Electrocardiographic Studies in Pulmonary Disease

I. Electrocardiographic Abnormalities in Diffuse Lung Disease

By David H. Spodick, M.D.

Electrocardiograms of 79 consecutively admitted patients with diffuse lung diseases were analyzed. The frontal plane P-wave axis and the P-wave configuration in limb and precordial leads emerged as the common denominator for the large majority of the group. Other abnormalities were common but not so characteristic.

In many respects the lungs and heart comprise a functional unit with interrelations such that disease of one may often affect the other. The electrocardiogram bears a unique relationship to this situation, not only because it reflects certain aspects of cardiac function but also because much of the cardiac potential must traverse lung tissue to reach the recording electrodes.

The observations in these studies suggest a marked, and relatively specific, effect of diffuse lung disease upon both normal and abnormal electrocardiograms.

Material and Methods

Electrocardiograms were analyzed in 79 consecutive hospital admissions (ages 32 to 84) for diffuse lung disease. Almost all of these patients had emphysema, in the majority associated with chronic bronchitis, bronchiectasis, or pulmonary fibrosis. This investigation revealed certain common characteristics in highly significant percentages of these tracings. Many of the results resembled the findings of Zuckermann1 and of Sodi-Pallares,2 but differed in detail.

Conventions adopted for this report are as follows: 1. The standard hexaxial modification of the Bayley reference system is used for plotting the derived frontal plane axes. 2. The designation "A" denotes mean manifest axis, e.g., A P = +90° or A QRS = +90° respectively indicate frontal mean P wave or QRS axis perpendicular to lead I and equally positive in leads II and III.

Results

The following elements of the electrocardiogram were most influenced by the presence of diffuse lung disease: mean frontal P-wave Axis (A P), P-wave configuration in frontal-plane leads; P-wave configuration in right precordial leads, mean frontal QRS Axis (A QRS). ST-T complex abnormalities were noted in the over-all electrocardiographic evaluation but were excluded from study in relation to lung disease because of the use of digitalis in some patients.

Mean Frontal A P

In most normal adults, the mean manifest frontal P axis is generally considered to vary within a narrow zone, +45° to +64°.1-3 The most constant finding in patients with diffuse lung disease is the relatively rightward (vertical) tendency of this vector. Table I indicates its orientation in 71 consecutive cases with sinus rhythm.* The overwhelming majority (83 per cent) were clearly vertical.

Because only 12 instances (17 per cent) were to the left of +70°, these cases were further analyzed to determine whether there were common factors causing them to differ from the majority. Pulmonary lesions in these patients were quite typical of the entire series. Seven cases with A P = 60° (i.e., P wave flat or diphasic in aVL) were considered intermediate or "borderline." Five of these had marked verticality of the QRS axis although 4 had conditions associated with left heart strain. Similarly, of the 5 cases with "leftward" P axes (+50° - +30°), 4 had systemic hypertension, yet 3 had QRS axes of +70° to +90°.

*There were 3 cases each of atrial fibrillation and atrioventricular nodal rhythm, and 2 with flat P waves in the limb leads, in the total 79.

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P-Wave Configuration in Frontal Plane Leads

Three types of P-wave configuration were present: 1. Classical P-pulmonale of Winter-nitz\(a\) (fig. 1A). 2. "Gothic" P of Zuckerman\(^1\) definite single peaking of a P of normal dimensions in leads II, III, and aV\(_F\) (fig. 1B). 3. Normal-appearing, cupola-shaped P wave (fig. 1C). P-pulmonale and Gothic type P waves occurred only with A P = +70\(^\circ\) or greater. Cupola P waves were found with any axis. The occurrence of these P types is listed in table 2, from which it is evident that over half of all cases (55 per cent) had either P pulmonale or Gothic P waves. Of the 59 cases with A P = +70\(^\circ\) to +90\(^\circ\), 30 (51 per cent) had Gothic P waves and 39 (66 per cent) had either Gothic or pulmonale P types.

P-Wave Configuration in Right Precordial Leads

Of 73 cases in sinus rhythm,* 37 (51 per cent) showed diphasic (− +) P waves in at least V\(_1\) and V\(_2\), and in some as far as V\(_4\) (fig. 2). Twenty-nine (78 per cent) of these were associated with A P = +70\(^\circ\) to +90\(^\circ\).

Mean Frontal A QRS

While the most consistent effect of lung disease was on the atrial complexes, verticality

*The 2 cases with flat P waves in the limb leads had clear precordial P waves.

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**Table 1.** Orientation of Frontal A P in Seventy-One Patients with Diffuse Lung Disease

<table>
<thead>
<tr>
<th>A P</th>
<th>No. of cases</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>+90(^\circ) to +70(^\circ)</td>
<td>59</td>
<td>83</td>
</tr>
<tr>
<td>+60(^\circ)</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>+50(^\circ) to +30(^\circ)</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

**Table 2.** P-Wave Configuration in Seventy-One Cases of Diffuse Lung Disease with Sinus Rhythm and Measurable Frontal P Waves

<table>
<thead>
<tr>
<th>P type</th>
<th>A P = +70(^\circ) to +90(^\circ)</th>
<th>A P = +60(^\circ) to +30(^\circ)</th>
<th>% of 71 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonale</td>
<td>9</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Gothic</td>
<td>30</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>Cupola</td>
<td>20</td>
<td>12</td>
<td>45</td>
</tr>
<tr>
<td>Totals</td>
<td>79</td>
<td>12</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 3.** Orientation of A QRS in Seventy-Nine Patients with Diffuse Lung Disease

<table>
<thead>
<tr>
<th>A QRS</th>
<th>Number of cases</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>+120(^\circ) to +70(^\circ)</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>+70(^\circ) to +30(^\circ)</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>+ 20(^\circ) to −60(^\circ)</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>−80(^\circ) to −90(^\circ)</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td>79</td>
<td>100</td>
</tr>
</tbody>
</table>

*There were no cases with A QRS = −70\(^\circ\).

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of frontal A QRS was seen in about one half of these patients (table 3). Almost one half (44 per cent) of the patients had an unmistakable vertical A QRS (+70\(^\circ\) or more), which is quite uncommon for these age groups. This figure is more impressive if to it is added those with A QRS = −80\(^\circ\) to −90\(^\circ\) and those with "indeterminate" frontal A QRS, the total thus becoming 57 per cent. These groups represent a special situation, which may be designated the "axis-illusion" phenomenon.

Axis-Illusion Phenomenon of A QRS. Littmann\(^6\) has pointed out that if the apical portion of the heart is rotated posteriorly (in an electrical sense), its are would eventually carry it above the "horizon" as viewed anteriorly. An axis of −80\(^\circ\) or −90\(^\circ\) is quite unusual in the absence of infarction of the
diaphragmatic aspect of the left ventricle. It was interesting to find 7 such axes in the lung disease group. None of these patients had evidence or history suggesting myocardial infarction and none had known left ventricular disease. Six of them had deep S waves in all precordial leads and the seventh had incomplete right bundle-branch block with rSr' in V1 and rS in aVF. The 2 designated "indeterminate frontal A QRS" were so labeled because R was equal to q + S in all extremity leads: both of these had deep S waves from V1 to V6. Thus, in all 9 cases A QRS was directed quite posteriorly. If this situation is visualized in the sagittal plane, it is clear to see why a -80° or -90° axis or an indeterminate frontal (i.e., directly posterior) axis may not be very different from an axis of +80° or +90°. Figure 3 demonstrates that the frontal projection of a posteriorly directed A QRS may be either +90° or -90° due to very small differences in its sagittal plane angle. The large frontal plane discrepancy (180°) is thus an illusion due to small deviations from the sagittal "horizontal" of mean vectors which are actually quite close to each other in space.

**Horizontal Axes**

The 12 cases of diffuse lung disease with a relatively leftward QRS axis (+20° to -60°) formed 15 per cent of the group. These were analyzed in the same manner as those with a relatively leftward P axis. Of 9 of these...
cases with measurable P vectors,* 5 had $\mathbf{A} \mathbf{P} = +90^\circ$ and there were 1 each with $\mathbf{A} \mathbf{P}$ of $+70^\circ$ and $+80^\circ$. Furthermore, half of these patients had evidence of left-sided heart disease. One of the others had a congenital chest deformity. As with the P vector, most cases with leftward deviation of $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$ can be accounted for by disease of the left side of the heart and systemic circulation. Despite this, the majority of these continue to show a vertically oriented $\mathbf{A} \mathbf{P}$.

Precordial QRS Configuration

The tendency to posterior orientation of $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$ was well shown in the precordial leads. In 51 cases (65 per cent) there was an S wave of 2 mm. or more to position $V_5$ or $V_6$ (to $V_7$ in all but 2). In many, rS or RS complexes occurred in all precordial leads. The presence or absence of this configuration had a close relation to the orientation of frontal $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$ and $\mathbf{A} \mathbf{P}$. This is shown in table 4, from which it is clear that there was a high degree of correlation with verticality of frontal $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$, 38 cases (75 per cent) having an axis of over $+70^\circ$, $-80^\circ$ to $-90^\circ$, or "indeterminate." More remarkable was the striking correlation with the frontal P axis: of 46 cases with measurable frontal $\mathbf{A} \mathbf{P}$, 41 (89 per cent) had $\mathbf{A} \mathbf{P}$ of $+70^\circ$ to $+90^\circ$.

*Three cases were not measurable because of atrial fibrillation, nodal rhythm, and flattened P waves.

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**Table 4.—Relation of Precordial QRS Configuration to Mean Frontal $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$ and $\mathbf{A} \mathbf{P}$**

<table>
<thead>
<tr>
<th>$\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>$+70^\circ$ to $+120^\circ$</td>
<td>30</td>
</tr>
<tr>
<td>$+80^\circ$ to $+60^\circ$</td>
<td>7</td>
</tr>
<tr>
<td>$+20^\circ$ to $-60^\circ$</td>
<td>6</td>
</tr>
<tr>
<td>$-80^\circ$ to $-90^\circ$</td>
<td>6</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\mathbf{A} \mathbf{P}$</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>$+70^\circ$ to $+90^\circ$</td>
<td>17</td>
</tr>
<tr>
<td>$+60^\circ$</td>
<td>3</td>
</tr>
<tr>
<td>$+30^\circ$ to $+50^\circ$</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>26†</td>
</tr>
</tbody>
</table>

*The other 5 patients had nodal rhythm or atrial fibrillation.
†The other 3 patients had flat P waves (2) and nodal rhythm (1).

**Additional Observations**

Thirty-six tracings were entirely within normal limits by standard criteria, excepting for P or QRS axes and configurations consistent with lung disease. There were but 7 cases of unequivocal right ventricular hypertrophy (Goldberger's criteria^5). Of 8 cases with the electrocardiographic diagnosis of left ventricular hypertrophy, each had leftward deviation of either $\mathbf{A} \mathbf{P}$ or $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S}$, despite which 3 had $\mathbf{A} \mathbf{P} = +80^\circ$ or $+90^\circ$ and 2 others had $\mathbf{A} \mathbf{Q} \mathbf{R} \mathbf{S} = +70^\circ$ and $+90^\circ$ respectively. Of 5 patients with incomplete right bundle-branch block (rSr' in $V_1$) and 2 with complete right bundle-branch block, 6 had $\mathbf{A} \mathbf{P} = +80^\circ$ or $+90^\circ$ and 1 had atrial fibrillation. A single patient had left bundle-branch block (but with an $\mathbf{A} \mathbf{P}$ of $+90^\circ$). Twenty-seven patients had a depression of the P-R interval in II, III, and aVF consistent with atrial T wave: 14 of these had Gothic and 4 others pulmonale-type P waves.

**DISCUSSION**

Verticalization of the QRS axis by lung disease has long been appreciated. Zucker-mann^1 and Sodi-Pallares^2 first called attention to the rightward tendency of the P vector. The present study emphasizes that P
verticality is the predominant and single entirely distinctive finding. Only 44 per cent of the patients had A QRS to the right of +60°; addition of the “axis illusion” groups raises this to just over one half (57 per cent). By contrast, the frontal P axis was +70° or more in fully 83 per cent, making this finding far more characteristic.

The specificity of P verticality relative to other conditions associated with right heart strain is suggested by comparison with the findings in patients with mitral stenosis and atrial septal defect. Electrocardiograms in 106 cases of mitral stenosis were reviewed; 40 of these were in sinus rhythm. The data on 90 patients with atrial septal defect in sinus rhythm reported by Toscano-Barboza and colleagues7 were converted to percentages. These groups are compared with the patients with lung disease in table 5. The enormous preponderance of vertical A P in the lung disease group is well shown. It is of interest that of the 6 mitral patients who had vertical A P, 3 had extensive pulmonary disease. Furthermore, 5 of the 6 had distinctive mitral P waves.

**Summary**

The results of this study indicate that the following statements may be made with regard to the electrocardiogram in patients with diffuse lung disease: 1. The chief single electrocardiographic finding in diffuse lung disease is verticalization of the mean frontal P axis. An axis of +70° to +90° is most characteristic. 2. A frontal A P of +50° or less in such patients is almost always associated with additional disease causing left-sided heart strain (i.e., arteriosclerotic or hypertensive heart disease). 3. Frontal A P = +60° is a borderline finding in these patients. 4. Distinct single-peaking (either “Gothic” or “pulmonale”) of frontal plane P waves is a characteristic occurrence but may be absent. 5. Diphasic (+ −) P waves in several right precordial leads occur in about one half of the cases and are more likely to be present when frontal P waves are of Gothic or pulmonale types. 6. A vertical frontal QRS axis occurs in almost 60 per cent of cases if those cases displaying the axis-illusion phenomenon are added to those with A QRS = +70° or more. 7. Leftward A QRS (+20° to −60°) in these patients, like “leftward” A P, is almost always associated with demonstrable conditions causing left heart strain. 8. Deep S waves over the left precordium (i.e., posterior spatial QRS orientation) occur in the majority of patients and correlate well with vertical A QRS (75 per cent), but much better with vertical A P (89 per cent).

It is clear that the P wave is the key to the electrocardiographic inference of diffuse lung disease. Rightward mean frontal P axis is its most constant single characteristic. Other factors occur in most cases and may be considered “typical” but are frequently absent. Among these are Gothic and pulmonale-type P waves, vertical A QRS, deep S waves over the left precordium, and prominent diphasic P waves over the right precordium. Absence of rightward frontal A P is strongly against the presence of diffuse lung disease. Absence of any other single factor is of little statistical value in itself.

**Acknowledgment**

The author wishes to acknowledge the technical assistance of Constance A. Dorr, B.M.

**Summario in Interlingua**

Le resultatos de iste studio indica que le sequente assertiones pot esser facite con respecto al electrocardiogramma de patientes
Il es clar que le unda P es le clave al inferentia electrocardiographic del presentia de diffuse morbo pulmonar. Un dextrose axe P frontal medie es su plus constante caracteristica individual. Altere factores occurre in le majoritate del casos e pote esser considerate como typie, sed il occurre frequente-mente que illos es absente. Istos include undas P del typos gothic e pulmonal, vertical A QRS, profunde undas S supra le precordio sinistre, e prominente diphasic undas P supra le precordio dextere. Le absentia de un dex-trose A P frontal argue fortemente contra le presentia de diffuse morbo pulmonar. Le absentia de un altere factor individual es de pauc valor statistic per se.

REFERENCES
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