Deacon's Challenge No. 11 Answer

A male adult insulin-dependent diabetic forgot to take his insulin. His blood glucose concentration, which was 5 mmol/L, rose to 15 mmol/L in two hours.

Estimate the effect on his plasma sodium concentration, assuming that no other water intake nor loss of water from the body takes place during this time, indicating what assumptions you make.

(MRCPath November 1998)

It is not possible to get anywhere with this question without making a number of assumptions:

1. That it is plasma glucose that is measured rather than whole blood.

2. That as a result of insulin deficiency there is no increase in glucose concentration in the intracellular fluid (ICF)

3. That the plasma glucose has equilibrated with interstitial fluid so that its concentration in the extracellular fluid (ECF) is the same as in plasma.

4. That there is negligible change in the concentrations of solutes other than glucose, sodium and chloride.

5. That the ratio of ICF:ECF volumes is 2 (i.e. ECF = 14L, ICF = 28L for average adult male).

The effect of an increase in plasma (and hence ECF) glucose will be to raise plasma (and ECF) osmolarity. The body will retain water (stimulation of thirst increases intake and stimulation of ADH reduces renal loss) until osmotic equilibrium is restored. If there is a plentiful supply of water, then the plasma osmolarity is returned to normal and since the plasma glucose has risen by 10 mmol/L the plasma sodium must have fallen by 10/2 = 5 mmol/L. However, the examiners emphasise that there is no net loss or gain of body water. Therefore, water will move from the ICF compartment (iso-osmolar) to the ECF (now hyper-osmolar) until osmotic equilibrium is established. Since movement of water from the ICF leads to an increase in ICF osmolarity, the movement of water is restricted and at equilibrium the ECF will reach a value somewhere between normality and the original value i.e. the osmotic load is shared between the ECF and ICF compartments, both of which become hyperosmolar.

The plasma glucose has risen by 15 - 5 = 10 mmol/L

Rise in amount of glucose in ECF = Rise in plasma glucose concentration (mmol/L) x ECF vol/L

= 10 x 14 = 140 mmol

(a slight underestimate since there has been a small expansion in ECF vol)

At equilibrium, the rise in osmolarity (which is the same in the ECF and ICF) is

$$\frac{\text{Increase in amount of glucose in body (mmol)}}{\text{Total body fluid (ECF + ICF) volume (L)}} = \frac{140}{42} = 3.33 \text{ mmol/L}$$

Therefore, since the plasma osmolarity has risen by 3.33 mOsmol/L and the plasma glucose by 10 mmol/L, then the amount of NaCl which has been displaced by glucose is

10 - 3.33 = 6.67 mmol/L

and so the sodium has fallen by $\frac{6.67}{2}$ = 3.34 mmol/L

i.e. the plasma sodium concentration has decreased by approximately 3 mmol/L. ■

Question No. 12

A 15 year old boy presents to casualty following a convulsion. It turns out that he had swallowed 30 of his mother's lithium tablets about 10 hours previously. On admission his lithium concentration is 4.1 mmol/L. A decision needs to be made whether to haemodialyse him to reduce the lithium concentration. As this is not going to be available quickly, the physicians want to know how long he will have toxic levels just with endogenous clearance. Estimate the following, indicating clearly any assumptions you have made:

a) The likely volume of distribution of the lithium at this stage in the situation, given a body weight of 65 kg.

b) How long it will be before his lithium concentration drops to the relatively safe level of 1.5 mmol/L below which toxicity is unlikely, given a clearance of 0.03 L/h/kg.

(MRCPath May 2001)