Deacon's Challenge
No 103 - Answer

It is becoming increasingly common practice to replace pH with hydrogen ion concentration when reporting acid-base data. A patient is admitted to ITU with a blood hydrogen ion concentration of 80 nmol/L, pCO_2 of 5.4 kPa and an actual bicarbonate of 12 mmol/L. After taking steps to improve ventilation and circulation a second set of blood gases were: pCO_2 5.1 kPa and bicarbonate 20 mmol/L. Calculate the new hydrogen ion concentration in nmol/L.

FRCPath, Spring 2009

It is possible to solve this problem by using the Henderson-Haselbalch equation to determine the new pH then converting the result back to hydrogen ion concentration. However it is much simpler to use the relationship between the hydrogen ion concentration, pCO_2 and bicarbonate concentration:

$$K = \frac{[H^+] \times [HCO_3^-]}{pCO_2}$$

where *K* is a constant with components from the equilibrium constants for carbonic acid formation and dissociation, water concentration and the Bunsen solubility coefficient for CO_2.

Therefore the parameters both before and after treatment are related:

$$\frac{\text{Initial } [H^+] \times \text{Initial } [HCO_3^-]}{\text{Initial } pCO_2} = \frac{\text{Final } [H^+] \times \text{Final } [HCO_3^-]}{\text{Final } pCO_2}$$

It does not matter if the units for the individual components differ as long as they are the same on both sides of the equation.

Rearrangement gives the following expression for the final hydrogen ion concentration:

$$\text{Final } [H^+] = \frac{\text{Initial } [H^+] \times \text{Initial } [HCO_3^-] \times \text{Final } pCO_2}{\text{Initial } pCO_2 \times \text{Final } [HCO_3^-]}$$

Substitute: Initial $[H^+]$ = 80 nmol/L

Initial pCO_2 = 5.4 kPa; Final pCO_2 = 5.1 kPa

Initial $[HCO_3^-]$ = 12 mmol/L; Final $[HCO_3^-]$ = 20 mmol/L

$$\text{Final } [H+] = \frac{80 \times 12 \times 5.1}{5.4 \times 20} = \mathbf{45\ nmol/L}$$ (to 2 sig figs)

Question 104

A patient who weighed 75 Kg presented with rapid atrial fibrillation. He was given a first 250 µg oral dose of digoxin on admission. Twelve hours later he is reviewed by a cardiologist who notes that he is still in atrial fibrillation and recommends a loading dose of digoxin in order to bring his next pre-dose plasma digoxin concentration to approximately 1.5 µg/L 12 hours later. Calculate the dose that should now be given. Assume the following:

- Digoxin volume of distribution 7.3 L/Kg
- Oral bioavailability 0.62
- Single first order half life of 36 hours

FRCPath, Spring 2009