ACID-BASE DISORDERS

The kidneys, lungs, and physiologic buffers normally maintain the serum pH within a narrow spectrum, between 7.36 and 7.44. Such precise physiologic control is required for normal cellular function. Consequently, disorders of kidneys, lungs, and physiologic buffers result in acid-base abnormalities.

Blood pH is determined by the ratio of CO_2 (respiratory influence) to HCO_3^- (renal influence).

$$H^+ + HCO_3^- \rightleftarrows H_2CO_3 \rightleftarrows H_2O + CO_2$$

Acidaemia: pH < 7.36 *Alkaemia:* pH > 7.44

Acidosis is a pathological process that lowers the HCO_3^- or raises the CO_2
Alkalosis is a pathological process that raises the HCO_3^- or lowers the CO_2

Physiologic Buffers.

Defined as a weak acid and its salt, which oppose marked changes in pH.

Buffers mitigate the impact of large changes in available hydrogen ion on plasma pH. These buffers include;

- haemoglobin
- phosphate
- proteins
- bicarbonate

$$H^+ + buffer^-Na^+ \rightleftarrows buffer^-H^+ + Na^+$$

Bicarbonate.

- Open-ended system w/ continuous removal of organic acid made possible by exhalation of CO_2.
- Large quantities in *kidneys & lungs.*

Intracellular Proteins.

- Particularly, *albumin & Hb.*

Bone as Buffer.

- Large reservoir of *bicarbonate & phosphate.*
- In reality, only two types of metabolic acidosis are long-lasting enough to cause bone demineralisation
    - *Renal tubular acidosis*
    - *Uraemic Acidosis*

Pulmonary Compensation.

This involves a relationship between peripheral chemoreceptors (carotid bodies) and central chemoreceptors (medulla); both of which drive minute ventilation.

- A drop in pH results in increasing minute ventilation (lowering CO_2).
- Takes ~ 4-12 hours for respiratory compensation to bring pH back to normal.

Renal Compensation.

The kidneys play little role in acute compensation of acid-base disorders, as they do not immediately respond to changes in pH.

- Requires 6-12 hours of sustained acidosis to result in active excretion of H^+.
- H^+ usually excreted in form of ammonia (NH^+), with retention of HCO_3^-.
- Conversely, 6+ hours of alkaemia stimulates renal excretion of HCO_3^- and retention of H^+ in form of organic acids.

In metabolic acidosis the kidney attempts to preserve Na^+ by exchanging it for excreted H^+ or K^+.

- The quantity of potassium excreted depends on the level of acidosis & the serum K^+ level.
- In the presence of large H^+ load, hydrogen ions move from ECF into intracellular fluid, displacing K^+ outside the cell (maintaining electroneutrality).

In cases of severe acidosis, there is significant overall depletion of total body K^+ despite serum hyperkalaemia.

In metabolic alkalosis, there is a shift of H^+ extracellularly (in exchange for K^+ and Na^+) with renal excretion of K^+ to preserve H^+.

- Kidneys will also excrete H^+ in cases of severe hypokalaemia (eg. prolonged NG suctioning) to preserve K^+.
- Paradoxical *aciduria* is a clinical clue to the magnitude of hypokalaemia.

DIAGNOSTIC STRATEGIES.

Thorough Hx & examination:

- PMHx
- Current medications
- Toxic ingestion
- Vomiting / diarrhoea
- Hydration status
- Urine output
- Level of consciousness
- Respiratory rate

Bloods:

- Serum electrolytes
- pH
- Anion gap & delta gap
- Osmolar gap

THE ANION GAP.

$$AG = Na^{+} - (Cl^{-} + HCO_3^{-})$$

- Normal AG = 12 (±3)
- Estimates ‘unmeasured anions’
    - Albumin
    - Phosphate
    - Sulfate
    - Organic anions (citrate).
- If AG is raised; consider an excess in organic acids or other acidic substances.

THE DELTA GAP.

$$\Delta G = (\text{calculated AG} - 12) - (24 - \text{measured } HCO_3^{-})$$

- Helps to resolve the possibility of;
    - Mixed acid-base disorder
    - Further differentiation of an elevated AG metabolic acidosis.
- ΔG > +6 = metabolic alkalosis or respiratory acidosis
- ΔG < -6 = a mixed disorder (greater loss of HCO_3^-).

Arterial Blood Gas Analysis

ABG Parameter			ABG result
pH	>7.45	Alkalaemia	
	7.36-44	Normal	
	<7.35	Acidaemia	
pCO2	>45	High	
	35-45	Normal	
	<35	Low	
HCO3	>26	High	
	24+/- 2	Normal	
	<22	Low	
AG	> 16	High	
	12+/-4	Normal	
	< 8	Low	
Glucose	>10	High	
	< 2	Low	
Gap: Gap	$\frac{\Delta \text{ AG}}{\Delta HCO_3} = \frac{\text{AG - 12}}{24 - HCO_3}$		
Lactate	**<1.9**	Normal	
	>2.0	High	
pO2	80-100	Normal	
	< 80	Hypoxia	

Calculation and interpretation		
pH	**pCO2**	**Interpretation**
↓	↓	Metabolic acidosis
↑	↑	Metabolic alkalosis
↑	↓	Respiratory alkalosis
↓	↑	Respiratory acidosis

Corrected standard AG for albumin

$$\frac{\text{Albumin}}{4} + 1.5 \times \text{Phosphate}$$

Anion Gap calculation

$\{[Na+] - [Cl^- + HCO_3]\} = 12+/-4$

Corrected Na+ for AG in hyperglycemia

$$\text{Corrected Na+} = \text{Na} + \frac{\text{Glucose} - 5}{3}$$

Gap: Gap calculation for metabolic acidosis

<0.4	Low or Normal AG metabolic acidosis
0.4-0.8	Normal + high AG metabolic acidosis
0.8-2.0	Pure high metabolic acidosis
>2.0	Metabolic acidosis with metabolic alkalosis/respiratory acidosis

PAO2 = [713 x FiO2] – [pCO2 x 1.25]

A-a gradient = PAO2 – PaO2 = $\frac{\text{Age}}{4} + 4$

Compensation rules for

	Metabolic acidosis	Metabolic alkalosis
Expected PCO2	1.5 X [HCO3] + 8 (+/- 2)	0.7 X [HCO3] + 20 (+/- 5)

	Respiratory acidosis		Respiratory alkalosis	
	Acute	Chronic	Acute	Chronic
Expected HCO3	$24 + \frac{pCO2 - 40}{10} \times 1$	$24 + \frac{pCO2 - 40}{10} \times 4$	$24 - \frac{40 - pCO2}{10} \times 2$	$24 - \frac{40 - pCO2}{10} \times 5$