
Simple Tests in the Diagnosis of Emphysema and Airway Narrowing

N. Berend, M.D.; Ann J. Woolcock, M.D., F.C.C.P.; and G. E. Martin, M.B., B.S., F.C.C.P.

It would be desirable to be able to determine, on the basis of results of lung function tests (LFT), if patients have emphysema, airway narrowing or a combination of these pathologic states, and if present, to quantitate them. This study of the structure-function correlations in a group of smokers was undertaken to see how accurately LFT can predict the presence of emphysema and airway narrowing.

METHODS

Lung function tests comprising spirometry, lung volumes, the single breath nitrogen test (SBNT), lung resistance (R_L), the pressure-volume (p-v) curve, the flow-volume curve, single breath diffusion capacity (DLCO_{SB}) and steady state gas exchange were performed using standard methods, although not all of the patients had all the tests. Following resection, the lobes were inflated via the bronchus with 10 percent formalin under a constant transpulmonary pressure of 25 cmH_2O. After fixation, the lungs were sectioned into 1 cm thick slices. The midsagittal slice was impregnated with barium sulphate for assessment of the degree of emphysema by comparison with emphysema grading pictures which grade emphysema on a scale of 0 - 100. Grade 15 or greater was regarded as significant emphysema. Eight to ten blocks were cut at random from the remaining slices. Small airway narrowing (SAN) was assessed on conducting non-cartilagenous airways less than 2 mm in internal diameter by measurement of the mean ratio of the internal bronchial diameter to the external adventitial diameter of the accompanying pulmonary artery. Large airway involvement was quantitated by measurement of the Reid index.

RESULTS

The DLCO_{SB} and fractional uptake of CO (FCO) were best correlated with the emphysema grade (R = -0.72, P < 0.001, in each case). However, in patients without significant emphysema, the DLCO_{SB} was sign-

*From the Respiratory Unit, RSH Concord, and the University of Sydney, Australia.

Reprints requests: Dr. Berend, Department of Pathology, Health Sciences Center, Winnipeg, Manitoba, Canada R3D 023

Table 1—Measurements Derived from the Pressure-Volume Curve

<table>
<thead>
<tr>
<th></th>
<th>Non-Emphysema</th>
<th>Emphysema</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group (11)</td>
<td>Group (9)</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>C_L</td>
<td>0.32 ± 0.11</td>
<td>0.46 ± 0.14</td>
</tr>
<tr>
<td>K</td>
<td>0.151 ± 0.035</td>
<td>0.183 ± 0.069</td>
</tr>
<tr>
<td>P_{max}</td>
<td>23 ± 8</td>
<td>22 ± 5</td>
</tr>
<tr>
<td>Coefficient of Retraction</td>
<td>3.6 ± 1.5</td>
<td>3.1 ± 1.0</td>
</tr>
</tbody>
</table>

Differences not significant; C_L = lung compliance; K = bulk elastic constant; P_{max} = maximum transpulmonary pressure, coefficient of reaction = P_{max}/total lung capacity.

significantly correlated with the degree of airflow obstruction (DLCO_{SB} versus MMFR, R = 0.61, P < 0.05). This was not the case for the FCO.

A single exponential was fitted to the expiratory p-v curve using the manual method of Salazar and Knowles, and K, the bulk elastic constant, calculated. Although lung compliance and K were significantly correlated with the emphysema grade (R = 0.49, P < 0.05), the results of measurements derived from the p-v curve did not distinguish the patients with significant emphysema (Table 1).

The forced expiratory volume in one second (FEV_1), maximal mid-expiratory flow rate (MMFR), maximal flow at 50% vital capacity (V_{50}) and R_L were correlated with the Reid index, IB/EEA and a combined index of airway involvement (1/Reid index × IB/EEA) in Table 2. For each LFT, the correlation was better with the combined index, suggesting that these LFT are influenced by pathology all along the airways. The closing volume was significantly related to the IB/EEA although some patients were poorly discriminated by this test (Fig 1). The slope of phase 3 of the SBNT was not correlated with the IB/EEA (R = 0.02) and some patients with typical "small airways disease" (Fig 2) had normal slopes. The correlation of slope phase 3 with the emphysema grade was better (R = 0.45, 0.1 > P > 0.05) suggesting that patchy loss of elastic recoil, insuf-

Table 2—Correlation Between Lung Function and Airway Measurements

<table>
<thead>
<tr>
<th></th>
<th>Reid Index</th>
<th>IB/EEA</th>
<th>1/Reid Index × IB/EEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV_1</td>
<td>R = -0.44</td>
<td>R = 0.44</td>
<td>R = 0.66</td>
</tr>
<tr>
<td></td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>MMFR</td>
<td>R = -0.36</td>
<td>R = 0.45</td>
<td>R = 0.57</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>P &lt; 0.05</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>V_{50}</td>
<td>R = -0.44</td>
<td>R = 0.32</td>
<td>R = 0.52</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>R_L</td>
<td>R = 0.31</td>
<td>R = -0.25</td>
<td>R = -0.55</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>NS</td>
<td>P &lt; 0.05</td>
</tr>
</tbody>
</table>

FEV_1 = forced expiratory volume in one second; MMFR = maximal mid-expiratory flow rate; V_{50} = maximal flow at 50% vital capacity; R_L = total lung resistance.
sufficient to markedly affect the whole p-v curve, may be a
more important cause for elevations of slopes of phase 3
than SAN.

Every patient with SAN (ten patients) had an ele-
vated closing volume ( > 120 percent predicted) or a
reduction in MMFR (< 80 percent predicted) or both.
There were five patients with abnormalities in these
tests without measurable SAN. Every patient with an
abnormal Reid index (ten patients) had a reduction in
FEV₁ (< 80 predicted). There were three patients
with a reduced FEV₁ who had a normal Reid index.
In this study, only airway narrowing was quantitated and
other causes of airflow obstruction, eg mucous plugs and
airway instability, were not able to be assessed.

It is concluded that the distinction between moderate
and mild or no emphysema can be reliably made using
simple tests of diffusion. Measurements derived from the
p-v curves are unable to distinguish between patients
with airway narrowing plus moderate emphysema and
patients with airway narrowing alone. Spirometry and
the SBNT can reliably detect airway narrowing although
these tests are also affected by other causes of airflow
obstruction.

REFERENCES

1 Thurlbeck WM, Dunnill MS, Hartung W, A comparison of
three methods of measuring emphysema. Human Pathol
1:215, 1970

2 Berend N, Woolcock AJ, Marlin GE: The relationship
between bronchial and arterial diameters in normal human
lungs. Thorax 34:354, 1979

3 Salazar E, Knowles JH: An analysis of pressure-volume

Q. (Hogg): Would you expect more change in time
costants with inflammatory changes than with other morpho-
logic changes? It would be interesting to look at scores of
individual morphologic parameters.

A. (Berend): The slope of phase 3 was better correlated
with emphysema grade than with small airflow changes,
possibly because of inhomogeneity of elastic recoil.

Q. (Permutt): The only way to have an abnormal MMFR
with normal FEV₁ is to have supernormal early flow. The
significance of abnormal MMFR in the presence of normal
FEV₁ is not clear.

A. (Berend): MMFR is abnormal earlier in the course of
disease. The site of the abnormality (small vs large airway)
is open to speculation.

Q. (Souhrada): Would your results be different if related
to changes in lung volume particularly in reference to DLco
and specific compliance?

A. (Berend): This did not alter our results.