Functional Examination of Each Lung Before and After the Paralysis of the Phrenic Nerve*

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In a previous work we started the study of the influences of different methods of collapse-therapy—and particularly pneumothorax—on the respiratory function of each lung. We are presenting here the results of the air content analysis of each lung before and after the surgical paralysis of the phrenic nerve. Gianotti and Ceruti have seen in tracheotomized dogs that the ventilation of the lungs and the oxygen consumption diminishes after the excision of the phrenic nerve and that these effects persist after several weeks. The reduction in the respiratory values is somewhat higher in the bilateral than in the unilateral paralysis. Brea and Ferrari made a functional study of seven cases of pulmonary tuberculosis before the paralysis of the phrenic nerve and also a few days and again one month after the surgical paralysis (by excision, alcoholization or crushing). After a few days they found a diminution of the voluntary apnea, the vital capacity, the respiratory volume per minute, the oxygen consumption, CO₂ elimination, and in the O₂ content of the alveolar air. Due to the development of compensatory mechanisms all these changes return to normal values one month after the intervention. Cournand and Richards, in eight cases of therapeutic phrenic paralysis found striking impairment of the pulmonary function, as evidenced by decreased breathing reserve, unsaturation of arterial blood and a distinct tendency to pulmonary congestion after intravenous infusion. According to Rossier, Petzold, Decker and Michaud, cited by Steinlin, the paralysis of phrenic nerve results in an unsaturation of arterial blood during moderate work and sometimes even during rest. To explain this finding it is suggested that although there is a reduced ventilation, the amount of blood circulating through the lower part of the homolateral lung remains constant. A pendular phenomenon in the air of lungs due to the paradoxical movement of the diaphragm has also been described.

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Bronchospirometric examinations in patients with surgical paralysis of the phrenic nerve were effected by Jacobaeus (1 case) and by Pinner, Leiner and Zavod (3 cases). Jacobaeus observed marked reduction of the ventilation, of the O₂ consumption and the diminution of CO₂. We believe that a bronchial obstruction existed which annulled nearly completely the functional value of the corresponding lung. Pinner, Leiner and Zavod admit that the paralysis of the phrenic nerve may have a considerably disfavourable effect on the pulmonary function.

**Technique**

Functional examination of the separate lungs was performed in ten cases of pulmonary tuberculosis (seven males and three females) before and after the therapeutical paralysis of the phrenic nerve obtained by: excision (3 cases), alcoholization (3 cases), crushing (3 cases) and phrenicotomy (1 case). In seven cases phrenic paralysis was produced on the right side and in the three others on the left. Functional studies were performed a few days before the intervention and between one and two months afterwards, except in two cases which were studied four and five months later respectively. The specific timing of the examinations was selected in order to eliminate the influence of the favorable or unfavorable progress of tuberculous lesions on the results and in this way to record only the differences due to the phrenic paralysis. We did not perform the examination immediately after the operation because we wished to avoid the immediate disequilibrium usually following surgery, and to permit the motor, sensory, vascular and trophic changes due to the phrenic paralysis to develop. Furthermore, with the study of each lung we could avoid any error produced by compensation of the other lung. The aim of our study was the observation of the more permanent physiological changes which occur after phrenic paralysis.

The bronchiospyrometric examination was performed with the Gebauer's and Zavod's gauges using the technique described by Vaccarezza and colleagues. With the patient in sitting position the following indices were determined: vital capacity, complementary air, reserve air, respiratory volume, oxygen consumption and equivalent of ventilation.

For the comparative study of the results before and after surgical intervention the relative values of the different indices were determined for the separate lungs. We did not use the absolute values because these may be altered in each determination by the emotional reaction of the patient or by the anaesthesia. Comparative values between lungs are valid because in each analysis both lungs were examined under the same conditions.
Results

The paralysis of the phrenic nerve produced in all cases (see Table I), a reduction of the bronchiospyrometric indices of the corresponding lung with exception of the complementary and the reserve air, which in some cases even showed an increase.

The diminution in $O_2$ consumption was very marked (41.7 per cent). This means that the phrenic paralysis reduces almost to half the oxygen uptake of the blood in the corresponding lung.

The respiratory volume was diminished in all cases with the exception of case 7 in which a slight increase was observed. The mean of the total observations shows a reduction of 17.7 per cent.

The vital capacity was also reduced in all cases with the exception of number 6 in which almost no change was demonstrated, the mean being 14.9 per cent. The complementary and the reserve air had a mean diminution of 14.7 per cent and 19.6 per cent respectively. However considering that both indices are included in the vital capacity (and this never increases), the small increments found in such cases are only apparent. This fact can be easily explained if one recognizes that during the examination many patients, because of the anaesthesia or due to emotional factors, vary the degree of thoracic breathing from one determination to the next. This fact may, of course, affect the relative values of the components of the vital capacity, especially in relation to the complementary and reserve air.

<table>
<thead>
<tr>
<th>Observations</th>
<th>Vital Capacity</th>
<th>Complementary Air</th>
<th>Reserve Air</th>
<th>Respiratory Volume</th>
<th>Oxygen Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.7</td>
<td>60.3</td>
<td>21.2</td>
<td>18.5</td>
<td>59.7</td>
</tr>
<tr>
<td>2</td>
<td>21.6</td>
<td>20.5</td>
<td>38.5</td>
<td>12.1</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>+14.3</td>
<td>42.3</td>
<td>18.9</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>+2</td>
<td>+36.5</td>
<td>+16.2</td>
<td>60.5</td>
<td>52.9</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>34.6</td>
<td>8</td>
<td>+4.4</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>28.4</td>
<td>28.5</td>
<td>55.4</td>
<td>18.5</td>
<td>27.8</td>
</tr>
<tr>
<td>7</td>
<td>24.9</td>
<td>42.5</td>
<td>8.3</td>
<td>11.3</td>
<td>40.4</td>
</tr>
<tr>
<td>8</td>
<td>18.2</td>
<td>+17.4</td>
<td>42.3</td>
<td>16.4</td>
<td>29.7</td>
</tr>
<tr>
<td>Mean of the percentage of reduction</td>
<td>14.9</td>
<td>14.7</td>
<td>19.6</td>
<td>17.7</td>
<td>41.7</td>
</tr>
</tbody>
</table>
The equivalent of ventilation increased in all cases with the exception of case 6. This functional deterioration indicates the more marked reduction of the oxygen consumption in relation to the respiratory volume. The decrease in values of the different indices are as follows: (1) oxygen consumption, (2) reserve air, (3) respiratory volume, (4) vital capacity and (5) complementary air.

Discussion

Changes observed in the different bronchiospyrometric indices show no strict relationship to the intensity of the diaphragmatic ascension. This is particularly manifested in cases 2, 3, 6 and 10.

One interesting fact is that the phrenic paralysis affects in a much higher degree the oxygen consumption than the other indices which are expressions of the function of ventilation. This predominating effect on the oxygen uptake of the blood can not then be explained on the basis of the unilateral paralysis of the diaphragm only.

It is known that the phrenic nerve has connections with the cervical sympathetic and the solar plexus and that it contains non-myelinated fibers. These two facts may indicate that this nerve has vasomotor effects on the pulmonary circulation, and this may explain why its section should produce important changes in the blood supply of the lung. It would be very interesting to determine the cause of this diminution in blood supply and the correlated diminution in oxygen consumption. To achieve this end, laborious experimentation which is beyond the scope of the present work would be necessary.

The differences observed between the two bronchiospyrometric examinations together with the short time elapsed between the phrenic paralysis and the second examination permit us to discard the presence of compensatory phenomena in the corresponding lung. In our studies of the separate functional characteristics of each lung such compensation was not observed. This compensation was however found by Brea and Ferrari by examining both lungs together.

We do not want to extend our discussion to the clinical importance of these observations. However it seems very interesting to compare the results here observed with those found after the artificial pneumothorax. Paralysis of the phrenic nerve reduces to nearly half the functional value of the corresponding lung. Pneumothorax almost always improves the equivalent of ventilation of the collapsed lung due to a smaller reduction in oxygen consumption in relation to the respiratory volume.
SUMMARY

Separate functional examinations of each lung were performed in ten patients with pulmonary tuberculosis before and after the paralysis of the phrenic nerve.

In the lung on the paralyzed side the following percentage of diminution of bronchospyrometric values were observed: oxygen consumption 41.7; reserve air 19.6; respiratory volume 17.7; vital capacity 14.9; complementary air 14.7.

Due to the marked reduction in oxygen consumption in relation to the lesser reduction in respiratory volume the equivalent of the ventilation is frankly impaired.

The surgical paralysis of the phrenic nerve reduces almost to half the functional value of the corresponding lung.

RESUMEN

Se llevaron a cabo exámenes funcionales separados de cada pulmón en diez tuberculosos pulmonares, antes y después de la parálisis del nervio frénico.

En el pulmón del lado paralizado se observaron los siguientes porcentajes de disminución de los valores broncoespirométricos: consumo de oxígeno, 41.7; aire de reserva, 19.6; volumen respiratorio, 17.7; capacidad vital, 14.9; aire complementario, 14.7.

Debido a la decidida reducción en el consumo de oxígeno en relación a la menor reducción en el volumen respiratorio, el equivalente de la ventilación está francamente perjudicado.

La parálisis quirúrgica del nervio frénico reduce casi a la mitad el valor funcional del correspondiente pulmón.

REFERENCES