Postural relief of dyspnoea in severe chronic airflow limitation: relationship to respiratory muscle strength

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ABSTRACT Maximal static inspiratory and expiratory pressures (Pimax and Pemax) were measured in six different positions in 40 patients with advanced chronic airflow limitation and in 140 normal subjects to determine whether posture influences respiratory muscle strength. Patients with chronic airflow limitation were studied on days 1 and 5 of an acute exacerbation. There was no postural effect on maximal static pressures in the normal subjects. We divided our patients with chronic airflow limitation into “moderate” and “severe” groups on the basis of a Pimax in the standing position greater or less than 35 cm H2O. The seated leaning-forward position was the preferred posture in 22 of the 23 “severe” patients and 13 of the 17 “moderate” patients. Pimax was greater in the seated leaning-forward position than in the other positions studied (p < 0.001) on days 1 and 5 in the “severe” patients and (p < 0.05) on day 5 in the “moderate” patients. Posture had no influence on Pemax in patients with chronic airflow limitation. There was a significant improvement in both Pimax (p < 0.01 for the “severe” group and p < 0.05 for the “moderate” group) and |Pemax| (p < 0.01 for both groups) between days 1 and 5. The seated leaning-forward position was the optimum posture for the patients to generate maximum inspiratory pressures and to obtain greatest subjective relief of dyspnoea.

Patients with severe chronic airflow limitation (synonyms chronic obstructive airways disease, chronic obstructive lung disease) have reduced inspiratory muscle strength.¹ Such patients may experience a reduction in dyspnoea by assuming a particular posture.² The present study was undertaken to confirm this observation in a large group of patients and to characterise further the relationship between posture and other clinical and physiological findings—in particular maximal static respiratory pressures as an index of respiratory muscle strength—in patients with severe chronic airflow limitation. In addition we wished to determine the effect of a period of hospital treatment on the findings.

Methods

Maximal static pressures were measured with two diaphragm pressure gauges, one recording negative and the other positive pressure by the method of Black and Hyatt.³ The gauges were calibrated with a differential pressure transducer (Statham PM-131, TC; Statham Instruments, Hato Rey, California); their recorded pressures were within ± 5% of transducer pressure up to 300 cm H2O expiratory pressure and 160 cm H2O inspiratory pressure.

One hundred and forty normal adults were tested to establish a normal range and to determine whether postural changes affected maximal pressures in normal subjects. All subjects were Caucasian and comprised 10 men and 10 women in each decade from 20 to 80 years and in the age group 80–85 years. All were symptom free, had a normal chest radiograph, and spirometric values⁴ within the predicted normal range. One hundred and sixteen of the subjects were patients on general medical and surgical wards; the remainder were...
healthy physicians, medical students, and laboratory technicians. Thirty of the men and 22 of the women were smokers. There was no correlation ($r = 0.221; p > 0.05$) between smoking history and the static pressures generated.

Measurements were made in six positions—standing erect, supine, seated erect, seated leaning forward at a $45^\circ$ angle, and right and left lateral decubitus. All subjects wore nose clips and pressed their lips tightly against the mouthpiece during the pressure measurements to prevent an air leak. They were instructed not to suck and to keep their hands closely applied to their cheeks. Maximal inspiratory pressure ($P_{\text{imax}}$) was measured at residual volume (RV) and maximal expiratory pressure ($P_{\text{emax}}$) at total lung capacity (TLC). The pressures recorded were maintained for at least one second. The determinations were repeated until three technically satisfactory measurements were obtained and the highest value of each was used. The order of positions in which the pressures were measured was varied in random sequence for each age group.

Forty patients with previously diagnosed chronic airflow limitation on the basis of FEV$_1$ and FEV$_1$/FVC ratio always less than 60% of the predicted value and less than 10% improvement after bronchodilator were studied during the course of an acute exacerbation. The study had been previously approved by the hospital ethics committee. The patient group comprised 23 men and 17 women with a mean age of 69.4 years and a range of 44–84 years. Patients having steroid treatment or with pulmonary infiltrates were excluded from the study. The patients were studied on days 1 and 5 of their hospital admission after informed consent had been obtained. All patients complained of dyspnoea at rest in the upright posture on day 1 of the study.

The patients were studied in each of six positions: standing, seated erect, seated leaning forward, supine, and right and left lateral decubitus. They were allowed to rest three minutes in each position before being tested. The following physical signs were assessed in each position: (1) costal paradox with decrease in lateral diameter of costal margin on inspiration (Hoover’s sign); (2) inward motion of the abdomen during inspiration; (3) tracheal descent with inspiration; (4) contraction of the sternomastoids during inspiration.

These physical signs were observed and recorded as present or absent by one of us (S O’N) before measurement of static pressures. The patient’s preferred posture and the sensation of dyspnoea or its relief in each position were recorded. To assess the sensation of dyspnoea and its relief or exacerbation, we adopted a category scale in which words describing increasing or decreasing degrees of breathless-
Results

The relationships of age to $P_{\text{imax}}$ and $P_{\text{emax}}$ in normal men and women in various age groups are presented in Table 1, expressed as the mean ± 2 SD. There were no significant differences between mean pressures in the six positions tested in the different age categories for either sex ($p > 0.05$). The average value for the individual coefficient of variation for duplicate determinations at one time was 8% for $P_{\text{imax}}$ and $P_{\text{emax}}$. Ten women and 10 men were tested in the same manner on three consecutive days. There was no significant difference between the mean values for the pressures on the first day and those on the second and third days. The highest value for $P_{\text{imax}}$ and for $P_{\text{emax}}$ on the third day was less than 10% greater than the value on the first day in seven subjects and was unchanged or lower in 13 subjects, suggesting that the short-term learning effect is slight. The decline in maximum static pressures with age and the influence of sex—women generating about 70% of the values obtained by men—are similar to the findings of previous studies.

We divided our patients with chronically airflow limitation into two groups on the basis of $P_{\text{imax}}$ as an index of inspiratory muscle strength, in the manner of Braun and Rochester. A "severe" group was arbitrarily defined as those having a $P_{\text{imax}}$ value of

<table>
<thead>
<tr>
<th>Age group</th>
<th>$P_{\text{imax}}$ (cm H$_2$O)</th>
<th>$P_{\text{emax}}$ (cm H$_2$O)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>20-29</td>
<td>118 ± 38</td>
<td>90 ± 24</td>
</tr>
<tr>
<td>30-39</td>
<td>116 ± 45</td>
<td>92 ± 28</td>
</tr>
<tr>
<td>40-49</td>
<td>120 ± 32</td>
<td>86 ± 22</td>
</tr>
<tr>
<td>(20-54)</td>
<td>(124 ± 44)</td>
<td>(87 ± 32)</td>
</tr>
<tr>
<td>50-59</td>
<td>108 ± 46</td>
<td>81 ± 25</td>
</tr>
<tr>
<td>(55-59)</td>
<td>(103 ± 32)</td>
<td>(77 ± 26)</td>
</tr>
<tr>
<td>60-69</td>
<td>101 ± 44</td>
<td>76 ± 24</td>
</tr>
<tr>
<td>(60-64)</td>
<td>(103 ± 32)</td>
<td>(73 ± 26)</td>
</tr>
<tr>
<td>65-69</td>
<td>99 ± 36</td>
<td>70 ± 26</td>
</tr>
<tr>
<td>70-79</td>
<td>93 ± 40</td>
<td>68 ± 22</td>
</tr>
<tr>
<td>(70-74)</td>
<td>(103 ± 32)</td>
<td>(65 ± 26)</td>
</tr>
<tr>
<td>80-84</td>
<td>94 ± 40</td>
<td>68 ± 22</td>
</tr>
</tbody>
</table>

*Figures in parentheses represent normal values of Black and Hyatt. There were no significant differences between mean pressures in the six positions ($p > 0.05$) in the different age categories.

Table 2  Maximal inspiratory pressure ($P_{\text{imax}}$) and other lung function measurements (means ±1 SD) in patients with moderate and severe airflow limitation

<table>
<thead>
<tr>
<th></th>
<th>Moderate group</th>
<th>Severe group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 5</td>
</tr>
<tr>
<td>$P_{\text{imax}}$ (cm H$_2$O) standing</td>
<td>50-8</td>
<td>61-5</td>
</tr>
<tr>
<td></td>
<td>± 5-9</td>
<td>± 9-2</td>
</tr>
<tr>
<td>supine</td>
<td>50-6</td>
<td>61-5</td>
</tr>
<tr>
<td></td>
<td>± 10-0</td>
<td>± 9-3</td>
</tr>
<tr>
<td>seated erect</td>
<td>52-1</td>
<td>61-7</td>
</tr>
<tr>
<td></td>
<td>± 11-3</td>
<td>± 10-8</td>
</tr>
<tr>
<td>seated leaning forward</td>
<td>60-5</td>
<td>71-5*</td>
</tr>
<tr>
<td></td>
<td>± 12-1</td>
<td>± 10-6</td>
</tr>
<tr>
<td>right lateral decubitus</td>
<td>53-5</td>
<td>63-0</td>
</tr>
<tr>
<td></td>
<td>± 10-7</td>
<td>± 9-8</td>
</tr>
<tr>
<td>left lateral decubitus</td>
<td>53-5</td>
<td>62-0</td>
</tr>
<tr>
<td></td>
<td>± 10-7</td>
<td>± 9-8</td>
</tr>
<tr>
<td>$\text{FEV}_1$ (% predicted)</td>
<td>28-2</td>
<td>30-9</td>
</tr>
<tr>
<td></td>
<td>± 4-6</td>
<td>± 9-8</td>
</tr>
<tr>
<td>Residual volume (% predicted)</td>
<td>232-9</td>
<td>207-8</td>
</tr>
<tr>
<td></td>
<td>± 49-3</td>
<td>± 45-3</td>
</tr>
<tr>
<td>Total lung capacity (% predicted)</td>
<td>127-8</td>
<td>123-4</td>
</tr>
<tr>
<td></td>
<td>± 19-1</td>
<td>± 14-9</td>
</tr>
<tr>
<td>Room air Pao$_2$ (mm Hg)</td>
<td>48-7</td>
<td>51-8</td>
</tr>
<tr>
<td></td>
<td>± 7-2</td>
<td>± 6-4</td>
</tr>
<tr>
<td>Room air Pao$_3$ (mm Hg)</td>
<td>49-3</td>
<td>45-8</td>
</tr>
<tr>
<td></td>
<td>± 8-7</td>
<td>± 4-3</td>
</tr>
</tbody>
</table>

*Significantly different from other postures: $p < 0.001$.
†Significantly different from other postures: $p < 0.05$.
Conversion: Traditional to SI units—Arterial oxygen (Pao$_2$) and carbon dioxide (Paco$_2$) tensions: 1 mm Hg = 0.133 kPa.
35 cm H₂O or less in the standing position, and a "moderate group" as those with a value greater than 35 cm H₂O. There were 23 and 17 patients in the severe and moderate categories. The severe group had a significantly (p < 0.05) lower FEV₁ than the moderate group (table 2), but the two groups did not differ significantly with respect to TLC, RV, or blood gases. Classification of patients into severe and moderate groups on the basis of the greatest Pimax or percentage of predicted FEV₁, instead of Pimax in the standing position, would have produced a similar distribution of patients and similar findings.

The seated leaning-forward position was the preferred posture in 22 of the 23 patients in the severe group and 13 of the 17 patients in the moderate group, and was assumed automatically by these patients in an attempt to relieve their dyspnoea. The effectiveness of this posture as the optimum inspiratory pressure-generating position was confirmed—Pimax being significantly greater (p < 0.001) on days 1 and 5 in the seated leaning-forward position than in the other positions in the "severe" group and greater (p < 0.05) on day 5 in the "moderate" group.

There was a significant increase in Pimax from day 1 to day 5 in all postures, the p values being <0.005 for the moderate group and <0.01 for the severe group. Posture had no significant effect on the Pimax generated in any of the six positions in either group of patients. There was, however, a significant improvement in Pimax from day 1 to day 5 in both moderate and severe groups (p < 0.01). The mean values of Pimax on days 1 and 5 were 120 ± 26 and 135 ± 27 cm H₂O in the moderate group and 73 ± 38 and 102 ± 26 cm H₂O in the severe group.

By linear regression analysis we related diminution in Pimax to age (r = 0.423, p < 0.05), percentage deficit from ideal body weight (r = 0.716, p < 0.001), and residual volume expressed as percentage of predicted value (r = 0.744, p < 0.001) and by linear contrast analysis we related it to radiological signs of hyperinflation (r = 0.414, p < 0.05). The relationship between Pimax and age simply reflects the normal decline with age.

The effect of posture on the sensation of dyspnoea by comparison with the sensation in the standing erect posture is presented in table 3. The superiority of the seated leaning-forward position over the other positions tested (p < 0.001) with regard to subjective relief of dyspnoea is striking.

Table 3 Effect of posture on perceived dyspnoea (with the standing erect position as the reference posture) in patients with moderate and severe airflow limitation

<table>
<thead>
<tr>
<th>Posture</th>
<th>% with dyspnoea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>relieved</td>
</tr>
<tr>
<td>Supine</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>17.7</td>
</tr>
<tr>
<td>Severe</td>
<td>12.9</td>
</tr>
<tr>
<td>Seated erect</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>11.8</td>
</tr>
<tr>
<td>Severe</td>
<td>12.9</td>
</tr>
<tr>
<td>Seated leaning forward</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>82.6*</td>
</tr>
<tr>
<td>Severe</td>
<td>95.7*</td>
</tr>
<tr>
<td>Right lateral decubitus</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>17.7</td>
</tr>
<tr>
<td>Severe</td>
<td>12.9</td>
</tr>
<tr>
<td>Left lateral decubitus</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>17.7</td>
</tr>
<tr>
<td>Severe</td>
<td>12.9</td>
</tr>
</tbody>
</table>

*p < 0.001.

Table 4 Effect of posture and treatment on physical signs (first figures are percentages of patients on day 1 and figures in parentheses percentages on day 5)

<table>
<thead>
<tr>
<th>Physical sign</th>
<th>Standing</th>
<th>Seated</th>
<th>Seated leaning forward</th>
<th>Supine</th>
<th>Right lateral decubitus</th>
<th>Left lateral decubitus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costal paradox</td>
<td>70 (37.5)</td>
<td>60 (27.5)</td>
<td>42.5 (17.5)</td>
<td>65 (30)</td>
<td>65 (35)</td>
<td>65 (35)</td>
</tr>
<tr>
<td>Abdominal inspiratory inward movement</td>
<td>25 (10)</td>
<td>20 (7.5)</td>
<td>7.5 (0)</td>
<td>15 (2.5)</td>
<td>12.5 (2.5)</td>
<td>12.5 (2.5)</td>
</tr>
<tr>
<td>Inspiratory tracheal descent</td>
<td>87.5 (42.5)</td>
<td>87.5 (42.5)</td>
<td>87.5 (42.5)</td>
<td>87.5 (42.5)</td>
<td>87.5 (42.5)</td>
<td>87.5 (42.5)</td>
</tr>
<tr>
<td>Inspiratory sternomastoid contraction</td>
<td>92.5 (47.5)</td>
<td>92.5 (47.5)</td>
<td>92.5 (47.5)</td>
<td>92.5 (47.5)</td>
<td>92.5 (47.5)</td>
<td>92.5 (47.5)</td>
</tr>
</tbody>
</table>
The improvement in physical signs over the five days of hospital treatment and the reduction in the percentage of patients with these signs in the seated leaning-forward position are shown in table 4.

Discussion

Our normal values for $P_{\text{imax}}$ are strikingly similar to those from the two other large series reported,13-15 in contrast to the lower values obtained in smaller series.14,15 The normal values for $P_{\text{emax}}$ are similar to those of Black and Hyatt,3 but considerably higher than the other reported values.13-15 We can only surmise that these differences reflect minor variations in technique and selection of subjects, yielding differences in motivation, respiratory muscle strength, and skill in performing ventilatory manoeuvres. The absence of any postural effect on the maximal static pressures generated by our normal subjects is noteworthy.

The preference for the seated leaning-forward position in 22 of the 23 "severe" patients and 13 of the 17 "moderate" patients confirms previous reports.2,16 This position was assumed automatically by these patients during acute exacerbations of their disease as the optimum position in which to obtain relief of dyspnoea. The superiority of this position as a generator of maximum inspiratory pressure (table 2) and its association with subjective relief of dyspnoea (table 3) is probably due at least in part to compression of abdominal contents and stretching of the diaphragm, thereby improving its length-tension relationship. Contrary to the findings of previous studies,2,17 the supine position was infrequently the preferred posture in our patients (5%) and offered no advantage over the other postures as an inspiratory pressure generator or in subjective relief of dyspnoea. It would appear that improvement of diaphragm length-tension relationships is only one factor operating in the postural relief of dyspnoea in severe chronic airflow limitation.

The improvement in $P_{\text{imax}}$ over the five days in hospital (table 2) might be due to a sustained therapeutic concentration of theophylline or improvement in arterial blood gas tensions, or both. The reduction in lung volumes (TLC and RV) and improvement in $FEV_1$ from day 1 to day 5 were not significant. Nevertheless, even a modest reduction in residual volume (25% of predicted volume in the moderate group and 28% in the severe group) may have significantly decreased the mechanical disadvantage of the inspiratory muscles.

We have used $P_{\text{emax}}$ as an index of general debility because the expiratory muscles are not necessarily at a mechanical disadvantage in severe chronic airflow limitation. The importance of malnutrition in producing respiratory muscle weakness has recently been emphasised by Arora and Rochester18 and our findings support this. The moderate and severe groups differed significantly ($p < 0.05$) in percentage of ideal body weight, which averaged $91 \pm 9\%$ and $80 \pm 7\%$ in the moderate and severe groups respectively. In parallel with this difference in weight loss, the two groups differed significantly ($p < 0.001$) in $P_{\text{emax}}$ (120 ± 26 and 73 ± 38 cm H$_2$O on day 1 in the moderate and severe groups respectively). This deficit in $P_{\text{emax}}$ in severe chronic airflow limitation has previously been described19 and presumably reflects malnutrition and general debility. The relatively greater initial diminution in $P_{\text{imax}}$—to mean values of 50% and 30% of predicted, compared with $P_{\text{emax}}$ values of 75% and 50% of predicted in the moderate and severe groups respectively—suggests that the mechanical disadvantage of the inspiratory muscles is an additional contributory factor acting in concert with malnutrition and general debility in the observed reduction in maximal static pressures.

We acknowledge the considerable degree of interobserver variability in previous studies of physical signs in the respiratory system19,20 and the consequent unsatisfactory nature of a one-observer approach to their detection. Despite this caveat, the postural dependence of costal paradox is interesting (table 4), and presumably reflects the enhanced pressure-generating efficiency of the inspiratory muscles in the seated leaning-forward position. All physical signs were significantly less on day 5 than on day 1, correlating with the improved inspiratory pressures and clinical state of the patients.

In conclusion, the seated leaning-forward position was associated with the ability to generate higher maximum inspiratory pressures and with the greatest subjective relief of dyspnoea. Improvement in maximum static inspiratory pressures with treatment during the course of an acute exacerbation of chronic airflow limitation is paralleled by a reduction in abnormal physical signs.

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References


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