VENTRICULAR HYPERTROPHY AND THE ELECTRICAL AXIS OF THE QRS COMPLEX IN INFANCY

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The recognition of ventricular hypertrophy is of paramount importance in the differential diagnosis of congenital anomalies of the cardiovascular system. In infancy the distinction between right and left ventricular hypertrophy may be impossible on clinical grounds, and the information contributed by radiological examination may be indecisive. In such circumstances considerable reliance is placed on the electrocardiographic appearances and especially on those in the unipolar precordial leads. Even so the recognition of mild hypertrophy may prove difficult largely because of the physiological preponderance of the right ventricle in early infancy and the gradual transition to left ventricular preponderance which follows (Massie and Walsh, 1960).

The electrical axis of the QRS complex, sometimes described as the mean manifest electrical axis of the QRS complex, is the frontal mean QRS vector or mean direction of the electrical forces associated with ventricular depolarization as projected in the frontal plane. Deviation of this axis or vector beyond the normal range is still regarded by some as a sign of diagnostic value in childhood (Nadas, 1957). Its validity as a measure of ventricular hypertrophy can be criticized, however, not only because the electrodes of the extremity leads from which the electrical axis is calculated are distant from the heart, but also because the axis is affected by the electrical position of the heart within the thorax. For this reason more reliable information regarding ventricular hypertrophy is expected from an analysis of the unipolar precordial leads to which these criticisms apply with less force. Nevertheless, just as the electrical axis reflects only the frontal projection of the cardiac vector, the precordial leads reflect electrical forces only in the horizontal plane (Massie and Walsh, 1960).

In an attempt to determine whether in infancy the electrical axis of the QRS complex is of any value in the diagnosis of right and left ventricular hypertrophy an analysis was made of the electrical axes of 100 healthy infants and of a group of patients subsequently shown to have preponderant right or left ventricular hypertrophy at autopsy.

MATERIAL AND METHODS

One hundred subjects aged from 2 weeks to 12 months, 25 in each quarter of the first year of life, were examined during a routine visit to the Child Welfare Clinic at the Royal Hospital for Sick Children, Glasgow. All were healthy and, in particular, none showed clinical evidence of heart disease. The standard limb leads were recorded simultaneously by means of a photographic electrocardiograph standardized before each examination so that beam deflections of 10 mm. represented 1 millivolt. The subjects were recumbent and recordings were made between 1 and 2 hours after a feed. The mean deflection of QRS complexes in each of 2 leads (usually leads I and III) were plotted as points on the appropriate sides of Einthoven’s equilateral triangle and the electrical axis

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of the QRS complex was indicated by the line drawn from the centre of the triangle through the intersection of perpendiculars dropped from these points.

Electrocardiograms were also examined from 19 infants suffering from congenital heart disease who died in heart failure and who at autopsy were found to have preponderent right or left ventricular hypertrophy. These electrocardiograms were recorded in a similar manner to those of the normal controls within one month before death. The electrical axis was calculated and correlated with the cardiovascular findings at autopsy.

In the description and discussion of results the mean manifest electrical axis of the QRS complex will be referred to as the "electrical axis," whereas the term "mean electrical axis" will be used to denote the arithmetic mean of groups of observations.

RESULTS

Healthy Infants. The electrical axis of the healthy subjects lay between +6° and +177°. Its correlation coefficient (r) with age was negative (−0·391) and highly significant (p<0·01) which indicates that the electrical axis moves to the left with increasing age. There was no significant correlation between the electrical axis and heart rate (r=+0·189).

An analysis of the variance of the electrical axis between the 4 quarters of the sample disclosed a highly significant value (F=12·1, p<0·001); this was a reflection of significant differences between their mean values except between those of the third and fourth quarters whose difference did not exceed twice their standard error. These findings indicate that the leftward trend of the electrical axis is much less pronounced during the second 6 months of life, and this is in agreement with the results of Ziegler (1951). The data from the third and fourth quarters have therefore been combined in Table I whereas those from the first and second quarters are given separately.

<table>
<thead>
<tr>
<th>TABLE I</th>
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<td>Electrical Axis in Healthy Infants</td>
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<table>
<thead>
<tr>
<th>Age</th>
<th>Number</th>
<th>Range of measured electrical axis</th>
<th>Arithmetic mean</th>
<th>Standard deviation (S.D.)</th>
<th>Statistical range (mean±2 S.D.)</th>
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<tbody>
<tr>
<td>2 weeks/3 months</td>
<td>25</td>
<td>+57° to +145°</td>
<td>+93°</td>
<td>26·37°</td>
<td>+41° to +146°</td>
</tr>
<tr>
<td>3/6 months</td>
<td>25</td>
<td>+30° to +177°</td>
<td>+73°</td>
<td>33·67°</td>
<td>+5° to +140°</td>
</tr>
<tr>
<td>6/12 months</td>
<td>50</td>
<td>+6° to +136°</td>
<td>+60°</td>
<td>24·36°</td>
<td>+11° to +108°</td>
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With increasing age the mean values declined but an important feature is the wide range of values in each group, reflected by large standard deviations (S.D.). The normal statistical range (arithmetic mean ±2 S.D.), has been calculated because, if the samples are representative, 95 per cent of values from a normally distributed population should fall within this range. In the youngest age group (25 subjects) all the measured values were within this range. In the age group 3 to 6 months (25 subjects) all but 2 (+156°, +177°) were within this range, and in the age group 6 to 12 months (50 subjects) all but 3 (+6°, +9°, +136°).

Infants with Ventricular Hypertrophy. The electrical axes of the QRS complex of 10 infants found at autopsy to have predominant right ventricular hypertrophy are given in Table II and compared with the statistical range derived from the control series of healthy infants.

Only one of the 6 patients less than 3 months old (No. 2) but all four of the older patients (Nos. 7, 8, 9, and 10) had axis deviation to the right of the statistical range established for healthy infants. However, the unipolar precordial leads of 2 patients (Nos. 8, 10) with, and of 2 patients (Nos. 4, 5) without, significant right axis deviation gave no diagnostic evidence of right ventricular hypertrophy.
The electrical axes of the QRS complex of 9 infants found at autopsy to have preponderant left ventricular hypertrophy are given in Table III and compared with the statistical range derived from the examination of healthy infants. Two of the 3 patients less than 3 months old (Nos. 11, 12) and 4 of the 6 older patients (Nos. 14, 16, 18, 19) showed left axis deviation beyond the range encountered in healthy infants. The electrical axis of another (No. 17) lay close to the limit of the normal range. Right ventricular hypertrophy in addition to left was discovered at autopsy in another case (No. 15) whose unipolar precordial leads showed evidence of hypertrophy of both ventricles. In the precordial leads of 2 patients with significant left axis deviation (Nos. 12, 16) there was no conclusive evidence of left ventricular hypertrophy.
Confirmation has been obtained for the view (Ziegler, 1951) that in early infancy the electrical axis of the QRS complex lies further to the right than in later childhood. It has been shown moreover that during the first 9 months its mean position moves towards the left. It is remarkable however that during the second 6 months of life there is no substantial change in direction, and that during this period the mean value and the statistical range are similar to those encountered in adult life (White, 1951; Wood, 1950). The simplest explanation for this finding would be that the ratio between the right and left ventricles in terms of their myocardial mass remains unchanged after the age of nine months. The recent work of Emery and Mithal (1961) has shown however that throughout childhood this ratio alters very little from about the age of 3 months, and it is clear therefore that additional factors are involved to bring about the slower transition of the electrocardiographic pattern.

An outstanding feature of the individual values for the electrical axis of healthy infants is their wide scatter about their mean values. That this is not peculiar to the present series is indicated by the data supplied by Ziegler (1951), and it is noteworthy that his mean values for the age groups 3 to 6 months (+67°) and 6 to 12 months (+64°) are remarkably similar to those of the corresponding groups in the present series (+73°, +60° respectively). His mean for the age group 1 to 3 months (+76°) does not resemble so closely the mean of 18 healthy infants of the same age in the present series (+88°), but his mean for infants aged from 1 week to 1 month (+105°) and that of 7 infants aged from 2 weeks to 1 month in the present series are again closely similar (+107°). This similarity between the mean values of the two series argues the existence of a remarkably stable balance throughout infancy between the forces which determine the electrical axis of the QRS complex, namely the electrical activity of the myocardium and the position of the heart within the thorax. There is reason therefore to expect that in the event of preponderant hypertrophy of either ventricle the balance would be disturbed and abnormal deviation of the electrical axis would result. Because of the wide scatter of normal values it remains to be determined whether this deviation is likely to be appreciable and therefore of diagnostic value.

Nadas (1957) expressed the opinion that axis deviation of +120° or more suggests right ventricular hypertrophy and this condition was satisfied by all the patients in this series with right ventricular hypertrophy. The wide range of normal values would suggest that this value is likely to be exceeded by some healthy infants particularly in the first 6 months of life, as was the case in 6 (12%) of this age group in the control series. Of the 50 healthy subjects older than 6 months only 1 had right axis deviation greater than +120°. Left ventricular hypertrophy according to Nadas (1957) is accompanied in 50 per cent of cases by leftward deviation of the electrical axis to more than −30°, a condition satisfied by only 4 of the 9 patients who had preponderant left ventricular hypertrophy at autopsy. In contrast to the value given by Nadas (1957) for the diagnosis of right ventricular hypertrophy, his value for the diagnosis of left ventricular hypertrophy lies so far outside (mean minus > 3 S.D.) the statistical ranges established for healthy infants in the present series that this diagnostic criterion would seem unlikely to be satisfied in instances in which there is only mild hypertrophy. Indeed 2 patients in this series (Nos. 18, 19) with tricuspid atresia and with preponderant, and unquestionably severe, left ventricular hypertrophy showed electrical axis deviation of only −18° and −15° respectively.

It is clear therefore that in certain cases of preponderant right ventricular hypertrophy the electrical axis gives no useful information because it may remain within the normal statistical range, and that this is more likely to occur in infants less than 6 months old. On the other hand preponderant left ventricular hypertrophy should be more often detected from deviation of the electrical axis because there is less likelihood in this instance of the angles of deviation shown by patients coinciding with the physiological range.

Eleven of 19 patients (58%) with preponderant right or left ventricular hypertrophy showed an electrical axis very significantly different from the mean electrical axis of healthy infants; this indicates that in some patients the electrical axis can supply independent confirmation of ventricular
hypertrophy. The unipolar precordial leads of 2 infants whose electrical axis was within the normal range gave no clear evidence of the right ventricular hypertrophy which was found at autopsy. In 4 infants however, 2 with right and 2 with left ventricular hypertrophy, the electrical axis suggested ventricular hypertrophy whereas the unipolar precordial leads failed to do so; this indicates that the electrical axis may on occasion give more reliable evidence than the præcordial leads of the presence of ventricular hypertrophy.

**SUMMARY AND CONCLUSIONS**

The mean manifest electrical axis of the QRS complex (electrical axis) of 100 healthy infants was found to lie within the range $+6^\circ$ to $+177^\circ$. The gradual leftward trend through the first 9 months of life from right axis deviation was demonstrated, and also the relative stability of the electrical axis during the second 6 months of life.

During the first 6 months of life determination of the electrical axis is of little value in the diagnosis of right ventricular hypertrophy. Confirmatory evidence of right ventricular hypertrophy in older infants and of left ventricular hypertrophy throughout infancy may however be obtained from the electrical axis. In a few instances it may also give an indication of ventricular hypertrophy when appearances in the precordial leads are equivocal. It is concluded that measurement of the electrical axis of the QRS complex should not be neglected when evidence of ventricular hypertrophy is sought, but that the significance of values obtained can be determined only by comparison with the range of values encountered in healthy infants of the same age.

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**REFERENCES**