Quality Control of Measurements of pH, Carbon Dioxide Tension, and Total Carbon Dioxide in Plasma

D. J. Savory and J. D. Pryce

We have measured total carbon dioxide in plasma with a new carbon dioxide analyzer, and compared the results with total carbon dioxide data derived from measurements of carbon dioxide tension and pH. The results agree sufficiently well to demonstrate that the new instrument provides a simple, efficient procedure for monitoring the precision and accuracy of pH, carbon dioxide tension, or total carbon dioxide in plasma.

Additional Keyphrases: Corning 960 CO₂ analyzer compared with Radiometer BMS3 - blood gases

Quality control of the routine measurement of pH, carbon dioxide tension (pCO₂), and total carbon dioxide, in plasma presents difficulties; pCO₂ can be checked by tonometry at a single concentration, and pH and pCO₂ can be checked by using commercial preparations with assayed values, although these preparations are moderately expensive. The usual commercial liquid or dried sera offered for quality control are not suitable for total CO₂ analyses because of the instability of bicarbonate. All of these procedures check the instrumentation and its standardization and operation; they do not monitor actual values reported by the laboratory on patients' samples.

The recent introduction of the Corning 960 carbon dioxide analyzer provides a possible means of cross-checking a sample of routine results obtained for plasma pH, pCO₂ or total CO₂ measurements. In this instrument a proprietary solution of lactic acid is used to release carbon dioxide from 100 µl of plasma. The released gas is passed through a thermal conductivity detector, from which the concentration of gas is shown as a digital display. The response of the instrument is linear from 0 to 50 mmol of total CO₂ per litre, and once the instrument is standardized the response is usually stable for many hours. A single estimation takes about 1 min, and requires no special skill other than accurate pipette handling.

This report concerns the possible use of the Corning instrument for quality control of plasma pH, pCO₂, or total CO₂ measurements.

Material and Methods

We studied 197 venous blood samples submitted for routine electrolyte analysis. These samples were received in bottles that contained lithium heparin as anticoagulant and polystyrene beads with a specific gravity intermediate between that of plasma and erythrocytes. The beads therefore form a physical barrier between the two phases, and we have previously established that under these conditions, plasma pH, pCO₂ and total CO₂ remain stable for about 6 h without plasma separation.

The blood samples were centrifuged on receipt, and then analyzed in batches. pH and pCO₂ were measured with a Radiometer BMS3 Mk II blood-gas analyzer. This instrument was calibrated with carbon dioxide at pCO₂ of 5.32 and 10.64 Pa (40 and 80 mmHg) and with proprietary buffers of pH 6.840 and 7.380. Within an hour, the total CO₂ content of the samples was measured with the Corning 960. The total CO₂ content of the blood samples was also calculated from the measured pH and pCO₂ values by use of the Henderson–Hasselbalch equation. If the measured total CO₂ and the calculated total CO₂ differed by more than 4 mmol/litre, both measurements were repeated, otherwise only single measurements were used.

Results

The analytical error of the two values for total CO₂ was estimated from 30 paired duplicate analyses for each method. This gave an SD of ±0.65 mmol/litre for the direct method for total CO₂ and ±1.35 mmol/litre for the calculated value. Twenty-eight samples in the survey gave a discrepancy of 4 mmol/litre or greater between the two methods. These samples were remeasured, and the means of the duplicate values were used in the statistical analysis of the data. Table 1 shows the means, standard deviations, and the two regression equations obtained. Figure 1 shows the scattergram of the values for the two methods, and the two regression lines calculated from the data. Table 2 shows the values for the discrepant data.

Discussion

It can be seen from Table 1 that there was no significant difference between either the means (P = 0.58) or the variances (P = 0.31) for the two different measurements of total CO₂. However, the regression coefficients for the two equations differ by two standard errors of the coefficient, and it can be seen from the graph that the slope for the calculated total CO₂ is shallower than the slope for the measured total CO₂. The discrepancy is not great; a measured total CO₂ of zero would give a calculated value of 4.2 mmol/litre, and a measured total CO₂ of 50 mmol/litre would yield a calculated value of 47.4 mmol/litre. So far, we have failed to discover the source of this discrepancy, but we suspect that with our pCO₂ electrode, the response slope to plasma may be less steep than the

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1 The graph lines should cross at the means. The graph is mainly intended to give a visual impression of the scatter; the estimating equations give the precise data.
Table 1. Regression Equations, Means, and Standard Deviations Calculated for the Two Methods

<table>
<thead>
<tr>
<th>Total CO₂</th>
<th>Mean (mmol/litre)</th>
<th>SD</th>
<th>MEASURED</th>
<th>CALculated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>28.12 ± 4.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated</td>
<td>28.52 ± 4.7</td>
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</tbody>
</table>

Measured total CO₂ = 1.688 + (0.927 X calculated total CO₂);
SE = ±2.18; r = 0.894

Calculated total CO₂ = 4.237 + (0.864 X measured total CO₂);
SE = ±2.11

response slope to gaseous carbon dioxide.

Another source of error could arise if the constant in the Henderson-Hasselbalch equation varies under pathological conditions. Some observers have asserted that the constant does vary (1, 2), others have failed to find significant variation (3). Of the 28 blood samples that gave discrepant results, the repeat analyses suggested that in 23 of these the calculated total CO₂ was at fault. In two cases—numbers 24 and 105—the measured value appeared to be wrong. In the remaining three cases—number 57, 108, and 125—duplication was good, suggesting an intrinsic discrepancy between the two measurements. It appears that if the constant in the equation does vary, it does not do so in more than 2% of patients' samples, for unknown reasons, and the size of the discrepancy is not sufficient to be clinically misleading.

Our results suggest, therefore, that the Corning instrument provides an efficient and simple procedure for checking both the precision and the accuracy of pH, pCO₂, or TCD analyses on routine plasma samples.

References


...The variation of pK' with pH reported by Severinghaus, pK' = 6.086 + 0.044 X (7.4 - pH), would operate in the direction of the contradiction that our results show, but is hardly of sufficient magnitude. pH 7 would give a pK' of 6.1036, as opposed to the value of 6.086 for pH 7.4, a difference of about 1 in 600, whereas our discrepancy at higher values was about 2 in 100.

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*Ed. note: cf. also Clin. Chem. 24, 1081, 1082 (1978).*