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pH

Acidaemia <7.35 ← pH → >7.45 **Alkalaemia**

Acidaemia

High pCO_2
>45mmHg

Respiratory acidosis

CAUSES:
Processes that cause hypoventilation
→ CNS depression (head injury, stroke, drugs)
→ Respiratory depression (myopathy, spinal cord injury, drugs)
→ Hypoventilation (pain, chest wall injury/deformity, raised intra-abdominal pressures)
→ Respiratory failure (pneumonia, pneumothorax, oedema, bronchial obstruction)
→ Airway obstruction
Chronic respiratory acidosis → COPD, restrictive lung disease

Acute or chronic?

For acute respiratory acidosis
For every 10mmHg CO_2 rises above 40mmHg, expect HCO_3 to increase by **1mmol/L**

For chronic respiratory acidosis
For every 10mmHg CO_2 rises above 40mmHg, expect HCO_3 to increase by **4mmol/L**

1-2-3-4-5 Rule

For every 10mmHg above/below 40mmHg	HCO_3 ACUTE	HCO_3 CHRONIC
↑pCO_2 (Resp. acidosis)	↑ 1	↑ 4
↓pCO_2 (Resp. alkalosis)	↓ 2	↓ 5

Low HCO_3
<22mmol/L

Metabolic acidosis

Albumin correction of anion gap
Albumin is an anion → **add** 2.5 to the anion gap for every 10g/L that Albumin is below normal
or
AG (Alb. correct) = AG + 0.25 (40 – Alb.)

Osmolar gap
Difference between measured osmolality & calculated osmolarity
Osmolarity = 2x [Na^+] + Urea + Glucose + (EtOH x 1.25)
Normal = <10
Causes ↑OG: Mannitol, glycine, methanol, ethylene glycol, ethanol, non-metabolised glycols, maltose
Convert EtOH to SI units (mmol/L) → (EtOH % x 217)
or (EtOH mg/dL ÷ 4.6)

Anion Gap
AG = [Na^+] – ([Cl^-] + [HCO_3^-])
Normal = 12 (±4)

HIGH

CAUSES:
Normal AGMA
"USED CRAP"
→ Ureterostomy
→ Small bowel fistula
→ Extra chloride
→ Diarrhoea
→ Carbonic anhydrase inhibitor
→ Renal tubular acidosis
→ Addison's disease
→ Pancreatic duodenal fistula

Low/negative (<3) AGMA
↓ unmeasured anions (↓ albumin, dilution)
↑ unmeasured cations (↑Ca, ↑Mg ↑K, lithium, paraproteinaemia)
Pseudohyperchloraemia (bromide, iodide, salicylates, thiocyanate)
Analytical error (↑Na, ↑ lipids, hyperviscosity)

CAUSES:
High AGMA
"Left Total Knee Replacement"
→ Lactate, Toxins, Ketones, Renal
"CAT MUD PILES"
→ Carbon monoxide, cyanide
→ Alcoholic ketoacidosis
→ Toluene
→ Methanol, metformin (phenformin)
→ Uraemia
→ Diabetic ketoacidosis
→ Paracetamol, pyroglutamic acid, paraldehyde, propylene glycol
→ Isoniazid, iron
→ Lactate (L-Lactate, D-Lactate)
→ Ethanol, ethylene glycol
→ Salicylates

Alkalaemia

Low pCO_2
<35mmHg

Respiratory alkalosis

CAUSES:
Processes that cause hyperventilation
"CHAMPS"
→ CNS disease (stroke, haemorrhage, psychogenic)
→ Hypoxia (Pneumonia, PE, asthma, altitude)
→ Anxiety, pain
→ Mechanical or excessive ventilation
→ Progesterone, pregnancy
→ Salicylates and sepsis

Acute or chronic?

For acute respiratory alkalosis
For every 10mmHg CO_2 gets below 40mmHg, expect HCO_3 to reduce by **2mmol/L**

For chronic respiratory alkalosis
For every 10mmHg CO_2 gets below 40mmHg, expect HCO_3 to reduce by **5mmol/L**

→ **1-2-3-4-5 Rule**

High HCO_3
>26mmol/L

Metabolic alkalosis

CAUSES:
"CLEVER PD"
→ Contraction (volume contraction)
→ Liquorice, laxative abuse
→ Endocrine (Conn's, Cushing's)
→ Vomiting, GI losses
→ Excess alkali (antacids)
→ Renal (Bartter's)
→ Post-hypercapnia
→ Diuretics

For metabolic alkalosis
Expected compensation is **respiratory acidosis**
Expected pCO_2 = (0.7 x HCO_3) + 20 (±5)

SECONDARY PROCESS OR COMPENSATION?

For metabolic acidosis

1. Winter's formula for expected pCO_2 = (1.5x [HCO_3]) + 8 (±2)
Or estimate: expected pCO_2 ≈ first 2 decimal places of pH

2. Calculate delta ratio
Ratio of change in AG from normal, compared to change in HCO_3 from normal

$$\text{Delta ratio} = \frac{(AG - 12)}{(24 - HCO_3)}$$

<0.4	0.4 – 0.8	0.8 – 2.0	>2.0
Pure NAGMA	Mixed NAGMA & HAGMA	Pure HAGMA	HAGMA + (metabolic alkalosis *or* respiratory acidosis)

Correcting potassium with pH
Alkalaemia lowers serum K^+ (shifts intracellularly)
Acidaemia raises serum K^+ (shifts intravascular)
Every 0.1 unit Δ in pH = 0.6mEq/L Δ in K^+
or
$K^+_{corrected} = [K^+]_{measured} - 0.6\left(\frac{7.4 - pH}{0.1}\right)$

Correcting sodium in hyperglycaemia
$[Na]_{corrected} = [Na] + \frac{1.6 \times (Glucose - 5.6)}{5.6}$
Roughly equivalent to [Na] + (Glucose – 5)/3

If measured HCO_3 or pCO_2 is different from expected – there is a mixed acid-base disorder
→ Concurrent respiratory acidosis (↑CO_2 than expected), metabolic acidosis (↓HCO_3 than expected), respiratory alkalosis (↓CO_2 than expected) or metabolic alkalosis (↑HCO_3 than expected)