Exercises with a Blood Gas Analyser*

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SUMMARY

In a study to assess the accuracy of pO₂ and pCO₂ electrodes as used for blood determinations, it was found that the error, using the pO₂ electrode, was 1.53 ± 1.82%, and that for the pCO₂ electrode was 1.315 ± 1.12%. Studies were also carried out on the diffusion of O₂ and CO₂ through plastic syringes; it was found that such syringes are quite suitable for the storage of arterial blood for blood gas analysis if they are kept at 2° - 5°C.

MATERIAL AND METHODS

Radiometer equipment (Radiometer A/S, Copenhagen) was used throughout these studies, and included the use of a blood microsystem BMS 2, a pH-meter PHM 71, a pO₂ electrode E 5046 and a pCO₂ electrode E 5036, the electrodes being housed in a blood gas electrode unit BEU 1; all the equipment was maintained at 38°C.

Accuracy Study

Blood samples were obtained from 20 children aged 1 month to 10 years. Five of these were venous for the express purpose of studying a low pO₂ range; the remaining samples were arterial, obtained by direct arterial puncture, usually of the radial artery. All blood specimens were collected anaerobically and stored at 2° - 5°C in a cold-box.

The pO₂ electrode was calibrated using Zero solution (Radiometer Type 10 S 4150) and then with room air (taken as having a partial pressure of oxygen of 120 mmHg at an altitude of 1763 metres). The pCO₂ electrode was calibrated using gases of known CO₂ partial-pressure, in this instance 22.9 and 45 mmHg.

The range of pO₂ measured was from 28 to 80 mmHg. The error, in recurrent estimation, was found to be 0.7 ± 0.64 mmHg, or expressed as a percentage, 1.53% ± 1.82%.

The range of pCO₂ studied was from 16 to 44 mmHg. The error was 0.414 ± 0.48 mmHg, or 1.315% ± 1.12%.

Diffusion Study

Arterial samples were obtained from 20 children and were stored anaerobically at 2° - 5°C, in disposable syringes made of polypropylene (Steriject and Galaxy syringes; Monoplast Ltd). Ten samples were obtained from normal children, and the remainder from patients with pneumonia or gastro-enteritis. Electrode calibration was carried out as in the accuracy study. Estimations of pO₂ and pCO₂ were carried out as soon as the sample was obtained (zero time) and then at 60, 120 and 180 minutes. Between estimations the samples were stored in the cold-box. Recalibration of the electrodes was carried out before each estimation.

RESULTS

Accuracy Study

Twenty children were studied; the number of estimations per sample varied from 3 to 20. Samples took 15 - 55 minutes to analyse (mean 26.2 min).

The range of pO₂ measured was from 28 to 80 mmHg. The error in recurrent estimation was found to be 0.7 ± 0.64 mmHg, or expressed as a percentage, 1.53% ± 1.82%.

The range of pCO₂ studied was from 16 to 44 mmHg. The error was 0.414 ± 0.48 mmHg, or 1.315% ± 1.12%.

These results are summarized in Table I.

| TABLE I. DEGREE OF ACCURACY OBTAINED USING pO₂ AND pCO₂ ELECTRODES FOR RECURRENT ESTIMATIONS OF ANY ONE BLOOD SAMPLE |
|-----------|----------|----------|
| pO₂ (mmHg) | Mean     | 0.7      |
| SD         | 0.64     |
| Error (%)  | Mean     | 1.53     |
| SD         | 1.82     |

Diffusion Study

These results are shown in Table II and are expressed as the percentage fall-off or rise in pO₂ or pCO₂ as compared with the initial level, i.e. zero time.

To be of significance these results must be looked at in conjunction with data obtained on the accuracy of the
TABLE II. PERCENTAGE FALL-OFF IN pO₂ and pCO₂ OF ARTERIAL BLOOD WHEN STORED IN PLASTIC SYRINGES OVER A 3-HOUR PERIOD AT 2°C - 5°C

<table>
<thead>
<tr>
<th>% fall-off</th>
<th>pO₂</th>
<th>pCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>Mean</td>
<td>2.61</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.94</td>
</tr>
<tr>
<td>2 hours</td>
<td>Mean</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.72</td>
</tr>
<tr>
<td>3 hours</td>
<td>Mean</td>
<td>3.14</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.14</td>
</tr>
</tbody>
</table>

Analyser being used at the time. Such a comparison is shown in Fig. 1 for pO₂ and Fig. 2 for pCO₂. For pO₂ the mean fall-off line approximates the mean accuracy line, and the standard deviations transgress those of the accuracy study on 4 out of 6 occasions. With regard to pCO₂ it can be seen that the mean fall-off is greater than the second standard deviation of accuracy, and the diffusion study standard deviations depart markedly from those of the accuracy study.

Fig. 1. Fall-off of pO₂ in arterial blood stored at 2°C - 5°C in plastic syringes, compared with the accuracy of the blood gas analyser being used for such studies.

Fig. 2. Fall-off of pCO₂ in arterial blood stored at 2°C - 5°C in plastic syringes, compared with the accuracy of the blood gas analyser being used for such studies.

DISCUSSION

In the accuracy study, the results obtained (Table I) imply that when used with care, the pO₂ and pCO₂ electrodes produce results in which error, certainly for clinical purposes, is insignificant.

With regard to the pO₂ electrode, Daly et al.¹ observed a standard error of 7.4 mmHg in the pO₂ range of 0 - 760 mmHg, and Norman et al.⁵ found an error of ± 2.4 mmHg. Both figures are somewhat higher than our mean error of 0.7 ± 0.64 mmHg. From our findings we cannot concur with the findings of Kanarek et al.⁴ that pO₂ readings within 3 mmHg of each other on the same sample, can be considered as acceptable.

As far as the pCO₂ electrode is concerned, Norman et al.⁵ found a mean error of 2.5% of the actual pCO₂ value; this represents a mean error double that found in our experience. In comparison with the equilibration technique where an accuracy of about 2% can be expected,¹ the pCO₂ electrode compares favourably.
The determination of diffusion of O$_2$ and CO$_2$ through plastic syringes is important because it has been suggested on several occasions that 'plastic syringes are unsuitable vehicles for storage of arterial blood for pO$_2$ estimation'. Such statements appear to be based upon the work of MacIntyre et al., where blood which was hyperbarically oxygenated was stored at 37°C in glass and plastic syringes and the fall-off in pO$_2$ was compared. This is an unphysiological level of pO$_2$ and the temperature is unsuitable for the storage of blood for this kind of analysis. In our experience (Fig. 1) a fall-off in the pO$_2$ of arterial blood stored in plastic syringes at 2°C - 5°C, does occur mainly in the first hour of storage, as previously stated by MacIntyre et al., but when the O$_2$ consumption by red cells (mainly reticulocytes) and leucocytes, which after an hour of storage at 1°C, accounts for a fall-off in pO$_2$ of about 2.3% is taken into consideration, it can be seen that in our studies the fall-off due to diffusion is minimal.

With regard to CO$_2$ diffusion, there is a distinct loss of CO$_2$ when blood is stored in plastic syringes (Fig. 2), but because CO$_2$ diffuses much more rapidly than O$_2$, this is to be expected. This is in contrast to Andersen's finding that there is a rise in pCO$_2$ of 0.6 ± 0.6 mmHg/h over 3 hours when arterial blood is stored at 4°C in glass syringes. Thus there does appear to be a considerable loss of CO$_2$ from plastic syringes. However, in a clinical light, for example in the case of a patient with respiratory acidosis and a pCO$_2$ of 80 mmHg (assuming the blood gas analyser accuracy to be the same at that level of pCO$_2$), from our studies, one would expect that after one hour of blood storage the error would be 5.28 mmHg using one standard deviation. Exactly how clinically significant this is must be a matter of individual opinion, but it does not appear to be a gross error in the example given.

Hence it would appear that, for clinical purposes at least, plastic syringes, if kept at 2°C - 5°C, are quite suitable for the storage of blood for gas analysis, as previously described by Laver and Seifen, provided that possible loss of CO$_2$ is borne in mind.

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REFERENCES