Arterial blood gases in elderly persons with chronic obstructive pulmonary disease (COPD)

B. Delclaux, B. Orcel, B. Housset, W.A. Whitelaw, J-P. Derenne

ABSTRACT: With the increasing number of elderly people in developed countries, physicians are often confronted with patients whose arterial oxygen tension, PaO₂, is lower than that of normal young adults. The normal values predicted in the literature for very old individuals are generally extrapolated from younger subjects. The purpose of the present study was to obtain PaO₂ values from a large population of elderly subjects with normal and obstructive ventilatory function.

We measured arterial blood gases in 274 subjects, aged 65–100 yrs (mean 82 yrs), with chronic bronchitis and moderate airways obstruction (mean forced expiratory volume in one second (FEV₁), 53% pred).

Mean PaO₂ was 10.0±1.4 kPa (75.2±10.8 mmHg) and mean arterial carbon dioxide tension (PaCO₂) was 5.4±0.8 kPa (40.5±6.1 mmHg). Both PaO₂ and PaCO₂ were independent of age. Blood gas abnormalities were associated with airways obstruction: PaO₂ was positively correlated to FEV₁ and PaCO₂ was negatively correlated to FEV₁. PaO₂ was 10.8±1.4 kPa (81.5±10.7 mmHg) in the patients with FEV₁ ≥90% predicted versus 9.5±1.3 kPa (71.5±10.1 mmHg) in those with FEV₁ ≤55% pred.

These findings suggest that the predicted PaO₂ extrapolated from younger normal values are often erroneously underestimated. It is probably more accurate to accept as normal a PaO₂ of 10.6–11.3 kPa (80–85 mmHg) for all subjects over 65 yrs, irrespective of their age.
### Ethical Considerations

All patients gave verbal consent after having the purpose of the study described by the physician in charge of the trial in the presence of a third party. The study was approved by the Ethics Committee of the Saint Antoine Faculty of Medicine (Paris).

### Measurement Principles and Techniques

A single medical investigator visited each institution and set up a portable laboratory. Arterial blood gases (PaO₂) and arterial carbon dioxide tension (PaCO₂) were measured on patients at rest, sitting or semi-recumbent, and breathing room air. Arterial blood samples were obtained in a disposable pre-heparinized system from the radial or brachial artery and processed in less than 5 min in a Corning 178 blood gas analyser.

The latter was calibrated twice a day using standard gas mixtures. Since it has been shown that the state of activity influences blood gas measurements [13], the patients rested for more than 10–15 min before blood samples were taken. After testing, four were excluded because of hyperventilation (pH >7.50), and three others because of uncompensated acidosis (pH <7.34). Therefore, the population analysed was 274 (128 men and 146 women). Mean age was 82±8 yrs (range 65–100 yrs); mean weight was 59±13 kg; mean height was 161±9 cm. Forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) were measured with a portable spirometer (Fukuda Sanyo Spiro Analyser ST 90). The patients were first shown how to make a forced expiration. After one or two training manoeuvres without the apparatus, they made a series of 2–4 forced expirations. The best values were kept for analysis. The predicted values were taken from QUANJER [15].

### Statistical Methods

Values are expressed as mean±standard deviation. Analysis of correlations was performed by the method of least squares. Correlations were established between each parameter and age, and between PaO₂, PaCO₂, and spirometric measures. Statistical significance was accepted at the 95% confidence level (p<0.05).

### Results

Mean PaO₂, PaCO₂ and alveolar-arterial gradient for oxygen (P A-aO₂) for the whole group were 10.0±1.4 kPa (75.2±10.8 mmHg); 5.4±0.8 kPa (40.5±6.1 mmHg); and 4.6±0.9 kPa (34.6±6.7 mmHg) respectively.

### Table 1: Effects of age on arterial blood gases according to previous studies

<table>
<thead>
<tr>
<th>Authors [Ref]</th>
<th>Subject</th>
<th>Agea</th>
<th>Age</th>
<th>Age</th>
<th>Pao₂ versus age</th>
<th>Predicted PaO₂ at age 82 yrs</th>
<th>r</th>
<th>p</th>
<th>Paco₂**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>yrs</td>
<td>≥60 yrs n</td>
<td>≥70 yrs n</td>
<td>kPa</td>
<td>mmHg</td>
<td>kPa</td>
<td>mmHg</td>
<td>kPa</td>
</tr>
<tr>
<td>LOEW and THEWS [2]</td>
<td>29</td>
<td></td>
<td>13.8 - 0.032 age</td>
<td>103.7 - 0.24 age</td>
<td>8.9</td>
<td>67*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RAIN and BISHOP [5]</td>
<td>70</td>
<td>17–66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONWAY et al. [6]</td>
<td>70</td>
<td>48</td>
<td>11</td>
<td>2</td>
<td>13.7 - 0.029 age</td>
<td>102.5 - 0.22 age</td>
<td>11.3</td>
<td>84.4*</td>
<td></td>
</tr>
<tr>
<td>MELEMEGAARD [7]</td>
<td>80</td>
<td>41±17</td>
<td>12</td>
<td></td>
<td>13.9 - 0.036 age</td>
<td>104.2 - 0.27 age</td>
<td>10.9</td>
<td>82*</td>
<td></td>
</tr>
<tr>
<td>SORINI et al. [8]</td>
<td>152</td>
<td>18–84</td>
<td>24</td>
<td></td>
<td>14.5 - 0.057 age</td>
<td>109.0 - 0.43 age</td>
<td>9.8</td>
<td>73.7*</td>
<td></td>
</tr>
<tr>
<td>DIAMOND and PALMER [9]</td>
<td>65M</td>
<td>43±17</td>
<td></td>
<td></td>
<td>14.6 - 0.041 age</td>
<td>109.5 - 0.31 age</td>
<td>11.2</td>
<td>83.9*</td>
<td></td>
</tr>
<tr>
<td>86F</td>
<td>45±16</td>
<td></td>
<td></td>
<td></td>
<td>15.3 - 0.055 age</td>
<td>114.8 - 0.41 age</td>
<td>10.8</td>
<td>81.1*</td>
<td></td>
</tr>
<tr>
<td>HURST et al. [10]</td>
<td>323</td>
<td>42±16</td>
<td>26</td>
<td>11</td>
<td>12.8 - 0.053 age</td>
<td>96.2 - 0.40 age</td>
<td>8.4</td>
<td>63.3*</td>
<td></td>
</tr>
<tr>
<td>GOTTGEN and JACOBSEN [11]</td>
<td>20</td>
<td>19–80</td>
<td>8</td>
<td>4</td>
<td>13.8 - 0.053 age</td>
<td>103.5 - 0.40 age</td>
<td>9.4</td>
<td>70.3*</td>
<td></td>
</tr>
</tbody>
</table>

*: range or mean±SD; **: mean±SD; *: extrapolated from figure 2. PaO₂: arterial oxygen tension; PaCO₂: arterial carbon dioxide tension. M: male; F: female.

### Notes

- Mean PaO₂, PaCO₂, and alveolar-arterial gradient for oxygen (P A-aO₂) for the whole group were 10.0±1.4 kPa (75.2±10.8 mmHg); 5.4±0.8 kPa (40.5±6.1 mmHg); and 4.6±0.9 kPa (34.6±6.7 mmHg) respectively.

- The predicted values were taken from QUANJER [15].

- All patients gave verbal consent after having the purpose of the study described by the physician in charge of the trial in the presence of a third party. The study was approved by the Ethics Committee of the Saint Antoine Faculty of Medicine (Paris).
and 3.2±1.4 kPa (24.3±10.3 mmHg), respectively. Paco₂ was between 6.1–6.7 kPa (46–50 mmHg) in 31 patients and above 6.7 kPa (50 mmHg) in 14.

Pao₂, Paco₂ and Pa-aO₂ were essentially similar in men (mean age 81 yrs) and women (mean age 83 yrs). Mean Pao₂ values were 10.1 kPa (75.9 mmHg) and 9.9 kPa (74.5 mmHg); Paco₂ 5.3 kPa (40.2 mmHg) and 5.4 kPa (40.7 mmHg); and Pa-aO₂ 3.2 kPa (23.9 mmHg) and 3.3 kPa (24.6 mmHg), respectively. The individual values for Pao₂ and Paco₂ as a function of age are shown in figure 1a and b. Pao₂ did not decrease with age. It was independent of age in men. It was positively correlated in women, but the correlation was weak: r=0.18; p<0.05. Paco₂ was independent of age. Pa-aO₂ was negatively correlated to Pao₂ (r=-0.74; p<0.001) and to Paco₂ (r=-0.30; p<0.001).

Mean FEV₁ was 1.0±0.5 l (53±24% pred). Mean FVC was 1.6±0.7 l (62±24% pred). Mean FEV₁/FVC was 67±18%.

There were significant correlations between blood gases and spirometric parameters. Pao₂ was positively correlated to FEV₁ (fig. 1c). Paco₂ was negatively correlated to FEV₁ (fig. 1d) and to Pao₂: Paco₂ kPa = 7.77 - 0.24 Pao₂ (Paco₂ mmHg = 58.4 - 0.24 Pao₂) (r=-0.42; p<0.001). The correlation coefficients between blood gases (Pao₂ and Paco₂) and FEV₁ expressed as % predicted values were 0.28 (p<0.001) and 0.39 (p<0.001). FVC was not correlated to Paco₂ and Pao₂. FEV₁/FVC was positively correlated to Pao₂ (r=0.29; p<0.001) and negatively to Paco₂ (r=-0.31; p<0.001).

In the patients with the more severe impairment in blood gases (Pao₂ <8 kPa or Paco₂ ≥6.12 kPa) there was no correlation between FEV₁ and Paco₂, and Pao₂ was positively but weakly correlated to FEV₁ (r=0.14; p<0.05).

Blood gases in the patients with the most severe airways obstruction (FEV₁ ≤35% pred) and in those with normal values (FEV₁ >90% pred) are shown in table 2. Mean Pao₂ was significantly lower and Paco₂ significantly higher in the patients with the more advanced disease. FEV₁ (% pred) was 43±17 in the patients with Paco₂ 6.1–6.7 kPa (46–50 mmHg) and 25±7 in those with Paco₂ >6.7 kPa (50 mmHg). Those values were significantly smaller than in the other patients.

Smoking status had little influence on blood gases and spirometric measurements. For the three groups (smokers, ex-smokers and nonsmokers), Pao₂ was 10.1±1.5 kPa (75.8±11.1 mmHg), 10.3±1.5 kPa (76.9±10.9 mmHg) and 9.9±1.4 kPa (74±10.5 mmHg); Paco₂ was 5.6±0.9

![Fig. 1.](image-url)
The patients described in this study are fairly typical of moderate chronic airways obstruction with reduced FEV\textsubscript{1} and FVC, chronic cough with expectoration and frequent episodes of apparent infection, leading their physicians to prescribe antibiotics. However, some patients had a moderate restrictive ventilatory defect or a combined restrictive and obstructive ventilatory defect. Since patients with clinical signs or chest X-ray pattern suggesting an interstitial lung disease have been excluded, the likely explanation for this condition in this type of population is the presence of kyphosis and/or muscle weakness. In fact, they were living in nursing homes for a variety of reasons, some because of respiratory disease itself, and therefore to have lower PaO\textsubscript{2} than comparable persons with healthy lungs. In our series, this supposition is borne out by finding a positive correlation between FEV\textsubscript{1} and Paco\textsubscript{2}. The worse the obstruction, the lower the oxygen. However, airway obstruction in itself is not the only determinant of blood gases, and several patterns of ventilation-perfusion inequality have been described in COPD patients [17].

In searching the literature for normal values of blood gases in old people we found 13 published articles [1–13] describing the relationship between PaO\textsubscript{2}, Paco\textsubscript{2} and age in populations of normal people. In addition, Stanescu et al. [19] reported a mean arterial oxygen saturation of 96% in 23 normal subjects aged 61–86 yrs (mean 71 yrs). Seven of them, listed in table 1, calculated linear regressions of PaO\textsubscript{2} and Paco\textsubscript{2} against age for sitting subjects. The studies of Diament and Palmer [5] and Rainie and Bishop [5] included both smokers and non-smokers. The regression lines of these series are shown in figure 2 together with our own. In addition, our patients with normal FEV\textsubscript{1} and those with more severe airways obstruction are illustrated separately.

If the regression lines, which had negative slopes ranging from 0.22–0.43 mmHg per year, were follo wed to age 82 yrs the mean age of our population, the various studies give predictions for normal PaO\textsubscript{2} ranging from 8.4–11.2 kPa (63.3–84.4 mmHg). The largest series, that of Hertle et al. [10], predicted a normal value of 8.4 kPa (63.3 mmHg), well below the mean value of our subjects with chronic bronchitis of 10.0 kPa (75.2 mmHg). The second largest series, that of Sorbini et al. [8], predicted 9.8 kPa (73.7 mmHg). These predictions are close to the measured values of PaO\textsubscript{2} in those of our patients with the most severe airways obstruction (table 2 and fig. 2), and must be in error. On the other hand, the large series

### Table 2. Arterial blood gases in patients with and without severe airways obstruction

<table>
<thead>
<tr>
<th>Patients groups</th>
<th>Patients n</th>
<th>Sex (M/F)</th>
<th>Age\textsuperscript{a} yrs</th>
<th>FEV\textsubscript{1} %pred</th>
<th>PaO\textsubscript{2}\textsuperscript{a} kPa (mmHg)</th>
<th>Paco\textsubscript{2}\textsuperscript{a} kPa (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV\textsubscript{1} ≥90% pred</td>
<td>15</td>
<td>6/9</td>
<td>84±10</td>
<td>108±19</td>
<td>10.8±1.4 (81.5±10.7)</td>
<td>4.8±0.6 (35.9±4.4)</td>
</tr>
<tr>
<td>FEV\textsubscript{1} ≤35% pred</td>
<td>51</td>
<td>29/22</td>
<td>80±7</td>
<td>27±6</td>
<td>9.5±1.3 (71.5±10.1)</td>
<td>5.7±0.9 (43.2±6.6)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}: data are presented as mean±sd. FEV\textsubscript{1}: forced expiratory volume in one second. For further abbreviations see legend to table 1.
of DIAMENT and PALMER [9], and the somewhat smaller ones of CONWAY et al. [6], MELLEMGAARD [7] and Raine and Bishop [5] predicted a PaO₂, between 10.9–11.2 kPa (82–84.4 mmHg) at age 82 yrs, which seems more reasonable by comparison with the values obtained in our patients with COPD.

Differences between the slopes and intercepts of the PaO₂-age relationships reported by various authors may reflect different populations of normals, sampling bias, differences in measurement techniques, or simply statistical variations. None of them report confidence intervals on their estimates of regression coefficients. Concerning their estimates of values of PaO₂ and PaCO₂ in very old individuals, it is important to note that their samples included few subjects over 60 yrs and even fewer over 70 yrs (table 1). Their predicted equations, thus, require the assumption that PaO₂ declines at exactly the same rate throughout life, from 20–100 yrs.

The study of BLOM et al. [13] suggests that PaO₂ in normal subjects does not, in fact, decline after 70 yrs. They presented the results of measurements in 111 persons in the form of a moving average of PaO₂ on age, and showed a descending limb followed by an ascending plateau in the patients >70 yrs.

Lack of decline of PaO₂ with age in elderly people could be explained in several ways. Loss of mechanical function may become less rapid in old age, or the relationship between changes in airways and pulmonary vessels with age may be such that ventilation-perfusion matching does not deteriorate in this age range. In cross-sectional studies, however, another explanation is that the subjects with the lower PaO₂ may have disappeared from the sample population. This possibility was suggested by BLOM et al. [13] for their population of normals. It is even more plausible as an explanation for the lack of decline of mean PaO₂ with age in our population of COPD patients. In a population of patients with chronic airways obstruction, life expectancy is strongly dependent on the severity of blood gas abnormalities [20]. When significant hypoxaemia and hypercapnia are present, a majority of patients will die in a few years. The natural history of such patients in the later stages of disease, as PaCO₂ begins to rise, is that FEV₁ declines steadily and PaO₂ declines slowly at first, then rather rapidly shortly before the patient dies. A cross-sectional study can, therefore, be expected to have few patients with low values of PaO₂. Thus, it is unlikely that our population of very old patients had been hypoxaemic for a long time. Whether these long survivors are exceptionally "healthy" subjects or are more like "normal" subjects, is debatable. Whatever the reason, our data indicate that PaO₂ in these patients is surprisingly high.

From a clinical point of view, this study points out that some of the published normal values for PaO₂ based on linear regressions with age cannot be relied upon for aged patients. Values predicted as normal by some equations [8, 10, 12], in fact, probably indicate a considerable gas exchange abnormality. Whilst there is not yet enough data to be certain, it is probably more accurate to accept as normal a PaO₂ of 10.6–11.3 kPa (80–85 mmHg) for all subjects over 65yrs, irrespective of their age. Our data indicate that very old patients with moderate COPD have PaO₂ values that are surprisingly close to normal. A very low PaO₂ in such patients cannot be safely attributed to age or to chronic airway disease, but should alert the clinician about the possibility of some additional acute or chronic respiratory problem.

References


