The Relation of Precordial and Orthogonal Leads

By J. A. Abildskov, M.D., and Robert S. Wilkinson, Jr., M.D.

It has become evident that much of the diagnostic information now obtained from precordial leads may be furnished by an adequate orthogonal lead system. This is important to the further development of diagnostic electrocardiography, since quantitative description of only three variables has obvious advantages over the description of larger numbers of body surface leads.

At present the optimum methods of recording and analyzing orthogonal leads have not been established. Conventional electrocardiograms, vectorcardiograms, polar co-ordinate displays, the "normalized" electrocardiogram, and digital computer analysis are all under investigation. Whatever methods of display and analysis of orthogonal leads prove to be most useful, it is desirable that they utilize the extensive diagnostic experience that has been accumulated with precordial leads. This requires definition of the spatial relation between precordial and orthogonal leads.

In the present study, a systematic search was made for the effective lead axes derived from an orthogonal system that corresponded most closely to actual pcardial leads V1 through V6. This differed from cancellation studies in that clinically significant details of configuration were the basis for selection of effective orthogonal lead axes corresponding to pcardial leads.

The results will be presented as the effective position of orthogonal axes that corresponded to actual pcardial leads and as the per cent contribution of X, Y, and Z components of the heart vector to each pcardial lead.

Materials and Methods

Observations were made on 35 patients, five of whom had normal electrocardiograms and the remaining 30 had miscellaneous electrocardiographic abnormalities. These included nine patients with evidence of myocardial infarction, nine with electrocardiographic evidence of left ventricular enlargement, eight with nonspecific abnormalities of the ST segments and T waves, two with evidence of right bundle-branch block, one with right ventricular enlargement, and one with evidence of right bundle-branch block and myocardial infarction.

A conventional 12-lead electrocardiogram was obtained on each patient. Orthogonal leads were recorded with the triaxial reference system designed by MeFee and Parmgao. A resolver was employed to rotate one of the axes of this system to the positions illustrated in figure 1. Three positions of the Z axis rotated around the X axis were employed as shown in figure 1A. At each of these positions 15 rotations about the Y axis were employed as illustrated in figure 1B. An electrocardiographic lead was recorded at each of the 45 positions named.

Rotated orthogonal leads corresponding to pcardial leads were selected in a systematic manner. The first step in this selection was to choose those leads containing the major clinically significant features of the pcardial lead under consideration. For example, if the pcardial lead showed a Q wave, only rotated leads showing such a deflection were considered for further selection. If the pcardial lead showed ST-segment displacement in addition to a Q wave, only rotated leads with both of these features were selected for further consideration.

The second step in the selection process was to choose those rotated leads in which the polarity of major deflections was the same as in the pcardial lead being considered. The polarity of the P waves was matched in all but one instance in which lead V1 showed negative P waves and none of the rotated leads showed P waves of this polarity. The polarity of the T wave was matched in all leads selected. The polarity of individual deflections making up the QRS complex was also matched in

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all selected leads but the choice was not restricted to that lead in which the relative amplitudes of Q, R, and S deflections provided the closest match with the precordial lead. Such a restriction would often have limited the selection to a single lead and this was not always the lead in which the detailed form of the lead and the relative amplitude of QRS and T deflections most closely matched the precordial lead.

The third step in the selection process was to choose those rotated leads in which the detailed form closely approximated precordial leads. A variety of individual items was considered in this choice. Slurring of the QRS complex, relative length of initial and terminal limbs of the T wave, and form of the ST segment are representative of the items considered at this stage of the selection process.

The final step in the selection was a quantitative comparison of the ratio of amplitudes of the QRS complex and the T wave in the precordial lead to that in the rotated leads.

The steps in the selection process were taken in sequence and the process was carried as far as necessary to identify the rotated lead corresponding to a given precordial lead. If only one rotated lead showed the major clinically significant features of the precordial lead being considered, that lead was selected. If multiple rotated leads provided the same significant features of a precordial lead but in only one of these the polarity of all major deflections matched that in the precordial lead, that lead was chosen to correspond to the precordial lead. In a few instances, two or more rotated leads matched precordial leads equally well in all respects in which they were evaluated, and in these instances the position of a lead axis representing the average of these rotated leads was calculated.

**Table 1**

Per Cent Contribution of XYZ Leads to Each of the Average Effective Lead Axes Chosen to Correspond to Precordial leads V₁ through V₆.

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>V₁</td>
<td>17.8</td>
<td>0.6</td>
<td>81.6</td>
</tr>
<tr>
<td>V₆</td>
<td>0.5</td>
<td>0.1</td>
<td>99.5</td>
</tr>
<tr>
<td>V₇</td>
<td>28.3</td>
<td>0.0</td>
<td>71.5</td>
</tr>
<tr>
<td>V₈</td>
<td>46.5</td>
<td>0.2</td>
<td>53.2</td>
</tr>
<tr>
<td>V₉</td>
<td>85.4</td>
<td>0.7</td>
<td>13.9</td>
</tr>
<tr>
<td>V₁₀</td>
<td>99.1</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

*These contributions were calculated as follows:

X contribution = \( \sin^2 \Delta \cos^2 \Theta \)

Y contribution = \( \cos^2 \Delta \)

Z contribution = \( \sin^2 \Delta \sin^2 \Theta \)

Where \( \Delta \) indicated an angle measured from the negative Y axis and \( \Theta \) indicated an angle around the Y axis measured counterclockwise when viewed from the top of the body and with 0° directed posteriorly.

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*Figure 1*

_Diagrammatic representation of the rotated orthogonal lead positions employed in this study._ As shown in A, three positions of the rotated lead axis designated as \( \Delta \) were employed. At each of the lead axis positions illustrated in A, the 15 rotations designated as \( \Theta \) and illustrated in B were carried out.

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Examples of actual precordial leads and rotated orthogonal leads chosen to match the precordial leads. The record shown in A represents the poorest match obtained in the study. Even in this record the information concerning form of deflections, which was judged to have clinical significance in all precordial leads except V₁, was present in rotated orthogonal leads. The absolute value of the amplitude of deflections in precordial and rotated leads cannot be compared, since uniform standardization of both precordial and rotated leads was employed. Such standardization does not take into account the variable distance of precordial electrode sites as compared to the distance of orthogonal leads from the heart. Lead V₁ showed QRS complexes of small amplitude with variations in form related to respiration. Some complexes such as the first illustrated showed relatively prominent R waves. None of the rotated leads contained QRS complexes with this feature. The precordial leads shown in B show evidence of right bundle-branch block and all their clinically significant features were judged to be present in the rotated leads shown.

Results

Only one of the 240 precordial leads could not be matched with a rotated orthogonal lead with the same clinically significant features. The record including that lead is shown in figure 2A and is described in the legend of that figure. Figure 2B shows an example of the other records in which the clinically significant information in all precordial leads was considered to be present in the rotated orthogonal leads. The position of the rotated leads chosen to correspond to precordial leads is illustrated graphically in figure 3. In that figure the per cent of leads selected to match each precordial lead from the various rotated orthogonal lead positions is shown.

The average rotated lead axes chosen to correspond to each precordial lead are shown in
Precordial and Orthogonal Leads

Figure 3
The position of rotated leads chosen to correspond to precordial leads. The per cent of leads from the various rotated lead positions that were chosen to correspond to each precordial lead is indicated.

Figure 4
The lead axis corresponding to $V_1$ was directed upward and toward the right. Axes corresponding to $V_2$ through $V_6$ were successively directed more downward and toward the left. As shown in the figure the largest angular step was between axes corresponding to $V_2$ and $V_3$, which were separated by 36°. The smallest angular separation was between $V_3$ and $V_4$, which were only 11° apart.

Table 1 shows the contribution of orthogonal leads X, Y, Z to each of the average rotated axes chosen to correspond to precordial leads.

These contributions were calculated by considering each rotated lead to be a vector of unit length (lead vector). The XYZ-lead voltages were assumed to be orthogonal vector components that defined the lead vector. The scalar sum of the orthogonal components on the lead vector equals the length of the lead vector according to geometric laws. The ratio of these projections to the lead vector length gave the per cent contribution of XYZ leads to the lead vector.

As indicated in the table the rotated lead axis corresponding to precordial lead $V_6$ was contributed almost exclusively by orthogonal lead X. The rotated axis corresponding to $V_2$ was almost entirely contributed by orthogonal lead Z. All other axes corresponding to precordial leads received significant contributions.
from orthogonal leads X and Z and all but the one corresponding to V₃ received small contributions from lead Y.

Discussion

Results of this study furnish a basis for further evaluation of the information content of orthogonal leads. The average rotated lead axes corresponding to precordial leads provide a guide to the orthogonal lead location of information now obtained from precordial leads. For example, results indicate that information now obtained from lead V₄ is likely to influence leads X and Z approximately equally. Information now obtained from lead V₁ is also likely to influence both X and Z leads; however, the predominant influence will be on lead Z. Such data should be useful in utilizing the diagnostic experience already available from the interpretation of precordial leads for the evaluation of orthogonal electrocardiograms, vectorecardiograms, or other displays of cardiac electrical activity.

This study is not equivalent to a cancellation test of the dipole hypothesis of cardiac electrical activity. The initial criterion applied in the choice of rotated leads to match precordial leads in this study was the presence of the same features of form already known to have clinical significance. Application of this criterion required knowledge of the features with such significance and judgment concerning which rotated lead best duplicated those features. In cancellation studies, optimum quantitative cancellation of the total electrocardiogram may not represent optimum cancellation of the details with most diagnostic value.

Summary

A systematic search was made for the effective axes from an orthogonal lead system that best duplicated the diagnostically significant features of precordial leads.

Only one of 240 precordial leads was not matched with a rotated orthogonal lead having the same features judged to be clinically significant.

The average rotated lead axes corresponding to precordial leads V₁ through V₆ were systematically located from an axis directed upward and to the right corresponding to V₁ to one directed downward and to the left corresponding to V₆.

The location of these average rotated axes has been presented and the per cent contribution of XYZ leads to each of these axes has been calculated.

These results provide a guide to the orthogonal lead location of diagnostic information now obtained from precordial leads.

*Figure 4*

The average of the rotated lead axes chosen to correspond to precordial leads V₁ through V₆.
References

Lister
His brow spreads large and placid, and his eye
Is deep and bright, with steady looks that still.
Soft lines of tranquil thought his face fulfil—
His face at once benign and proud and shy.
If envy scout, if ignorance deny
His faultless patience, his unyielding will,
Beautiful gentleness and splendid skill,
Innumerable gratitudes reply.
His wise, rare smile is sweet with certainties,
And seems in all his patients to compel
Such love and faith as failure cannot quell.—
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