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ACID-BASE BALANCE

Clinically important disturbances

ABB Parameters

pH = 7,36 – 7,44

HCO₃⁻ at pCO₂ 5,3 kPa, t= 37° C 22 - 26 mmol/l

pCO₂ 4,64 - 6,0 kPa

pO₂ 10,0 – 13,3 kPa

H⁺ 35 – 45 nmol/L

Summary BB in blood 48 ± 2 mmol/l

BE (base excess) ± 2,5 mmol/l

> than 2,5 mmol/l – metabolic alkalosis

< than 2,5 mmol/l – metabolic acidosis

AG (anion gap) 15,2 ± 1,6 mmol/l

AG = (Na⁺ + K⁺) – (Cl⁻ + HCO₃⁻)

> than 18 mmol/l ↑ acidosis

H⁺ CONCENTRATION

[H⁺] could be expressed in pH units

pH is negative logarithm of the hydrogen ion concentration

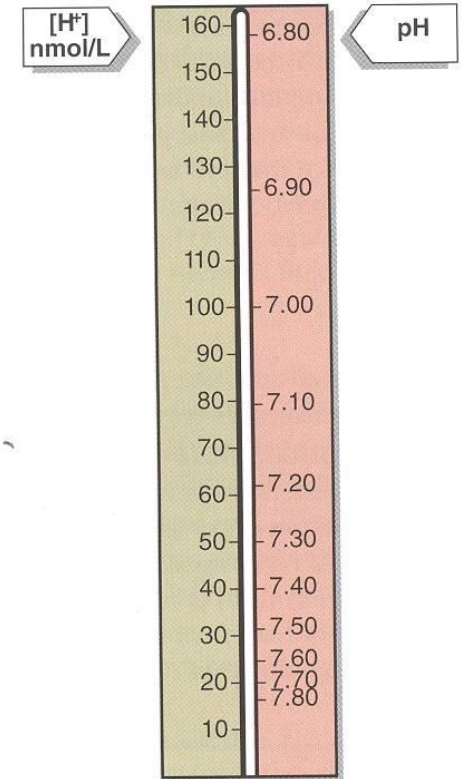
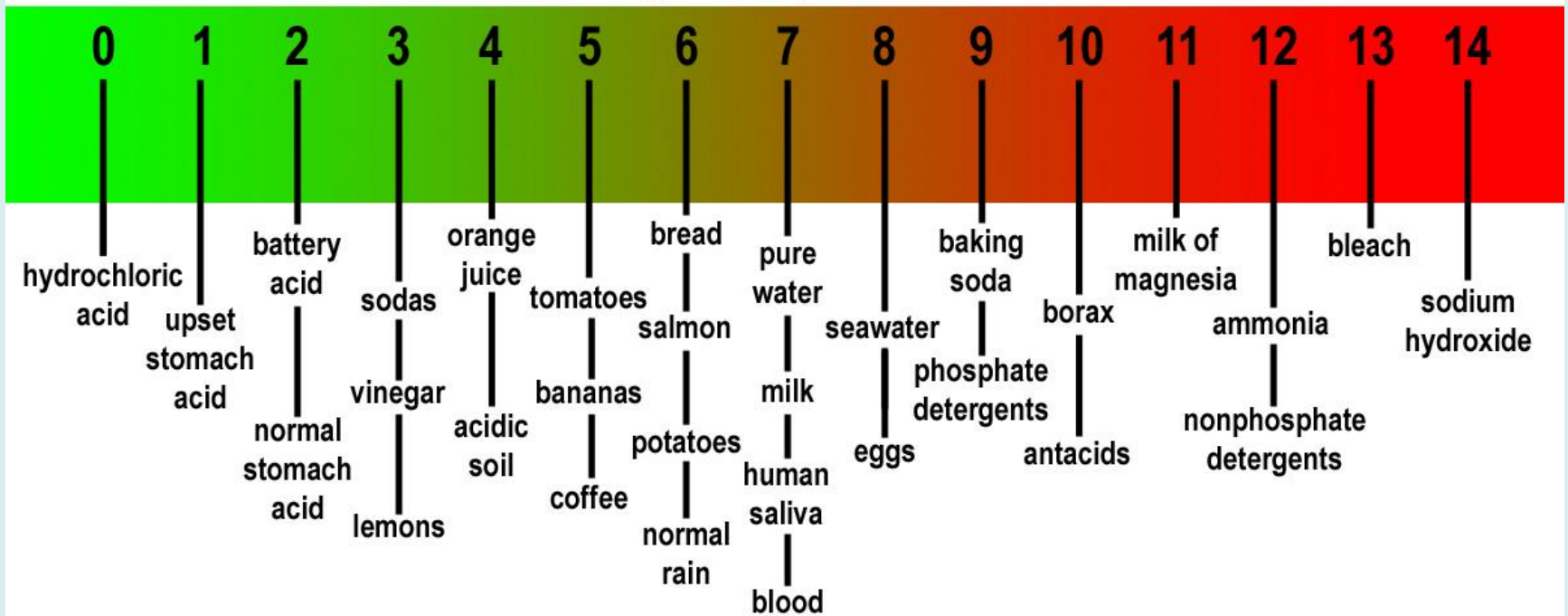


Fig 20.1 The negative logarithmic relationship between [H⁺] and pH.

pH scale*

*approximate pH numbers



Fysical- chemical buffer systems

- **Bicarbonate**
- **Phosphates**
- **Proteins**
- **Hemoglobin/Oxyhemoglobin**

Biological buffer systems

- **Metabolic reactions**
 - **Proton-producing**
 - **Proton- consuming**
 - **Proton- neutral**

Biological buffer systems

1. Producing proton

- anaerobic glycolysis 2 H
- lipolysis 3 H
- ketogenesis 3 H
- complete oxidation of AA containig sulphur (methionine 4 H)
- complete oxidation of lysine 1 H

2. Consuming proton

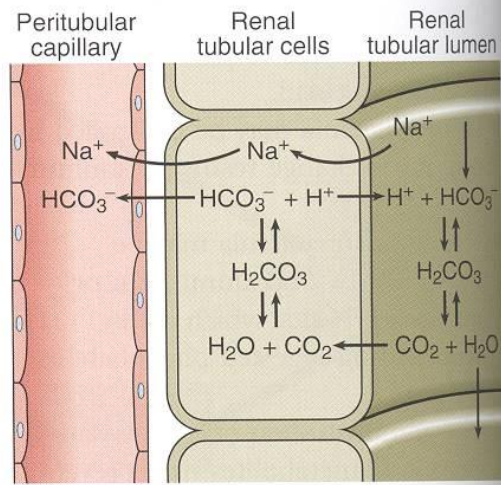
- gluconeogenesis from lactate - 2 H
- complete oxidation of neutral and acidic AA

3. Proton neutral

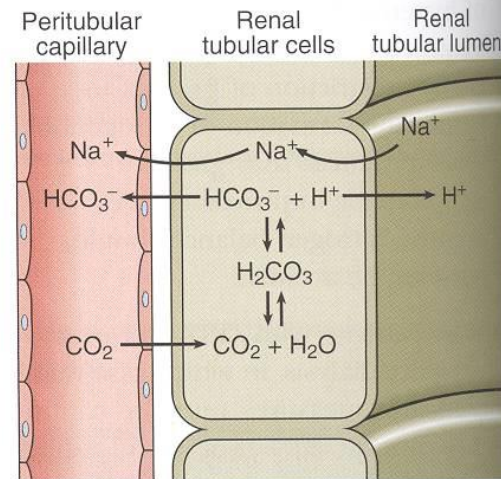
- complete GLU oxidation on CO_2 and water
- glutamine production
- transamination reactions

H⁺ excretion from the body

- **Proton excretion from the body via kidney**
- **Bicarbonate reclaim from the primary urine**
- **Buffering of proton in urine by the phosphate or ammonia**

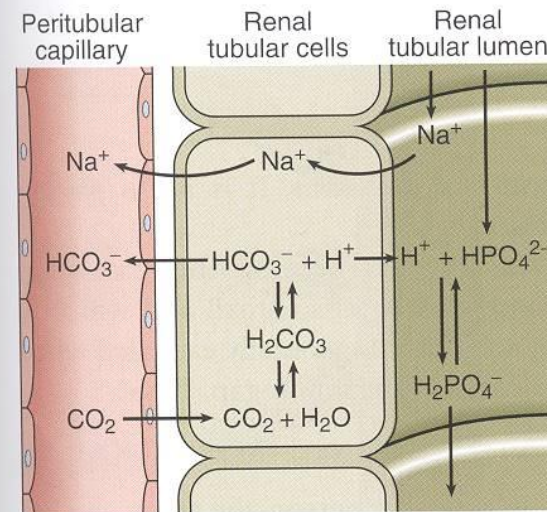


'Recovery' of bicarbonate

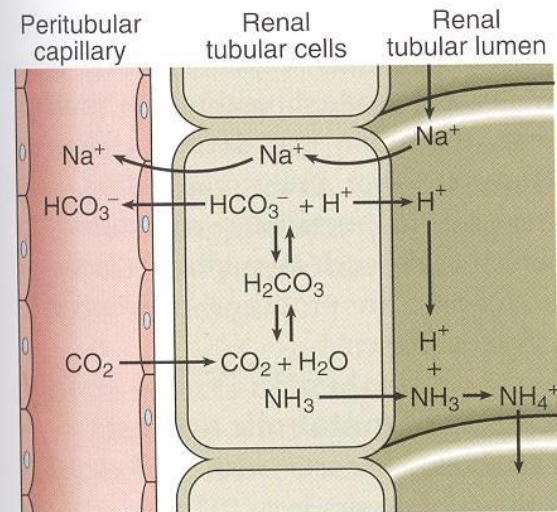


'Regeneration' of bicarbonate — excretion of hydrogen ion

Fig 20.2 The recovery and regeneration of bicarbonate by excretion of H^+ in the renal tubular cell. Note that H^+ is actively secreted into the urine while CO_2 diffuses along its concentration gradient.



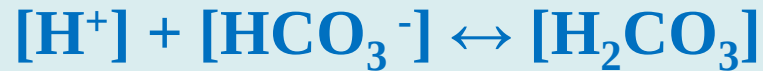
Phosphate buffer



Ammonia buffer

Fig 20.3 Buffering of hydrogen ions in urine.

ASSESSING STATUS



$$[\text{H}^+] \text{ is proportional to } \frac{p \text{ CO}_2}{[\text{HCO}_3^-]}$$

$[\text{H}^+]$ in blood varies: a/ bicarbonate concentration
b/ $p\text{CO}_2$ changes

Conclusion:

- Adding H^+ , removing bicarbonate, increasing in $p \text{ CO}_2 \rightarrow$ the same effect an increase $[\text{H}^+]$
- Removing H^+ , adding bicarbonate, lowering in $p \text{ CO}_2 \rightarrow$ the same effect like fall $[\text{H}^+]$

METABOLIC ACID-BASE DISORDERS

**Causes: a/ increase in proton production
b/ loss of the proton triggering compensatory mechanisms**

Direct loss or gain of HCO_3^-

Primary metabolic acid–base disorders – inspection of bicarbonate concentration

**Two possibilities: 1/ METABOLIC ACIDOSIS
2/ METABOLIC ALKALOSIS**

TERMINOLOGY

Primary acid-base disturbances:

a/ACIDOSIS

b/ ALKALOSIS

- **Metabolic acidosis** - the primary disorder is a decrease in bicarbonate concentration
- **Metabolic alkalosis** - the primary disorder is an increase in bicarbonate concentration
- **Respiratory acidosis** - the primary disorder is an increase in $p\text{CO}_2$
- **Respiratory alkalosis** - the primary disorder is a decrease in $p\text{CO}_2$

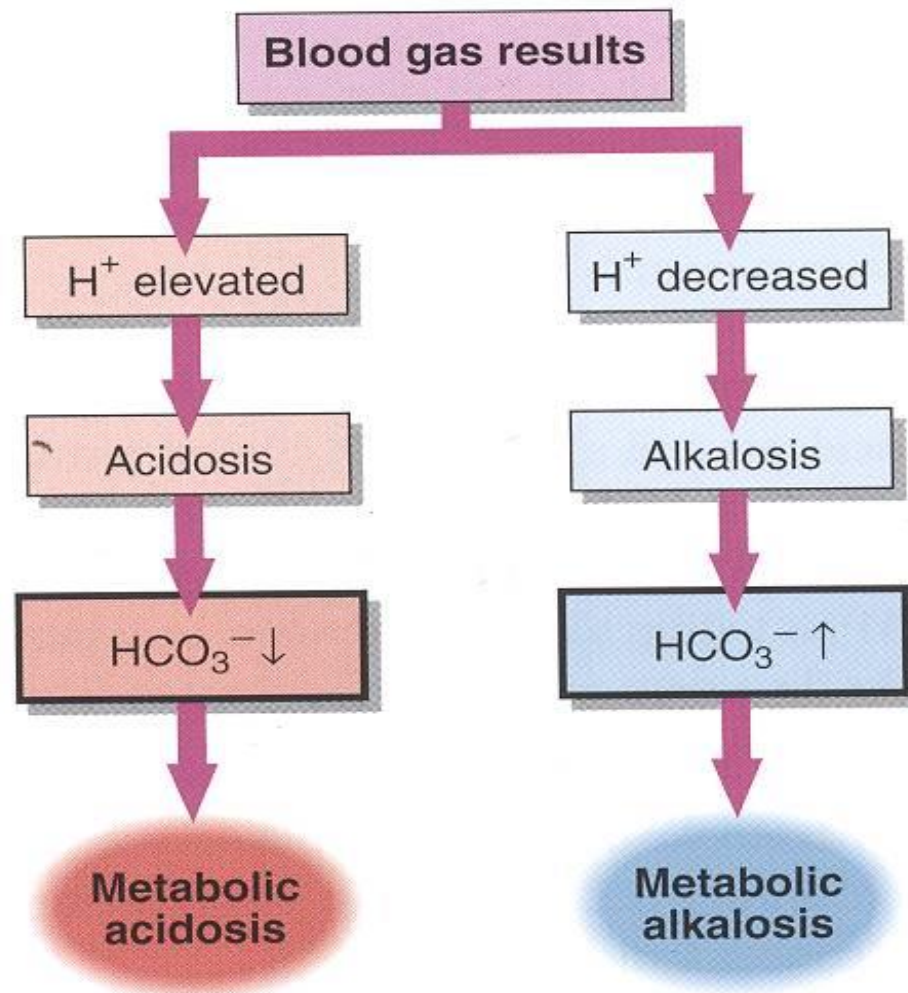


Fig 21.1 Recognizing primary metabolic acid–base disorders by inspecting the HCO_3^- concentration.

CLINICAL EFFECTS OF ACIDOSIS

- **Hyperventilation → increased proton concentration is a powerful stimulation of the respiratory center (Kussmaul breathing, gasping respiration)**
- **Increased neuromuscular irritability → arrhythmias – cardiac arrest**
- **Hyperkalaemia**

CAUSES OF METABOLIC ACIDOSIS

Metabolic acidosis with elevated anion gap occurs:

- Renal diseases – hydrogen anions are retained along with anions sulphate and phosphate
- Diabetic ketoacidosis - elevated acetoacetic and beta-hydroxybutyric acid
- Lactic acidosis – hypoxia, anoxia, liver diseases,
- Overdosis or poisoning – production of acids in the metabolism e.g.
 - e.g. salicylate → lactate
 - methanol → formate
 - ethylene glycol → oxalate

Metabolic acidosis with normal anion gap occurs:

- Chronic diarrhoea or intestinal fistula – fluids containing bicarbonate are lost from the body
- Renal tubular acidosis – renal tubular cells are not able to excrete protons efficiently, bicarbonate is lost from the body

THE ANION GAP

The anion gap: difference between sum of the main kations and sum of the main anions

- proteins are negatively charged at the normal proton concentration
- is biochemical tool helping in the assessing acid- base problems
- it is not a physiological reality

$$\text{Anion gap} = [(\text{Na}^+) + (\text{K}^+)] - [(\text{Cl}^-) + (\text{HCO}_3^-)]$$

CAUSES OF METABOLIC ALKALOSIS

- **Loss of hydrogen ions in gastric fluid during vomiting**
- **Ingestion of an absorbable alkali such a sodium bicarbonate**
- **Potassium deficiency – during the diurethic therapy – hydrogen ions are retained inside of the cells to replace of the missing potassium ions**
 - **in renal tubule more hydrogen ions, rather than potassium are exchanged for reabsorbed sodium**
 - **„paradoxical“ acid urine**

CLINICAL EFFECTS OF ALKALOSIS

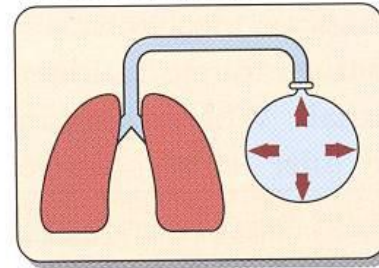
- **Hypoventilation – retention of CO₂**
- **Confusion and eventually coma**
- **Muscle cramps, tetany, paraesthesia → consequence of decreased unbound plasma calcium concentration as a consequence of alkalosis**

COMPENSATION

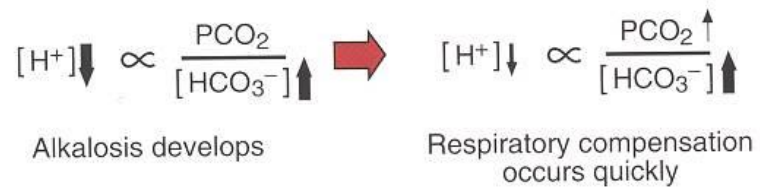
Metabolic acidosis



Increased ventilation



Metabolic alkalosis



Decreased ventilation

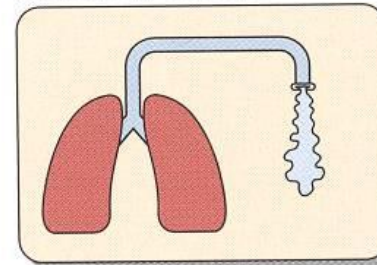
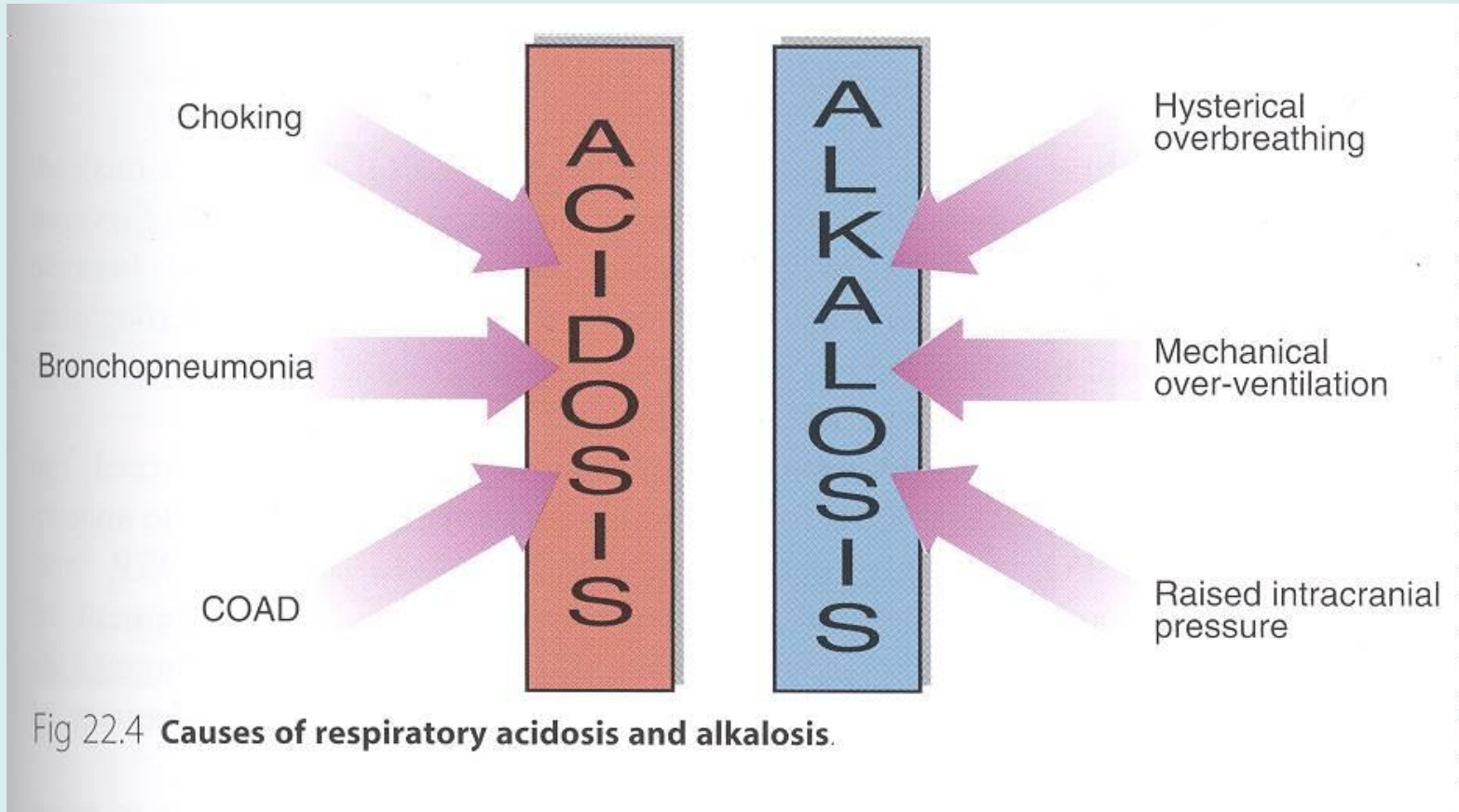


Fig 21.2 Compensation in primary metabolic disorders.

RESPIRATORY ACID-BASE DISORDERS



ACUTE RESPIRATORY ACIDOSIS

- **Choking**
- **Bronchopneumonia**
- **Acute exacerbation of asthma/COAD – Chronic Obstructive Airways Disease**

CHRONIC RESPIRATORY ACIDOSIS

- **Chronic bronchitis**
- **Emphysema**

RESPIRATORY ALKALOSIS

Respiratory alkalosis – less common than acidosis

- respiration is stimulated or no longer feedback control**
- acute conditions**
- no renal compensation**

Examples:

a/ hysterical overbreathing

b/ mechanical over-ventilation in an intensive care patients

c/ raised intracranial pressure, or hypoxia → stimulation of the respiratory center

MIXED ACID-BASE DISORDERS

They are no rare combination of the acid –base disorders

Examples:

a/ chronic bronchitic patient with renal impairment

- raised $p\text{CO}_2$ and $[\text{H}^+]$. Bicarbonate concentration is low
- conclusion: **primary respiratory and primary metabolic acidosis**

b/ a patient with chronic obstructive airways disease, causing a **respiratory acidosis**

- thiazide – induced potassium depletion and consequent **metabolic alkalosis**

c/ hyperventilation causing a **respiratory alkalosis**

- prolonged nasogastric suction that causes **metabolic alkalosis**

MIXED ACID-BASE DISORDERS

Examples:

- d/ salicylate poisoning → stimulation of the respiratory center → **respiratory alkalosis**
 - salicylate effect on the metabolism → **metabolic acidosis**

CONCLUSION: 1/ Precise interpretation of the biochemical findings

2/ When the compensation mechanism of the primary acid-base balance disorders falls outside expected limits – second acid – base disorder is present

3/ Knowledge of the clinical picture is essential

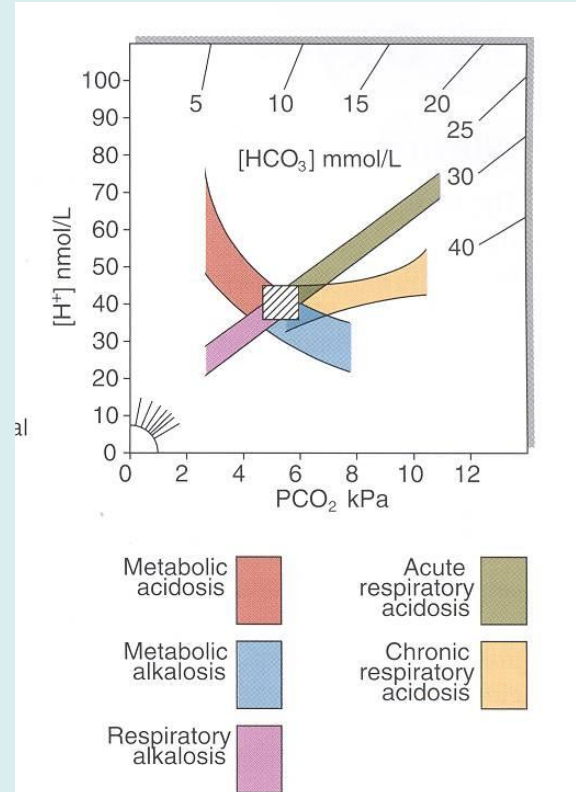


Fig 22.5 **The 95% confidence intervals for arterial blood gases in primary acid-base disorders.** Arterial $[H^+]$ is plotted against PCO_2 with lines of equal $[HCO_3^-]$ radiating from origin. The hatched box shows normal values. Graphs such as these may be used to chart the progress of a patient under treatment to correct an acid-base disorder.