and Vectorial Electrocardiographic Criteria. The majority of the remaining parameters measured showed ranges that were not significantly smaller or larger than those reported for conventional leads. Considering the uniformity in configuration this finding was surprising. Many of the wide ranges, however, could be explained by shortcomings of conventional analytic criteria which make them unsuitable for quantitative data analysis.

The direction of the initial QRS vectors in the frontal plane (0.01-second vectors) was found to be a function of the direction of their maximal vectors in this plane (table 4). Measurements of direction and magnitude of these initial forces are meaningful only when correlated with the main spatial direction of the QRS loop. This was pointed out for the spatial vectorcardiogram previously by Wolff and associates. Without taking into account the main QRS direction in a more quantitative fashion, the diagnostic significance of initial QRS vectors and Q waves must necessarily be very limited.

The beginning of the QRS complex when
determined from simultaneously recorded scalar leads varied from one lead to another in a great number of cases. The Q-wave duration taken from a single lead, therefore, does not always indicate the interval between onset of QRS and beginning of R waves. Accurate time measurements were possible only from simultaneously recorded scalar leads. The vector loop display was very unreliable for accurate determinations of initial forces.

No symmetric Gaussian distribution was found for maximal QRS vectors in the sagittal and horizontal planes. Their direction is determined mainly by the largest single deflection of the 2 leads used in each plane. Time lags between the incidence of $R_X$ and $R_Y$ on one side and $S_Z$ on the other caused the large scatter of findings. In 90 per cent of the cases maximal QRS vectors were not identical in all 3 planes. The attempt to determine spatial QRS-T angles from maximal QRS vectors was abandoned as by definition an angle has only 2 sides. Spatial angular discrepancies of maximal QRS vectors from different planes of up to 106° illustrate the fallacies of spatial angle determinations. A QRS vector common to all planes is required for true spatial evaluations. The present situation in "spatial" vectorcardiography could be clarified by abandoning the term "mean" QRS for maximal QRS axes as a true mean should include all parameters of the complex, namely amplitude and time. The spatial mean QRS vector (S Å QRS) of Ashman appears as the most satisfactory approach to spatial vector analysis. When determined graphically, with reasonable accuracy, this method is very time-consuming. Electronic computation of this vector is limited to a few laboratories. The mean of "half-area" vectors from 3 planes has been found to be very close to S Å QRS. As a graphic method, it combines simplicity and accuracy as the resulting vector is common to all planes.

Maximal T vectors were found to be common to all planes almost without exception. This was due to the narrow and peaked configuration of the T loops. The range of maximal T vector directions in the horizontal and sagittal planes was roughly half of that for QRS (table 2). This relatively small range for the T direction also suggests that the large ranges for maximal QRS vector directions in the sagittal and horizontal planes were due mainly to the inadequacy of the criterion itself.

Planar loop recordings appeared superior to scalar tracings for the determinations of vectors of large amplitude. The electronic integration of different leads greatly improves the accuracy of angular measurements. Planar vectorcardiography as used in most laboratories at present, however, does not necessarily lead to a spatial evaluation of vectors unless these are carefully identified in all planes.

In view of the uniformity in loop configurations further reductions of normal ranges appear possible. A re-evaluation of commonly used analytic criteria and recording methods seems to be needed in order to decrease many normal ranges. Explorations and tests of new methods of electrocardiographic data analysis and processing are in progress in this and several other laboratories.

**SUMMARY AND CONCLUSIONS**

Corrected orthogonal electrocardiographic leads (Schmitt's SVEC III system) were applied to 100 normal subjects in order to establish preliminary normal ranges as a basis for future studies on pathologic series. As such a lead system can be used for electrocardiography and vectorcardiography, both methods of display were used for statistical analysis. Conventional electrocardiographic and vectorcardiographic criteria were applied.

Time relations of the vector loop records could be determined accurately only by the additional use of simultaneously recorded scalar leads. Electronic lead integration through vector loops proved superior for determinations of vector directions. Vectorial and multichannel scalar display appeared as complementary methods and the accuracy of recorded data was largely enhanced by the use of both.
The normal range for the direction of maximal QRS vectors in the frontal plane was approximately half of that for conventional electrocardiographic leads. It was concluded, therefore, that extreme horizontal and vertical QRS axes obtained with conventional leads are due to the skewness of their effective lead axes. In spite of a considerable uniformity of loop configurations most normal ranges of other parameters were not significantly smaller than those of conventional lead systems. This was due mainly to intrinsic shortcomings of the applied analytic criteria.

Amplitude and directions of initial QRS vectors and Q waves were found to be a function of the further sequence of the QRS complex. Their significance can be increased by combined analysis of initial and main QRS vectors. Due to time differences in the onset of QRS in different leads, Q-wave measurements should be re-evaluated.

Maximal QRS vectors (often incorrectly designated as "mean" vectors) were identical in all 3 planes in only 10 percent of the cases. Large angular discrepancies between maximal QRS vectors of different planes indicated that this criterion cannot be used for spatial vector analysis.

The inadequacy of several commonly used electrocardiographic and vectorcardiographic criteria makes a re-evaluation of data analysis desirable. A decrease of the large scatter of normal findings would improve the electrocardiogram as a diagnostic tool. Further range reductions for corrected orthogonal lead systems appear possible by exploration of more adequate analytic criteria.

ACKNOWLEDGMENT

The author gratefully acknowledges the very helpful suggestions and criticisms of Dr. Edward D. Freis. He is very much indebted to Mrs. Hanna A. Pipberger for her technical assistance and the statistical analysis.

SUMMARIO IN INTERLINGUA

Corrigite orthogone derivationes electrocardiographique (systema SVEC III de Schmitt) esseva applicate a 100 subjectos normal con le objectivo de establis, de maniera preliminari, limites de normalitate como bases pro futur studios in serie pathologic. Proque le sistema in question pote esser usate in electrocardiographia e in vectorcardiographia, ambe methodos de presentation esseva usate in le analyse statistic. Le criterios electrocardiographie e vectorcardiographie usate esseva le criterios conventional.

Le relations temporal in le registrationes de ansas vectorial poteva esser determinate accuratemente solmente per le uso additional de derivationes scalar a registration simulanea. Le integration de derivation electronic per ansas vectorial se provava superior pro le determination del directiones vectorial. Le presentation vectorial e le presentation scalar a canales multiple pareva esser methodos complementari. Le uso de ambas resultava in un augmento del accuratia del datos registrate.

Le area de normalitate pro le direction de vectores QRS maximal esseva circa un medietate de illo obtenite in derivationes electrocardiographie conventional. Ergo il esseva concludente que extreme axes QRS horizontal e vertical obtenite con derivationes conventional es le resultato del obliquitate de lor efficace axes derivational. In despecto de un considerabile uniformitate del configurationes ansal, le areas de normalitate pro le majoritate del altere parametros non esseva significativemente minus diffuse que in le caso del systems de derivation conventional. Isto esseva causate principalmente per intrinsec debilitates del criterios analytic usate.

Le amplitude e le direction de initial vectores QRS e undas Q esseva recognoscite como functiones del sequentia subsequente in le complexo QRS. Lor significacion pote esser augmentate per le analyse combinante de vectores QRS initial e principal. A causa de differentias temporal in le declaration de QRS in diferente derivationes, le mesuration del unda Q deberea esser re-evaluata.

Vectores QRS maximal (frequentemente designate incorretamente como vectores "medie") esseva identic in omne le 3 planes in solmente 10 pro cento del cases. Grande discrepancias angular inter le vectores QRS maximal in diferente planes indicava que
istio criterio non poter essere usato in le analyse
de vectores spatial.

Le inadeguatio de plure criterios electrocardiographic et vectocardiographic in uso
commun rende desirabile un re-evaluation del
methodos usate in le analyse del datos. Un
minus extense area de normalitate pro le
varie parametros meliorare le utilitate del
electrocardiogramma como utensile diagnostic.
In le caso del systemas de corrigite
orthogone derivationes, un reduction de ille
areas de normalitate pare possibile per
esplorar plus adequate criterios analytice.

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An erratum has been published regarding this article. Please see the attached page for:
/content/18/2/286.full.pdf


ERRATUM
On pages 1104-1106 of the June issue (article by Hubert V. Pipherger) the amplitude data in tables 2 and 3 have to be divided by a constant factor of 1.75 for the correction of an error made in the computation.