ACID BASICS

Understanding fluids, urea and electrolyte balance;
a quantitative approach. Part Three.

QUICK QUESTIONS

The guy at the gym told Sam to drink plenty of water

- What is the hydrogen ion concentration of water at standard temperature and pressure?
- What is the pH of 0.9% sodium chloride solution?

You probably know that the pH of water is 7.0, and you might recall that "p is the negative logarithm"; so the $[H^+]$ of water is 10^{-7}mol l^{-1}, which sounds easier if you call it 100 *nano*moles per litre. pH 7.4 is 40 nmol l^{-1}.

5.5 (it is written on the bag). We are now into big micromolar quantities of $[H^+]$. Putting solutes into water changes its pH.

ACIDAEMIA

So the normal hydrogen ion concentration of plasma is about 40 nmol, and is mostly determined by the carbon dioxide tension, the anion effect of weak acids [A_{TOT}] and the strong ion difference (SID). A 50% increase of [H^+] to 60 nmol is a serious acidaemia (pH 7.22). Systemic vascular resistance falls, pulmonary VR rises, cardiac contractility falls, and the Hb-O_2 dissociation changes impair tissue oxygenation.

It is a curious and useful fact that the activities of clotting factors are inversely proportional to hydrogen ion concentration, so a priority in treating the bleeding patient is to reverse acidaemia, and if possible bring about a mild alkalaemia.

For the most elementary bedside assessment of acid base balance, Dr Eugene notes the results of pH, PCO_2, base excess, albumin, Na and Cl. Lactate is often useful too. Dr Eugene does not ask the analyser to adjust for body temperature.

He looks at the pH; is the patient acidaemic ("acid blood"), normal, or alkalaemic?

He looks at the carbon dioxide tension; is it acidotic (raised and tending to make the blood acidaemic), normal or alkalotic?

He considers what the non-respiratory -osis would be.

Base excess is the theoretical amount of strong ion (like chloride in hydrochloric acid) which would return the pH to normal if the CO_2 was normal.

- Which BE (+6, -5, -10) goes with which patient?

a	pH 7.41, PCO_2 3.9
b	pH 7.19, PCO_2 4.9
c	pH 7.47, PCO_2 5.1

patient *a* has respiratory alkalosis, but with normal pH there must be a non-respiratory acidosis of about -5.

patient *b* is very acidaemic with only a limited respiratory alkalosis, so must have big non-respiratory acidosis of about -10.

patient *c* is alkalaemic with no respiratory -osis, so must have a non-respiratory alkalosis of about +6.

The base excess is ***not*** an independent physiological variable, it is just the result of a calculation the machine performs on the measured hydrogen ion concentration and carbon dioxide tension. It is a prediction of a titration of the blood sample (CO_2 corrected, normal Hb and albumin presumed, and in a glass tube) against acid or alkali. *In vivo*, the blood is buffered by ecf through the capillary bed, and may have significant abnormalities.

BE

Whatever it's shortcomings, Dr Eugene likes BE because it is a wonderfully simple number that summarises the non-respiratory acid-base situation, very welcome when you have six patients to prepare for presentation on Dr B'Staad's ward round, and so little time to do it.

ALBUMIN EFFECT ON BE

In the ICU patient population, a greater or lesser degree of hypoalbuminaemia is very common and needs to be taken into account when reading a base excess. Hypoalbuminaemia causes alkalosis. Dr Eugene calculates how far the albumin deviates from a normal value of 42, divides that number by 4 and takes the result to indicate the magnitude of the effect of albumin on BE.

SOD/CHLOR EFFECT ON BE

What's more, Dr Eugene looks at the difference between the sodium and chloride concentrations, subtracts 38 and takes that to be a rule-of-thumb approximation of the effect those ions are having on the BE.

These calculations are quick and easy to perform, and help Dr Eugene not to miss important acid-base derangements. For example, this was Salty Sam's ABG one hour into his anaesthetic for hemicolectomy;

pH 7.30, PCO_2 6.9, BE 1, Na 145, Cl 107.

- comment on these results.

No albumin result, but let's hope at that point Sam had not (yet) been flooded into hypoalbuminaemia. There is no significant effect of Na/Cl on base excess, which is itself normal. This shows a straightforward respiratory acidaemia.

Dr Eugene remembers Salty Syd, the anaesthetist who prescribes liberal amounts of normal saline. His patients typically return to ICU with a non-respiratory acidosis, like this one;

- BE -6, Na 141, Cl 111.
- What other ion should Dr Eugene check? Explain.

Looks like a straightforward hyperchloraemic acidosis, but Dr Eugene really ought to check the lactate to make sure; there could be a combination of lactataemia and hypoalbuminaemia cancelling out one another's effect on BE.

When Sam developed ARDS, Dr Eugene recorded the following ABG on 65% oxygen; pH 7.31, PCO_2 6.5, PO_2 8, BE -2. Na 136, Cl 102, lactate 2. Albumin 22.

- analyse that!

A hypoalbuminaemic alkalosis of about +5, a sodium / chloride effect of about -4, lactate -2; these just about account for the BE -2. The important lesson is that this situation is not just a respiratory acidaemia; Sam also has a clinically-significant non-respiratory acidosis concealed by a common non-respiratory alkalosis.

Dr Eugene recorded this ABG on Salty Sam a couple of days after his ICU admission.

pH 7.15, BE -9, Na 130, Cl 96, lactate 4, albumin 14.

- Analyse that!

hypoalbuminaemic alkalosis effect +7, sodium / chloride effect of about -4 and lactate -4 give net BE effect of -1, but as the total BE is -9 there is a BE effect of about -8 from anions we have not measured. This picture is typical of severe acute renal failure as part of the multi-organ failure syndrome, and the "unmeasured" anions include sulphate, phosphate and urate.

- what effect would you expect from 50 ml 8.4% sodium bicarbonate as a bolus?

8.4% Sod Bic is designed for your convenience to contain 1 mmol Na and 1 mmol HCO_3 per ml. 50 mmol sodium without chloride distributed through 20 litres ECF will increase the sodium/chloride difference by about 2.5 mmol l^{-1} and thereby increase the sodium/chloride effect on the base excess. In practice, give the 50 ml of bicarb then repeat the ABG to gauge the effect.

Dr Eugene's "base-excess effect" approach to acid base analysis is obviously very approximate, but as a busy junior on ICU it serves him well. His Consultant, Dr B'Staad, likes to use a spreadsheet to calculate things like the actual and estimated strong ion differences, and he corrects the anion effect of albumin for pH. He worries about the phosphate. He talks about Stewart, Figge, Fencl and Gilfix, but Dr Eugene rarely finds time to go into that level of detail. As long as the patient gets better....

- A final activity for you... Examine the ion concentrations and pH of the fluids you use carefully. When you prescribe them, think about the effect you expect them to have on that particular patient. When you next check the patient, see if you were right.

FINAL REFLECTIONS...

- This account is based on Peter Stewart's quantitative approach to acid base balance, which even at its simplest gives more insight into complex critical illnesses.
- Use these calculations regularly and they will become second nature. If you want to go a little deeper, the effects of free water and chloride adjusted for sodium can be calculated separately. More ions can be taken into account, and more precise calculations used.

On Sam's saga...

- Remember that patients will usually be OK if you can just get their water, electrolyte, acid-base, nutrition and excretory needs approximately right; homeostasis will do the fine tuning.
- A working familiarity with the numbers involved in balancing the various accounts is invaluable, because serious deviations in clinical management will have fatal consequences.

print this page...

fluidphysiology.org

CERTIFICATE

I have now completed the three Parts of *fluidphysiology.org* self-directed learning activity on quantitative fluids, urea and electrolyte balance for rational prescribing. After following the saga of Salty Sam, Dr Eugene and his Consultant Dr B'Staad I am ready to answer all and any questions on the subject.

Name of student	*signature*	*date*