Electrocardiogram in Asthmatic Children

By Terumasa Miyamoto, M.D., Irving Kass, M.D., and Murray S. Hoffman, M.D.

The electrocardiogram of presumably normal infants and children has been the subject of extensive investigation. On the other hand, an extensive review of the literature failed to reveal reports of the electrocardiograms of infants and children suffering from pulmonary disease.

Ziegler in 1951 recorded the electrocardiograms of normal infants and children ranging in age from birth to 16 years. Using only standard and unipolar extremity leads, he studied 250 children initially. Later complete electrocardiograms were taken on 300 children with the 3 standard extremity leads, augmented unipolar leads, and 6 unipolar precordial leads. Electrocardiograms of 137 children suffering from airway obstruction diagnosed as bronchial asthma are evaluated and compared with those of Ziegler's normal group.

Methods and Materials

A 13-lead electrocardiogram taken with a direct-writing instrument (General Electric Cardioscribe) was obtained on 137 asthmatic children in residence at the Jewish National Home for Asthmatic Children, Denver, Colorado. The patients had intractable bronchial asthma, which had not responded well to medical management prior to removal from home. Patients with acute severe obstruction were not studied until their airway obstruction lessened.

All electrocardiograms were recorded with the patient in the supine position. With the exception of the routine asthmatic regimen, no other medications were used. Ages of the patients ranged from 5 to 16 years. Table 1 shows the relationship between age and sex, and duration of symptoms.

The heart rate, duration of P wave, P-R interval, QRS complex, P-T interval, the amplitude of P waves, R waves, and S waves, and the time of onset of the intrinsic deflection were measured. The widest P wave, QRS complex, P-R interval, and Q-T interval were chosen for the measurement of the duration, as described by Ziegler. These figures were then compared with Ziegler's published data to see if there were any statistically valid variations from his normal electrocardiographic studies.

All data were subjected to the "t test" for unpaired data in order to determine their statistical significance. Probability of less than 0.05, the usual level accepted for significance of biologic phenomena, indicated that the groups most likely did not come from the same population. For simplicity, only significant data have been presented.

Results

P Waves

The mean values of the amplitude of the P waves were lower in all the leads in all age groups of asthmatic children than in normal children.

Statistically significant results were found in all leads except lead III (table 2). There was also some prolongation of the P waves in the younger age groups (table 3).

R Waves

The R waves were lower in almost all leads in all age groups of asthmatic children than in normal children. This difference was especially pronounced in the precordial leads (table 4). Significant differences were found in leads I, aV1, V3, V4, and V5 in all age groups.

S Waves

There were no significant differences in the amplitude of S waves in the limb leads. In all age groups, however, the S wave in aVR was

\[ t = \sqrt{\frac{\sum (x_1 - \bar{x})^2 + \sum (x_2 - \bar{x})^2}{N_1 + N_2 - 2 \left( \frac{N_1}{N_1} + \frac{N_2}{N_2} \right)}} \]

\[ \bar{x}_1 = \text{mean of group 1} \]
\[ \bar{x}_2 = \text{mean of group 2} \]
\[ \Sigma (x - \bar{x})^2 = \text{sum of squares of the differences between the mean and each variate} \]
\[ N_1 = \text{number of variates in group 1} \]
\[ N_2 = \text{number of variates in group 2} \]

From the National Jewish Hospital at Denver, Denver, Colo.
ELECTROCARDIOGRAM IN ASTHMATIC CHILDREN

Table 1
The Duration of Asthmatic Attacks Related to Age and Sex

<table>
<thead>
<tr>
<th>Age groups (yrs.)</th>
<th>&lt;2 yrs.</th>
<th>2-4*</th>
<th>4-6</th>
<th>6-8</th>
<th>Durations (years) 5-10</th>
<th>10-12</th>
<th>12-14</th>
<th>14-16</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>8-12</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>19</td>
<td>19</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>12-16</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>15</td>
<td>6</td>
<td>5</td>
<td>47</td>
</tr>
</tbody>
</table>

*Between 2 years and the end of the third year.
F, female patients; M, male patients.

Table 2
Mean Values of Amplitude of P Waves

<table>
<thead>
<tr>
<th>Age</th>
<th>Leads</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>aV_R</th>
<th>aV_L</th>
<th>V_1</th>
<th>V_2</th>
<th>V_3</th>
<th>V_4</th>
<th>V_5</th>
<th>V_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N</td>
<td>1.1</td>
<td>1.7</td>
<td>0.8</td>
<td>-1.3</td>
<td>0.5</td>
<td>1.3</td>
<td>1.5</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
<td>-0.8</td>
<td>0</td>
<td>0.7</td>
<td>0.7</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>8-12</td>
<td>N</td>
<td>1.0</td>
<td>1.5</td>
<td>0.7</td>
<td>-1.3</td>
<td>0.6</td>
<td>1.2</td>
<td>1.4</td>
<td>1.3</td>
<td>1.1</td>
<td>1.0</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.7</td>
<td>1.0</td>
<td>0.6</td>
<td>-0.8</td>
<td>0.1</td>
<td>0.8</td>
<td>0.5</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>12-16</td>
<td>N</td>
<td>1.0</td>
<td>1.6</td>
<td>0.9</td>
<td>-1.2</td>
<td>0.4</td>
<td>1.2</td>
<td>1.1</td>
<td>1.2</td>
<td>1.0</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>0.6</td>
<td>1.0</td>
<td>0.5</td>
<td>-0.8</td>
<td>0.1</td>
<td>0.9</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

*Measured in 1/10 millivolt.
N, normal children; A, asthmatic children.

significantly smaller in the asthmatic children. In the right precordial leads, the asthmatic children showed a decreased amplitude of the S waves, which became significantly deeper in all age groups in the left precordial leads (table 5). When compared with normal children, the difference was statistically valid particularly in leads V2, V4, and V5.

Intrinsicoid Deflection
The onset of the intrinsicoid deflection was delayed in the right precordial leads (V1 and V2) in all age groups of the asthmatic children; however, no significant difference was demonstrated in the left precordial leads, (V5 and V6) as shown in table 6.

Duration of QRS Interval
No difference was found in the 5 to 8-year-old group, but significant difference was demonstrated in the 8 to 12 and 12 to 16-year-old groups (table 7).

Heart Rate, Duration of P-R and Q-T Intervals
The heart rates, particularly in older age groups, were more rapid in asthmatic children (table 8). However, there was no statistical difference in the duration of P-R and Q-T intervals.

Discussion
The electrocardiograms in the asthmatic children differed from the electrocardiograms of normal children as documented by Ziegler in the following important respects:
Table 4

Mean Values of Amplitude of R Waves

<table>
<thead>
<tr>
<th>Age</th>
<th>Leads</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>aVR</th>
<th>aVL</th>
<th>aVF</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N</td>
<td>6.1</td>
<td>12.2</td>
<td>8.3</td>
<td>1.6</td>
<td>2.5</td>
<td>9.1</td>
<td>6.7</td>
<td>11.5</td>
<td>13.1</td>
<td>25.3</td>
<td>20.2</td>
<td>13.4</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>4.0</td>
<td>12.2</td>
<td>9.1</td>
<td>1.2</td>
<td>1.4</td>
<td>10.6</td>
<td>5.0</td>
<td>7.6</td>
<td>8.1</td>
<td>9.7</td>
<td>12.1</td>
<td>12.7</td>
</tr>
<tr>
<td>8-12</td>
<td>N</td>
<td>6.3</td>
<td>13.2</td>
<td>8.3</td>
<td>1.4</td>
<td>2.6</td>
<td>10.0</td>
<td>5.7</td>
<td>9.6</td>
<td>10.8</td>
<td>25.1</td>
<td>21.9</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>4.2</td>
<td>11.8</td>
<td>8.6</td>
<td>1.4</td>
<td>1.3</td>
<td>10.0</td>
<td>4.5</td>
<td>7.1</td>
<td>8.0</td>
<td>12.8</td>
<td>12.1</td>
<td>11.4</td>
</tr>
<tr>
<td>12-16</td>
<td>N</td>
<td>5.6</td>
<td>13.2</td>
<td>8.6</td>
<td>1.3</td>
<td>2.4</td>
<td>1.3</td>
<td>4.8</td>
<td>8.1</td>
<td>10.4</td>
<td>22.2</td>
<td>17.2</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>3.7</td>
<td>11.6</td>
<td>8.3</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
<td>3.7</td>
<td>7.0</td>
<td>8.6</td>
<td>15.9</td>
<td>13.2</td>
<td>10.3</td>
</tr>
</tbody>
</table>

*Measured in 1/10 millivolt.
N, normal children; A, asthmatic children.

Table 5

Mean Value of Amplitude of S Wave

<table>
<thead>
<tr>
<th>Age</th>
<th>Leads</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>aVR</th>
<th>aVL</th>
<th>aVF</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N</td>
<td>2.1</td>
<td>1.5</td>
<td>0.9</td>
<td>4.8</td>
<td>2.9</td>
<td>1.0</td>
<td>12.7</td>
<td>22.2</td>
<td>15.0</td>
<td>6.6</td>
<td>2.4</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>1.7</td>
<td>1.4</td>
<td>0.7</td>
<td>4.6</td>
<td>3.0</td>
<td>0.8</td>
<td>11.9</td>
<td>16.4</td>
<td>17.0</td>
<td>14.5</td>
<td>10.0</td>
<td>7.0</td>
</tr>
<tr>
<td>8-12</td>
<td>N</td>
<td>1.7</td>
<td>1.5</td>
<td>1.0</td>
<td>6.8</td>
<td>2.7</td>
<td>1.0</td>
<td>14.0</td>
<td>23.2</td>
<td>13.2</td>
<td>6.3</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>1.6</td>
<td>2.0</td>
<td>1.2</td>
<td>5.1</td>
<td>3.1</td>
<td>0.8</td>
<td>10.5</td>
<td>15.5</td>
<td>14.6</td>
<td>11.6</td>
<td>7.9</td>
<td>4.7</td>
</tr>
<tr>
<td>12-16</td>
<td>N</td>
<td>1.4</td>
<td>1.4</td>
<td>0.9</td>
<td>6.1</td>
<td>2.4</td>
<td>0.9</td>
<td>13.4</td>
<td>22.0</td>
<td>10.6</td>
<td>4.6</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>1.4</td>
<td>1.7</td>
<td>0.9</td>
<td>3.7</td>
<td>2.6</td>
<td>1.2</td>
<td>12.1</td>
<td>17.2</td>
<td>13.5</td>
<td>8.6</td>
<td>5.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*Measured in 1/10 millivolt.
N, normal children; A, asthmatic children.

Table 6

Interval between Onset of QRS Complex and Onset of Intrinsicoid Deflection

<table>
<thead>
<tr>
<th>Age</th>
<th>No. of cases</th>
<th>V1</th>
<th>V4</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N 40 (41)**</td>
<td>.013</td>
<td>.008</td>
</tr>
<tr>
<td></td>
<td>A 25</td>
<td>.021</td>
<td>.014</td>
</tr>
<tr>
<td>8-12</td>
<td>N 44 (45)**</td>
<td>.014</td>
<td>.009</td>
</tr>
<tr>
<td></td>
<td>A 65</td>
<td>.022</td>
<td>.007</td>
</tr>
<tr>
<td>12-16</td>
<td>N 45</td>
<td>.013</td>
<td>.010</td>
</tr>
<tr>
<td></td>
<td>A 47</td>
<td>.023</td>
<td>.008</td>
</tr>
</tbody>
</table>

*Mean value, measured in seconds.
†Standard error of the mean.
‡Value of t test.
§Probability.
**No. in parentheses are number of cases, recorded in V6.
N, normal children; A, asthmatic children.

P Waves

The P waves of the asthmatic children were lower in voltage than in normal children (table 2). The degree of pulmonary hyperinflation and the voltage of the P waves appeared to be related. In terms of specific resistance (ohm/cm.), Kaufman and Johnston16 reported that the deflated lung had 401 ohm/cm.; inflated lung had 744 to 766 ohm/cm.; and superinflated lung had 1,227 to 1,367 ohm/cm. specific resistance. Table 9 reveals the results of chest x-rays in our asthmatic children: 18 per cent had increased roentgenographic radiolucency and 32 per cent had anterior bulging of the thorax. From these data it appeared that the low amplitude
of the P waves could be attributed not only to the pulmonary hyperinflation but to the secondary displacement of the heart.

**R Waves**

The R waves are generally low in voltage, especially in the left precordial leads, in asthmatic children (table 4). In 1930 Wilson indicated the following factors as the principal responsible for lower voltage: lower potential produced by a diseased condition of heart muscle; accidental neutralization of effects of different parts of the heart; and changes in conductivity of tissues adjacent to the heart. The electrocardiograms of asthmatic children showed generalized low voltage of R waves as part of the effect of decreased pulmonary conductivity.

**S Waves**

If the excitatory process were still spreading through some part of the ventricular wall when the intrinsicoid deflection occurred, the negativity of the ventricular cavity should outlast this deflection and the S wave should be inscribed. In asthmatic children, S waves over the left precordial were remarkably deep in comparison with normal children (table 5). In right ventricular hypertrophy generally speaking, S waves are relatively prominent over the left precordial leads. Such changes may not be specifically diagnostic since they could be the result of simple rotation of a normal heart. It seems plausible, however, that the abnormally deep S waves in left precordial in asthmatic children may constitute an early sign of right ventricular hypertrophy.

**Intrinsicoid Deflection**

The intrinsicoid deflection is recorded when the activation wave reaches the subepicardial muscle of the heart underlying the exploring electrode. The measurement of the time of onset of intrinsicoid deflection, particularly in the right precordial leads, is difficult and at times may be inaccurate. In this study there was slight delay in intrinsicoid deflections in right precordial leads in asthmatic as compared with normal children (table 6). This delay may be attributable to early right ventricular hypertrophy in asthmatic children.

**Duration of QRS Complex**

The duration of the QRS complex was significantly prolonged in asthmatic children as compared with normal children (table 7), although there were a number of individual exceptions. Myers and his associates stated that when QRS duration was compared with

---

**Table 7**

<table>
<thead>
<tr>
<th>Age</th>
<th>No. of cases</th>
<th>S.E.</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N 90</td>
<td>.07</td>
<td>.001</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A 25</td>
<td>.07</td>
<td>.002</td>
<td></td>
</tr>
<tr>
<td>8-12</td>
<td>N 87</td>
<td>.07</td>
<td>.001</td>
<td>6.2 &lt;.001</td>
</tr>
<tr>
<td></td>
<td>A 65</td>
<td>.08</td>
<td>.0012</td>
<td></td>
</tr>
<tr>
<td>12-16</td>
<td>N 68</td>
<td>.07</td>
<td>.0012</td>
<td>5.8 &lt;.001</td>
</tr>
<tr>
<td></td>
<td>A 47</td>
<td>.08</td>
<td>.0014</td>
<td></td>
</tr>
</tbody>
</table>

*Mean value, measured in seconds.
†Standard error of the mean.
§Probability.
N, normal children; A, asthmatic children.

**Table 8**

<table>
<thead>
<tr>
<th>Age</th>
<th>No. of cases</th>
<th>X*</th>
<th>S.E.</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8</td>
<td>N 90</td>
<td>96.2</td>
<td>1.8</td>
<td>1.07</td>
<td>.3 &lt; P &lt; .2</td>
</tr>
<tr>
<td></td>
<td>A 25</td>
<td>98.8</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8-12</td>
<td>N 88</td>
<td>78.5</td>
<td>1.6</td>
<td>4.2</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>A 65</td>
<td>88.6</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12-16</td>
<td>N 66</td>
<td>75.4</td>
<td>1.6</td>
<td>4.3</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>A 47</td>
<td>83.3</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Mean value, measured per minutes.
†Standard error of the mean.
‡Value of t test.
§Probability.
N, normal children; A, asthmatic children.

**Table 9**

<table>
<thead>
<tr>
<th>Age group (yrs.)</th>
<th>Increased radiolucency (localized or generalized)</th>
<th>Anterior bulging of thorax</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-8 yrs.</td>
<td>4 (16%)</td>
<td>8 (32%)</td>
<td>25</td>
</tr>
<tr>
<td>8-12 yrs.</td>
<td>11 (17%)</td>
<td>20 (31%)</td>
<td>65</td>
</tr>
<tr>
<td>12-16 yrs.</td>
<td>10 (22%)</td>
<td>16 (43%)</td>
<td>47</td>
</tr>
<tr>
<td>Total</td>
<td>25 (18%)</td>
<td>44 (32%)</td>
<td>137</td>
</tr>
</tbody>
</table>

**Circulation, Volume XXII, July 1960**
heart weight, a trend was found toward slightly longer QRS duration with increasing weight, even though no close correlation could be made. It can, therefore, reasonably be concluded that the ventricular mass of the adolescent asthmatic patient is increased as compared with the normal.

**Heart Rate and Duration of P-R and Q-T Intervals**

Heart rates were increased in the older asthmatic age groups (table 8), but the clinical significance of this finding is not clear. Although the duration of P-R and Q-T intervals became longer with increasing age in both asthmatic and normal children, there was no significant difference between the 2 groups.

**Electrocardiographic Position of the Heart**

In 1952 Goodwin18 charted the electrocardiographic position of the heart in 53 healthy children from 16 months to 15 years in age. The heart assumed the intermediate position in 29 cases (55 per cent), vertical position in 21 cases (40 per cent), and horizontal position in 3 cases (5 per cent). There was a great discrepancy between these cases and our asthmatic children (table 10).

The asthmatic child thus has a much greater tendency toward a vertical heart, perhaps associated with the displacement of the diaphragm resulting from early emphysema.

**Summary**

Electrocardiograms of 137 asthmatic children, 5 to 16 years in age, were compared with findings in normal children.

The following deviations from normal were found: lower voltage and longer duration of P waves in all leads; lower voltage of R waves in all precordial leads and almost all limb and unipolar leads; deeper S waves over left precordial leads; slight delay of intrinsicoid deflection in right precordial leads, but no difference in left precordial leads; somewhat increased duration of QRS complexes; increased heart rate in the older age groups, but no differences in P-R and Q-T intervals; predominantly vertical electrocardiographic position of the heart.

These observations provide further electrocardiographic evidence that asthmatic children, compared with normal children of the same age range, show a tendency toward right ventricular hypertrophy and hyperinflated lungs.

**Summario in Interlingua**

Le electrocardiogrammas de 137 juveniles astmaticos de 5 a 16 annos de etate esseva comparete con observationes in juveniles normal.

Le sequente deviationes ab le norma esseva trovate in le astmaticos: Un plus basse voltage e un plus longe duration del unda P in omne le derivationes; un plus basse voltage del unda R in omne le derivationes precordial e in quasi omne le derivationes extremital e unipolar; un plus basse unda S super le derivationes sinistro-precordial; un leve retardo del deflexion intrinsecoide in le derivationes dextero-precordial sed nulle differentia in le derivationes sinistro-precordial; un leve augmento in le duration del complexo QRS; un plus alte frequentia cardiac in le gruppos de etate plus matur sed nulle differentia in le intervallos P-R e Q-T; e un position electrocardiographic del corde de character predominantemente vertical.

Iste constatationes provide un prova electrocardiographic additional que juveniles astmatic—in comparation con juveniles normal del mesme etate general—manifesta un tendentia de disveloppar hypertrophia ventricular e pulmones hyperinflata.

**References**

ELECTROCARDIOGRAM IN ASTHMATIC CHILDREN

veal the identifying initials for Funaro. Georg Nicolai was the second author, and the original title in the journal was misspelled as indicated above. Miyamoto.)


AHA Scientific Sessions Program

Six sessions of broad clinical interest will be held again during the American Heart Association’s annual Scientific Sessions in Kiel Auditorium, St. Louis, October 21-23. The American Academy of General Practice has classified these sessions as acceptable for Category II credit for members.

The six clinical programs, to run concurrently with the special scientific sessions, will stress the practical application of findings in cardiovascular research. They will be proportioned among symposia, panels, lectures of general interest and submitted papers on recent results of investigations.
Electrocardiogram in Asthmatic Children
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Circulation. 1960;22:90-95
doi: 10.1161/01.CIR.22.1.90
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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