Anatomic and Electrocardiographic Position of the Heart

By Noble O. Fowler, M.D., and John R. Braunstein, M.D.

Thirty-four patients were studied by electrocardiogram for electrical position of the heart, and by x-ray and angiocardiogram for anatomic position of the heart. A significant association between electrocardiographic and anatomic positions of the heart was found insofar as rotation about the anteroposterior and longitudinal axes is concerned. No association between electrocardiographic and anatomic positions was found with regard to rotation about the transverse axis.

The heart may rotate about three anatomic axes: anteroposterior, becoming horizontal or vertical in position; longitudinal, becoming clockwise or counterclockwise in position as viewed from the apex; and transverse, causing the apex to move forward or backward. This is illustrated in figures 1, 2, and 3. This study was undertaken in order to ascertain whether or not the rotation of the heart about its three axes can be estimated from ordinary unipolar electrocardiographic leads.

In 1942, Master presented a detailed study concerning the effect of change in heart position upon the configuration of the standard leads of the electrocardiogram. In the same year Wilson described six positions of the heart from the electrocardiographic standpoint: horizontal, semihorizontal, vertical, semivertical, intermediate, and indeterminate. These positions were determined from a study of the relationship between the unipolar extremity leads and the unipolar precordial leads, and were concerned with rotation around the anteroposterior axis only. In 1943, Gardberg and Ashman, and in 1946, Ashman described forty-five electrocardiographic positions of the heart in the three standard leads produced by rotation of the heart about three axes: anteroposterior, transverse, and longitudinal. In the most recent edition of his monograph, Goldberger described criteria for determining the position of the heart with rotation about its three axes, using the unipolar extremity and precordial leads.

However, there have been few studies of the correlation between the electrocardiographic and anatomic positions of the heart in man. In 1946, Hyman, Failey, and Ashman showed that rotation of the human heart about its anteroposterior axis could be satisfactorily predicted from the standard electrocardiographic leads, using the criteria described by Ashman. In 1950 Rosenman and Katz indicated that studies in their laboratory had shown a high degree of correlation between the configuration of the unipolar electrocardiographic leads and the anatomic rotation of the heart about its anteroposterior axis if the heart were not grossly enlarged. There has been, however, no study to indicate whether or not rotation of the heart about its transverse and longitudinal axes can be determined from the electrocardiogram. For this reason the following study was made.

Material and Methods

Thirty-four subjects, selected from the wards of the Cincinnati General Hospital, were studied. Those having electrocardiograms which showed clearly the electrocardiographic position of the heart were given preference.

Anatomic Axes

Rotation about Anteroposterior Axis. A 7 foot anteroposterior teleoentgenogram of the chest was taken with the subject in the supine position. On the developed film, a line was drawn from the cardiac apex to the junction of the lower border of the right pulmonary artery with the cardiac silhouette. The
angle between this line and the horizontal of the roentgenogram was measured. This angle was used to determine the degree of rotation about the anteroposterior axis, a small angle indicating a horizontal position of the heart and a large angle, a vertical position of the heart.

Rotation about Transverse Axis. A 7 foot left lateral teleroentgenogram of the chest was made with the subject in the supine position. On the developed film, a line was drawn from the cardiac apex to the center of the lower border of the hilum of the lung. The angle between this line and the horizontal of the subject was measured. This angle was used to indicate the degree of forward or backward movement of the cardiac apex: a small angle indicated a backward displacement of the apex and a large angle, a forward displacement of the apex.

Rotation about Longitudinal Axis. With the subject in the supine position, an angiocardiogram was made according to the technic of Robb and Steinberg. Films were taken with the x-ray tube at a distance of 5 feet, the maximum permitted by the machine. After the injection of a radiopaque dye, films were exposed every half-second, using a Fairchild camera. Upon the developed films, the location of the junction between right and left ventricles was noted as shown by the dye-filled right ventricle. Since anterior or ventral rotation of the right ventricle occurs in clockwise rotation, and anterior rotation of the left ventricle in counterclockwise rotation, the degree of clockwise and counterclockwise rotation about the longitudinal axis could be determined. The per cent of the transverse diameter of the heart occupied by the right atrium and right ventricle at the level of the apex was measured. The distance from the midinternal line of the body to the left border of the right ventricle was also measured.

Electrocardiographic Position.

With the subject supine, the electrocardiogram was made with the Cambridge Simplitrol Electrocardiograph immediately before or immediately after the taking of the x-rays and angiocardiogram. Three standard leads, three unipolar extremity leads, and six or more unipolar precordial leads were taken. The criteria of electrocardiographic position outlined by Goldberger were used.

Anteroposterior Axis. The heart was considered to be horizontal if lead aVL contained a qR* or QR complex. The heart was considered vertical if lead aVL contained QS or Rs pattern.

Transverse Axis. The apex was considered to be displaced forward if lead aVL contained a qR complex. The apex was considered displaced backward if lead aVF contained an Rs complex or RS pattern.

Longitudinal Axis. Clockwise rotation was considered to be present if lead aVF contained a qR, QR, rs or RS complex. Counterclockwise rotation was considered to be present if leads V5, V4, or V3 contained a qR complex.

RESULTS

Anteroposterior Axis. The departure from the horizontal, as measured by x-ray, ranged between 22 and 54 degrees. For the purpose of statistical analysis, patients having rotation between 22 and 37.9 degrees were considered to have horizontal hearts. Those having rotation between 38 and 54 degrees were considered to have vertical hearts. Twenty-six of the 34 cases studied had electrocardiograms showing either horizontal or vertical position of the heart. Eighteen of these cases had normal electrocardiograms. The results are shown in table 1.

In only 3 cases did the electrocardiographic and anatomic positions fail to agree; only one of these was in a patient having a normal

* Following the usual convention, a small letter is used to indicate a relatively small deflection; a capital letter is used to indicate a relatively large deflection.

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**TABLE 1.—Rotation of the Heart about Its Anteroposterior Axis**

<table>
<thead>
<tr>
<th>Electrocardiographic Position</th>
<th>Anatomic Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Vertical</td>
<td>No. Horizontal</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

\[X^2 = 11.65; p < 0.01\]
electrocardiogram. In the 3 cases where the x-ray and electrocardiogram failed to agree, the hearts were vertical anatomically and horizontal electrocardiographically. In each of these 3 cases the hearts were only slightly vertical, having anatomic axes at 40, 40 and 41 degrees from the horizontal. The results shown in table 1 were analyzed by the chi square test and were found to show a high degree of association between the anatomic and electrocardiographic positions insofar as rotation about the anteroposterior axis is concerned. Chi square was 11.65, giving a $p$ much less than 0.01, which is a highly significant value, and would occur by chance much less often than once in one hundred times.

**Table 2.—Rotation of the Heart about Its Transverse Axis**

<table>
<thead>
<tr>
<th>Electrocardiographic Position</th>
<th>Anatomic Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Forward</td>
<td>No. Forward</td>
</tr>
<tr>
<td>No. Back</td>
<td>No. Back</td>
</tr>
<tr>
<td>$X^2 = 0.495; p &gt; 0.50$</td>
<td>$X^2 = 0.495; p &gt; 0.50$</td>
</tr>
</tbody>
</table>

**Transverse Axis.** The angles found after measurement upon the films varied from 25 to 57 degrees. Those hearts having an angle between 25 and 40.9 degrees were considered to have backward rotation of the apex; those having angles between 41 and 57 degrees were considered to have forward rotation of the apex. Twenty-seven of the 34 cases studied had electrocardiograms showing forward or backward rotation of the cardiac apex in accordance with the criteria given above. Eighteen of the 34 cases studied had normal electrocardiograms. The results are shown in table 2. In only 12 of the 27 cases did the electrocardiographic and anatomic positions agree. A statistical analysis of the results, using the chi square test gave a $p$ value of slightly more than 0.50, indicating no statistical significance in the results obtained. In other words, in 12 cases out of 27, electrocardiographic position could easily be the same as the anatomic position as a result of chance alone.

**Longitudinal Axis.** Angiocardiograms were made in 22 of the 34 patients. Those cases in whom the right atrium and right ventricle occupied 26.6 per cent to 47.4 per cent of the transverse diameter of the heart were considered to have counterclockwise rotation; those in whom the right auricle and right ventricle occupied 47.4 per cent to 68.3 per
cent of the transverse diameter of the heart were considered to have clockwise rotation about the longitudinal axis. Unfortunately, only 13 of the 22 cases studied had electrocardiograms revealing definite clockwise or counterclockwise rotation according to the criteria above. The results are shown in table 3. The number of cases is too small to be analyzed by the chi square test. In order to study the problem in another way, a graph of the electrocardiographic and anatomic locations of the transitional zones was made (fig. 4). The ordinate shows distances from the midline of the chest to the left border of the right ventricle. The abscissa shows the location of the transitional zone according to the precordial unipolar leads of the electrocardiogram. The transitional zone electrocardiographically was
taken at the point where the R and S waves of one of the six unipolar precordial leads were of equal amplitude. As shown by the graph, the correlation is by no means linear. However the correlation coefficient was calculated. The $r$ value was 0.63. This value is very significant since any $r$ above 0.590 is significant at the 1 per cent level when there are sixteen degrees of freedom and two variables, as in the present instance. It also indicates that there is a very significant correlation between the anatomic and electrocardiographic locations of the transitional zone. Both, however, are influenced by other factors and one can by no means be predicted from the other with any degree of accuracy.

**Discussion**

Wilson, in discussing rotation about the anteroposterior axis, indicated that there should exist a high degree of correlation between electrocardiographic and anatomic positions of the heart, but stated that perfect correlation should not be expected. The best correlation, according to Wilson, is to be anticipated when the electrocardiogram is normal, or shows no abnormality other than ventricular hypertrophy or bundle branch block. The high degree of correlation found in this study between electrocardiographic and anatomic positions of the heart with regard to rotation about the anteroposterior axis bears out Wilson's statement.

**Table 3.—Rotation of the Heart about Its Longitudinal Axis**

<table>
<thead>
<tr>
<th>Electrocardiographic Position</th>
<th>Anatomic Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Clockwise</td>
</tr>
<tr>
<td>No. Clockwise</td>
<td>7</td>
</tr>
<tr>
<td>No. Counterclockwise</td>
<td>4</td>
</tr>
<tr>
<td>Undetermined</td>
<td>5</td>
</tr>
</tbody>
</table>

The lack of significant association between electrocardiographic and anatomic position of the heart insofar as rotation about the transverse axis is concerned would seem to indicate that the electrocardiographic criteria of Goldberger cannot be used to predict rotation about the transverse axis. Goldberger admits that in horizontal hearts, the apex may be backward by his criterion—that is, lead $aV_p$ shows an rs or RS pattern—and forward when seen fluoroscopically.

Unfortunately, insufficient cases were studied to test the criteria of Goldberger with regard to electrocardiographic prediction of rotation
of the heart about the longitudinal axis. However, the validity of the location of the electrocardiographic transitional zone as a criterion of rotation about the longitudinal axis was tested. A significant correlation was shown between the electrocardiographic and anatomic locations of the transitional zones. The correlation between the two is not linear, however, and it must be borne in mind that backward displacement of the apex may cause an apparent shift of the transitional zone to the left in the electrocardiogram.

SUMMARY AND CONCLUSIONS

An electrocardiographic and anatomic study of rotation of the heart about its anteroposterior, transverse, and longitudinal axes was made in 34 subjects. A high degree of correlation was found between the electrocardiogram and x-ray insofar as rotation about the anteroposterior axis is concerned. No correlation between the electrocardiogram and x-ray was found with regard to rotation about the transverse axis. With regard to rotation about the longitudinal axis, there was found a very significant correlation between electrocardiographic and roentgenologic locations of the transitional zone.

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