Acta vet. scand. 1981, 22, 597—599.

Brief Communication

EXTRAPOLATION OF ACID-BASE PARAMETERS IN PHYSIOLOGY. CARBON DIOXIDE CHANGES IN STORED BLOOD

In vivo, the concentration of carbon dioxide in blood is regulated by the tissue production of CO_2 and its excretion through the lungs. Likewise, the bicarbonate concentration is regulated by the excretion of HCO_3^- through the kidneys. The HCO_3^-/H_2CO_3 buffer system, consequently, behaves as in an open system. In vitro, i.e., in a blood sample stored properly with respect to the prevention of CO_2 escape to the atmosphere, a shift in the CO_2 partial pressure (pCO_2) will occur on account of the buffering effect of HCO_3^- on H^+ produced by anaerobic glycolysis in the blood cells. Furthermore, pCO_2 may change as a consequence of CO_2 production by aerobic metabolism in leucocytes and reticulocytes. Aerobic CO_2 production, however, contributes only little to the pCO_2 changes, depending among other factors on the storage temperature and duration (*Capel et al.* 1965, *Lenfant & Aucutt* 1965, *Greenbaum et al.* 1967).

The purpose of this investigation was to examine if it is possible to calculate the original pCO_2 in a blood sample from the initial pH and the final pH and pCO_2. If so an estimation of acid-base balance might be made by measuring the initial pH and, at a more convenient time, the final pH and pCO_2. Such an approach could be of value if it is not possible to get a complete acid-base characterization immediately after taking the blood sample.

It is assumed that a blood sample represents a closed system. If only anaerobic glycolysis is taking place the total CO_2 concentration ($H_2CO_3 + CO_2 + HCO_3^-$) is constant and independent of storage time and temperature. Only the ratio bewteen H_2CO_3 or $S \cdot pCO_2$ (S = solubility coefficient of CO_2) and HCO_3^- will change. In such a system the concentration of total CO_2 ($[CO_2]_T$) is expressed by the following equation:

$$[CO_2]_T = S \cdot pCO_{2,0} + [HCO_3^-]_0 = S \cdot pCO_{2,t} + [HCO_3^-]_t$$

with the suffixes o and t indicating the values at time zero and time t, respectively. Determination of pH and pCO_2 at time t

gives a complete characterization of the acid-base balance at this time based on the Henderson-Hasselbalch equation:

$$pH_t = pK_1'' + \log \frac{[HCO_3^-]_t}{S \cdot pCO_{2,t}} \quad (1)$$

By introducing $[HCO_3^-]_t = [CO_2]_T - S \cdot pCO_{2,t}$ the equation can be rearranged:

$$[CO_2]_T = S \cdot pCO_{2,t} \cdot (1 + 10^{pH_t - pK_1''}) \quad (2)$$

The hypothesis which is tested is that $[CO_2]_T$ is constant. If so:

$$[CO_2]_T = S \cdot pCO_{2,0} \cdot (1 + 10^{pH_0 - pK_1''}) \quad (3)$$

By combining (2) and (3) $pCO_{2,0}$ may be calculated if pH_0, pH_t and $pCO_{2,t}$ are known:

$$pCO_{2,0} = pCO_{2,t} \cdot \left(\frac{1 + 10^{pH_t - pK_1''}}{1 + 10^{pH_0 - pK_1''}}\right) \quad (4)$$

Poulsen & Surynek (1977), *Assal & Poulsen* (1978) and *Assal et al.* (1978, 1980a, 1980b) investigated the effect of storage on acid-base parameters for different species. Using their mean values of pH_0, pH_t, and $pCO_{2,t}$, equation (4) has been reexamined. Based on the discussion by *Siggard-Andersen* (1963) 6.10 was chosen as the value of pK_1''.

From Table 1 it appears that the calculated $pCO_{2,0}$ values are in close agreement with the observed ones. The increase in pCO_2

Table 1. Carbon dioxide partial pressure at the time of blood sampling ($pCO_{2,0}$) calculated on the basis of initial pH (pH_0) and pH and pCO_2 after 24 h of storage.

Species	Arterial/ venous	Storage temperature °C	pH_0	pH_{24}	$pCO_{2,24}$ (mm Hg)	$pCO_{2,0}$ (mm Hg) calc.	obs.
Dog	V	21—24	7.327	6.999	83.44	41.7	44.0
Horse	V	21—24	7.397	7.188	64.29	40.9	40.4
Horse	A	21—24	7.424	7.240	59.19	39.7	40.4
Mink	A	21—24	7.385	7.005	105.29	46.9	48.6
Swine	V	21—24	7.299	7.082	88.11	55.5	56.9
Cattle	V	21—24	7.383	7.253	58.8	44.3	44.1
Dog	V	0—4	7.322	7.236	53.11	44.1	43.9
Mink	A	0—4	7.382	7.263	61.81	47.2	48.9
Swine	V	0—4	7.296	7.277	59.21	56.8	55.2

pCO_2 (calc.) = pCO_2 (obs.) · 1.00—0.59 (mm Hg).
($r^2 = 0.9555$, $P < 0.001$).

can be explained by a constant CO_2 concentration in blood and a changed relation between pCO_2 and $\left[HCO_3^-\right]$. CO_2 production from aerobic metabolism in leucocytes and reticulocytes appear to have been insignificant.

Based on these results it should be possible to determine acid-base balance from an initial "simple" pH measurement in a clinical situation. The blood sample can then be mailed or transferred to a laboratory where a complete characterization of acid-base balance can be made. Such a method may be of interest in the evaluation of metabolic and respiratory disturbances in connexion with, e.g., chronic gastroenteritis, ketosis, diabetes mellitus, insufficiency of the kidneys, or pneumonia.

The results are, however, based on average figures for pH and pCO_2, and before a final conclusion can be drawn they must be confirmed in individual animals. Furthermore, it must be investigated whether it is possible to obtain precise pH_0 values in blood at 37°C by using a rather simple pH-meter and carrying out the measurements at lower temperatures. Such investigations are in progress.

Preben Fogd Jørgensen
The Department of Veterinary Physiology and Biochemistry, Royal Veterinary and Agricultural University, Copenhagen, Denmark.

REFERENCES

Assal, A. N. & J. S. D. Poulsen: Acid-base status of equine blood during storage. Nord. Vet.-Med. 1978, *30*, 354—363.
Assal, A. N., J. Arnbjerg & J. S. D. Poulsen: Acid-base status of canine blood during storage. Nord. Vet.-Med. 1978, *30*, 345—353.
Assal, A. N., I. J. Christiansen & J. S. D. Poulsen: Acid-base status of porcine blood during storage. Nord. Vet.-Med. 1980a, *32*, 9—16.
Assal, A. N., Ø. R. Jepsen & J. S. D. Poulsen: Acid-base status of mink blood during storage. Nord. Vet.-Med. 1980b, *32*, 1—8.
Capel, L. H., E. C. Fletcher & J. F. Nunn: Carbon dioxide production of whole blood in vitro. Nature (Lond.) 1965, *208*, 82.
Greenbaum, R., J. F. Nunn, C. Prys-Roberts & G. R. Kelman: Metabolic changes in whole human blood (in vitro) at 37°C. Respiration Physiol. 1967, *2*, 274—282.
Lenfant, C. & C. Aucutt: Oxygen uptake and change in carbon dioxide in human blood stored at 37°C. J. appl. Physiol. 1965, *20*, 503—508.
Poulsen, J. S. D. & J. Surynek: Acid-base status of cattle blood. Nord. Vet.-Med. 1977, *29*, 271—283.
Siggaard-Andersen, O.: The Acid-base Status of the Blood. Munksgaard, Copenhagen 1963.

(Received October 12, 1981).

Reprints may be requested from: Preben Fogd Jørgensen, the Department of Veterinary Physiology and Biochemistry, Royal Veterinary and Agricultural University, Bülowsvej 13, DK-1870 Copenhagen V, Denmark.