Electrocardiographic Changes in Pulmonary Collapse: Artificial and Spontaneous Left-Sided Pneumothorax Studied by Conventional and Unipolar Methods

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In a previous paper Feldman and Silverberg described the electrocardiographic changes produced by the induction of artificial pneumothorax in patients with pulmonary tuberculosis, using Leads I, II, III, and CF precordial leads. A characteristic electrocardiographic pattern was noted in cases with left pneumothorax, consisting of a low T1, T3 higher than T1, together with lowering and frequent inversion of QRS complexes and T waves in CF leads, maximal in the more lateral precordial leads. In several left pneumothorax cases QS complexes were noted in CF. The above described changes tended to revert toward normal with tracings taken in the sitting position. The electrocardiographic changes were ascribed to positional changes of the heart together with the interposition of a non-conductor between the heart and the chest wall. The present study was undertaken to determine whether "unipolar" electrocardiography might aid in explaining the changes previously described.

Method

Two categories of patients were studied: Group I comprising those with spontaneous left-sided pneumothorax, Group II composed of patients with pulmonary tuberculosis in whom therapeutic left-sided pneumothorax was planned. In the first group, electrocardiograms were taken while the lung was partially collapsed and repeated when re-expansion had taken place. In the second group, tracings were taken prior to induction of pneumothorax, and then repeated soon after pneumothorax was estab-

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lished. In each case the degree of collapse or re-expansion of the lung was correlated with the electrocardiograms, although previous studies indicated that the degree of pulmonary collapse had little bearing on the electrocardiographic changes. Electrocardiograms were made in both the supine and sitting positions, since the recumbent CF changes in left pneumothorax have been noted to revert toward normal in the upright position.\textsuperscript{1,2} In addition to Leads I, II, and III, Leads CF\textsubscript{1} through CF\textsubscript{6}, Leads V\textsubscript{1} through V\textsubscript{6} (Wilson terminal\textsuperscript{3}), and the augmented unipolar limb leads (Goldberger\textsuperscript{4}) were taken. Measurements of the direction and amplitude of the various complexes in each lead were made, and the numerical value of the mean electrical axis of the QRS complexes determined by the triaxial reference system of Bayley. The electrocardiographic position of the heart was estimated from the unipolar limb leads.\textsuperscript{5} Chest roentgenograms were taken in the P-A position at a target film distance of six feet in the first and five feet in the second group. Lateral displacement of the heart was determined by measuring the lateral shift of the left contour of the heart shadow at the level of the superior border of the tenth costovertebral junction. The degree of pulmonary collapse was estimated from the chest films.

\textit{Results}

In Group I, comprising four patients with spontaneous left-sided pneumothorax, the electrocardiographic pattern in Leads I, II, III, and CF\textsubscript{1} through CF\textsubscript{6} in the recumbent position corresponded with the previously described pattern. Since the more pronounced precordial electrocardiographic changes occur toward the lateral portion of the left side of the chest, only positions C\textsubscript{p}, C\textsubscript{r}, C\textsubscript{p}, and C\textsubscript{t} are illustrated. The V precordial leads show a striking and significant difference from the CF leads. In those positions where the CF lead shows a small inverted QRS, or even a QS complex, and inverted T waves, the V lead has an upright QRS and T wave of normal contour, but perhaps of decreased amplitude. These differences are striking in CF\textsubscript{5} and CF\textsubscript{6} as contrasted with V\textsubscript{5} and V\textsubscript{6}, while the differences between CF\textsubscript{5} and CF\textsubscript{6} are not significant. Marked differences between CF and V leads have recently been described in individuals without evidence of heart disease.\textsuperscript{6} The differences in left-sided pneumothorax are illustrated in Figure I, patient G.C., columns 1 and 3. The conventional limb leads show a low QRS in Lead I, a higher QRS in Lead III, and T\textsubscript{q} larger than T\textsubscript{r}. In the augmented unipolar limb leads both the right and left arm tracings reveal the cavitory type of potential, and the left leg a left ventricular epicardial pattern, indicative of a vertical position. On assumption of the sitting position, the CF leads return
FIGURE 1: Single complexes from each lead in illustrative case of spontaneous left pneumothorax. Columns 1, 3, 5, and 7 were taken in the recumbent position; 2, 4, 6, and 8 in the sitting position (marked "Up"). One to 4 were taken when the lung was approximately 50 per cent collapsed, 5 to 8 after re-expansion.
toward normal, and although the amplitude may be relatively small in CF4 through CF6, definite R waves and upright T waves are present in all CF leads. The amplitude of QRS and T waves in the V leads also increases when the patient assumes the sitting position. Although Leads I, II, and III were not recorded in the sitting position in patient G.C., the unipolar limb leads indicate that the heart is less vertical in the sitting position than in the recumbent. Measurements of the mean electrical axes revealed that the heart was less vertical in the sitting than in the recumbent position in four of the five remaining patients. After re-expansion of the lung in patient G.C., Leads I, II, and III are within normal limits with T1 greater than T3. The CF and V leads are within normal limits. The unipolar extremity leads indicate a vertical heart, with aV/R representing the cavitary potential, aV/L the epicardial surface of the right ventricle, and aV/F the epicardial surface of the left ventricle. The remaining three patients with a spontaneous left-sided pneumothorax showed similar changes.

In Group II, composed of two patients with pulmonary tuberculosis, the control electrocardiograms were within normal limits. Both hearts were in a semi-vertical position electrocardiographically. The electrocardiograms obtained in patient B.N. before and following the institution of left pneumothorax are illustrated in Figure 2. Prior to the induction of pneumothorax, the electrocardiogram indicated no significant positional change between the sitting and the recumbent position. With pneumothorax present, the heart was more vertical in the recumbent than in the sitting position. The same general pattern occurred in the CF leads as previously described. Precordial V leads, on the other hand, showed a normal contour, although a decreased amplitude. In Figure 2, Lead aV/F taken in the sitting position has an inverted T wave which accounts for the diphasic T2 and inverted T3. Similar electrocardiographic changes occurred in patient C.W., who also was subjected to therapeutic left pneumothorax.

Discussion

In a previous paper, a characteristic electrocardiographic pattern was described in patients with therapeutic left-sided pneumothorax, using Leads I, II, III, and CF precordial leads. This pattern was of such a nature that it might give rise to a mistaken electrocardiographic diagnosis of coronary disease. The present study was undertaken to determine whether "unipolar" electrocardiograms might explain the previously described abnormalities.

Leads I, II, III, and CF are related to the V leads as follows:7a,7b
PATIENT: B.N.

FIGURE 2: Single complexes from each lead in illustrative case of induced left pneumothorax. Columns 1 to 4 taken prior to induction of pneumothorax; 5 to 8 after establishment of pneumothorax with approximately 15 per cent collapse.
### TABLE 1: Data in Six Cases of Left-Sided Pneumothorax

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age &amp; Sex</th>
<th>Date</th>
<th>Heart Position</th>
<th>Pulmonary Collapse</th>
<th>——— AXI——</th>
<th>——— SIT——</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUP I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G.C.</td>
<td>26</td>
<td>M</td>
<td>12-1-47</td>
<td>11.0 cm.</td>
<td>50</td>
<td>+80°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6-3-48</td>
<td>7.0 cm.</td>
<td>0</td>
<td>+83°</td>
</tr>
<tr>
<td>J.D.</td>
<td>22</td>
<td>M</td>
<td>12-19-47</td>
<td>6.8 cm.</td>
<td>75</td>
<td>+75°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2-20-48</td>
<td>7.0 cm.</td>
<td>0</td>
<td>+36°</td>
</tr>
<tr>
<td>W.P.</td>
<td>39</td>
<td>M</td>
<td>5-13-48</td>
<td>14.0 cm.</td>
<td>75</td>
<td>+3°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7-6-48</td>
<td>13.8 cm.</td>
<td>0</td>
<td>+5°</td>
</tr>
<tr>
<td>S.S.</td>
<td>24</td>
<td>M</td>
<td>3-22-48</td>
<td>8.5 cm.</td>
<td>95</td>
<td>+80°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5-20-48</td>
<td>9.0 cm.</td>
<td>0</td>
<td>+78°</td>
</tr>
<tr>
<td><strong>GROUP II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.N.</td>
<td>45</td>
<td>F</td>
<td>1-26-48</td>
<td>7.4 cm.</td>
<td>0</td>
<td>+10°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-2-48</td>
<td>7.9 cm.</td>
<td>15</td>
<td>+74°</td>
</tr>
<tr>
<td>C.W.</td>
<td>45</td>
<td>M</td>
<td>2-5-48</td>
<td>6.2 cm.</td>
<td>0</td>
<td>+58°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-2-48</td>
<td>9.3 cm.</td>
<td>30</td>
<td>+78°</td>
</tr>
</tbody>
</table>

**TABLE 1**: Table showing heart position, degree of pulmonary collapse, and electrical axis of heart as determined by the triaxial reference system of Bayley (normal axis deviation is between 0 and +90 degrees; right axis deviation is considered present when the electrical axis is more positive than +90 degrees, left axis deviation when the axis is more negative than 0 degrees). Heart position measured as described in text using chest roentgenograms taken in upright position.
Leads I = Lead V/L – V/R = (aV/L – aV/R) 2/3
Lead II = Lead V/F – Lead V/R = (aV/F – aV/R) 2/3
Lead III = Lead V/F – Lead V/L = (aV/F – aV/L) 2/3
Lead CF = Unipolar (V) precordial lead – Lead V/F = V – 2/3 aV/F

With these relationships in mind, the electrocardiographic changes noted in Leads I, II, III, and CF precordial leads can be explained. The tracings in aV/L, aV/R, and aV/F taken during the pneumothorax explain the low T1 and the T5 larger than T1, on the basis of the markedly vertical heart position. In the presence of left-sided pneumothorax, the amplitude of the unipolar precordial potential is markedly reduced. Since the unipolar left leg potential is greater than that of the unipolar precordial lead, the subtraction of the former from the latter, which occurs in the CF leads, explains the inverted rS or QS complexes, and low or inverted T waves in leads CF1 through CF6.

The facts that the potentials in the V leads increase, and CF leads return toward normal and aV/F remains relatively unchanged when the patient is upright, suggest that most of the change is due to the increased distance of the heart from the chest wall with the interposition of a non-conductor (air) between the heart and the chest wall.

In five of the six patients, numerical measurements of the electrical axis and positional interpretation of the unipolar extremity leads indicate that in the presence of left pneumothorax the heart is more vertical when the patient is recumbent than when he is sitting, contrary to the usual findings in patients without left pneumothorax. The probable explanation for this finding is that the pleural air tends to accumulate in the apical portions of the pleural space when the patient is sitting, thus permitting the lower part of the lung to approach the lateral chest wall more closely than in the recumbent position, and allowing the heart to assume a less vertical position.

**SUMMARY AND CONCLUSIONS**

1) Conventional and unipolar limb leads, and CF and unipolar chest lead electrocardiograms, and chest films were taken in four patients with spontaneous left-sided pneumothorax, and in two tuberculous patients in whom therapeutic pneumothorax was planned. In the first group the studies were made during pneumothorax and following the re-expansion of the lung. In the latter group the studies were made before and after institution of pneumothorax.

2) The characteristic electrocardiographic pattern for Leads I, II, III, and the CF precordial leads was repeated in all six cases. This pattern consisted of a small T1, a T3 larger than T1, QRS
small and inverted (or a QS complex), and low or inverted T waves in the chest leads, the chest lead changes being maximal in the more lateral precordial positions.

3) This previously described pattern can be explained on the basis of the "unipolar" lead findings. The standard limb lead changes are apparently produced by the heart assuming an extremely vertical position in the presence of left pneumothorax. The CF lead abnormalities in the recumbent position are related chiefly to the decreased voltage of the precordial V leads, resulting from the interposition of a non-conductor (air) between the heart and the chest wall.

4) The use of the CF precordial leads in the presence of left-sided pneumothorax might lead to a false electrocardiographic impression of coronary artery disease, or even of old myocardial infarction. In the same situation the V leads (Wilson terminal) show a tracing with a low amplitude but with a more normal contour. This would minimize the likelihood of erroneous interpretation.

SUMARIO Y CONCLUSIONES

1) Se tomaron electrocardiogramas ordinario unipolar con electrodo en los miembros y CF, unipolar con electrodo e nel torax, y radiografías del torax en cuatro enfermos con pneumotórax espontáneo izquierdo, y en dos enfermos en los cuales se había contemplado el pneumotórax terapéutico. En el primer grupo los estudios se hicieron durante el pneumotórax y después de que el pulmón se ha expandido. En el segundo grupo los estudios se hicieron antes y después de que el pneumotorax se ha iniciado.

2) El tipo de electrocardiograma característico, se repitió en el electrodo I, II, III y en el electrodo precordial en los seis casos. El tipo hallado fue una pequeña T₁, una T₃ más grande que T₁, QRS más pequeña e invertida (o el complejo QS) y baja ó onda T invertida, en el electrodo del tórax, especialmente en la posición lateral.

3) Lo descrito previamente, se puede explicar con la idea del electrodo "unipolar." Los cambios obtenidos en los electrodos de los miembros son producidos aparentemente por la posición vertical del corazón, debida al pneumotórax izquierdo. Las anormalidades en el electrodo CF, en la posición horizontal son debidas principalmente a la reducción del voltaje del electrodo precordial, debido a la interposición de aire entre el corazón y la pared costal.

4) El uso del electrocardiograma precordial en los casos con pneumotórax izquierdo puede dar un electrocardiograma falso, por ejemplo: enfermedad de las arterias coronarias ó un infarto del miocardio. Al mismo tiempo el electrodo V (la terminal de Wilson) muestra
un trazado con baja amplitud, pero con un contorno más normal. Esto contribuirá a la reducción de interpretaciones erróneas.

REFERENCES


