Respiratory acidosis and respiratory alkalosis

What is an ABG?

An arterial blood gas (ABG) is a test that measures the :

oxygen tension (PaO_2),

carbon dioxide tension ($PaCO_2$),

acidity (pH),

oxyhemoglobin saturation (SaO_2),

and bicarbonate (HCO_3)

concentration in arterial blood.

Arterial puncture :

Where to place -- the options •

Radial –

Femoral –

Brachial –

Dorsalis Pedis –

Axillary –

The Components :

pH / $PaCO_2$ / PaO_2 / HCO_3 / O_2sat / BE

Desired Ranges:

pH - 7.35 - 7.45

$PaCO_2$ - 35-45 mmHg

PaO_2 - 80-100 mmHg

HCO_3 - 21-27

O_2sat - 95-100%

Base Excess - +/-2 mEq/L

Acid Base Balance

The body produces acids daily

15,000 mmol CO_2

50-100 mEq Nonvolatile acids

The lungs and kidneys attempt to maintain balance

Extra cellular fluid concentration

-6 -9

$[H+] = 40 \times 10^{-6}$ mEq/lit $= 40 \times 10^{-9}$ Eq/lit

PH = - log [H+]

PH = 7.35 - 7.45

Definitions :

***PH**: is a negative logarithm of Hydrogen ion concentration;*

and it is the initials of these two wards (puiessence Hydrogen) that mean the power of hydrogen

Acid Base Balance

- ***Assessment of status via bicarbonate-carbon dioxide buffer system***

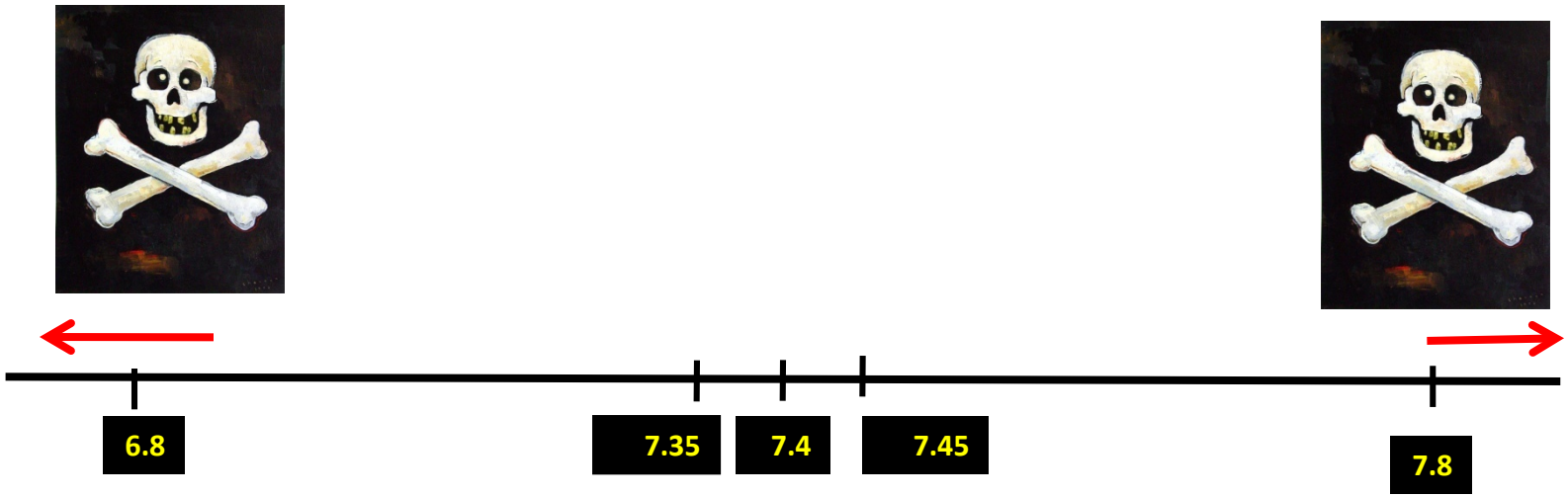
➢ $CO_2 + H_2O <--> H_2CO_3 <--> HCO_3^- + H^+$

➢ $pH = 6.10 + \log ([HCO_3] / [0.03 \times PCO_2])$

Importance of acid-base balance:

The hydrogen ion (H+)concentration must be precisely maintained within a narrow physiological range

Small changes from normal can produce marked changes in enzyme activity & chemical reactions within the body



Arterial PH

Regulation of pH:

***Buffer systems - very rapid (seconds), incomplete**

***Respiratory responses - rapid (minutes), incomplete**

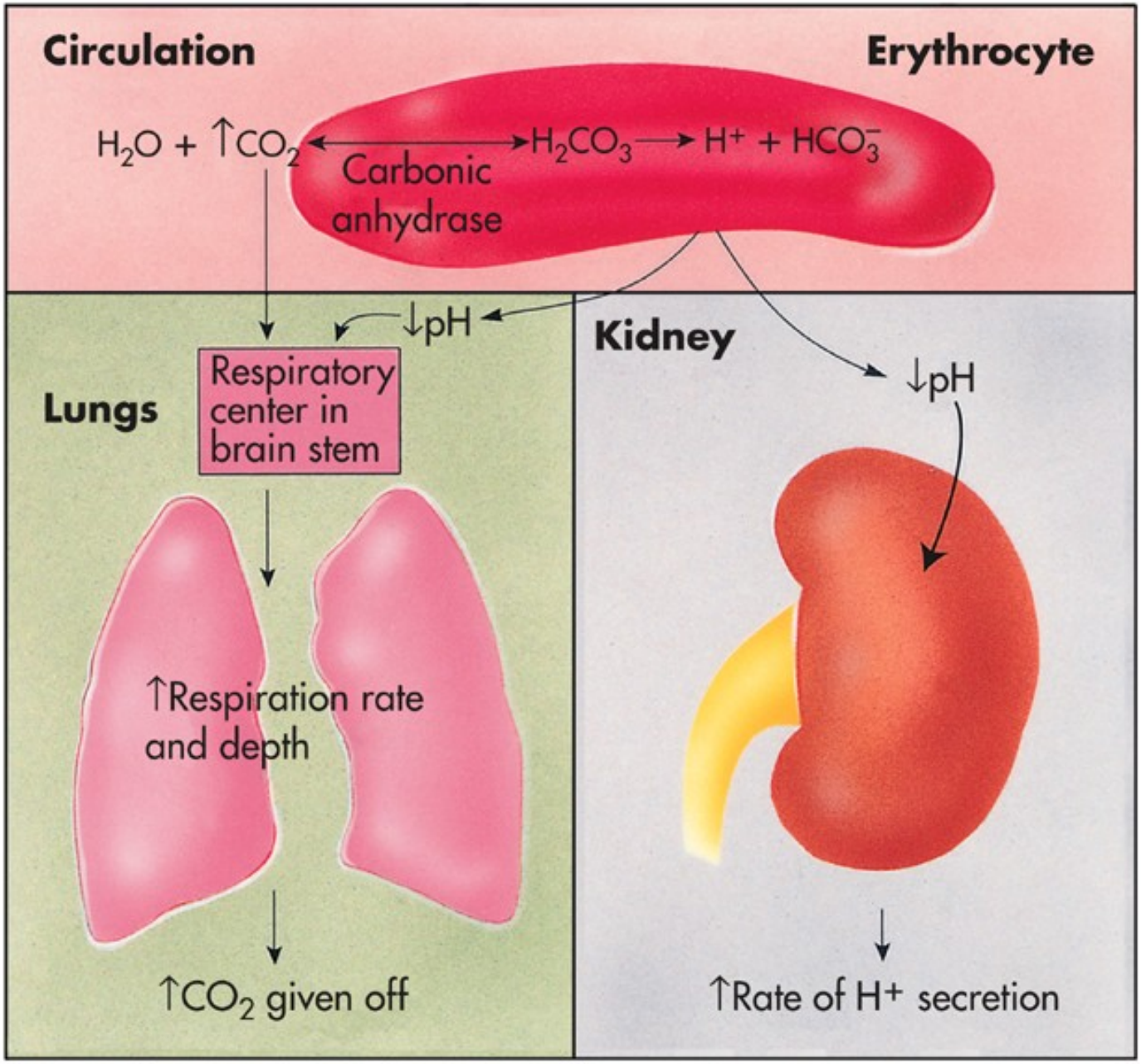
***Renal responses - slow (hours to days), complete**

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3$$

*CO2 regulated by the lungs - rapidly

*HCO3- is regulated by the kidneys – slowly

*Not powerful



From Thibodeau GA, Patton KT: *Anatomy & physiology,* ed 5, St Louis, 2003, Mosby.

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Respiratory Acidosis

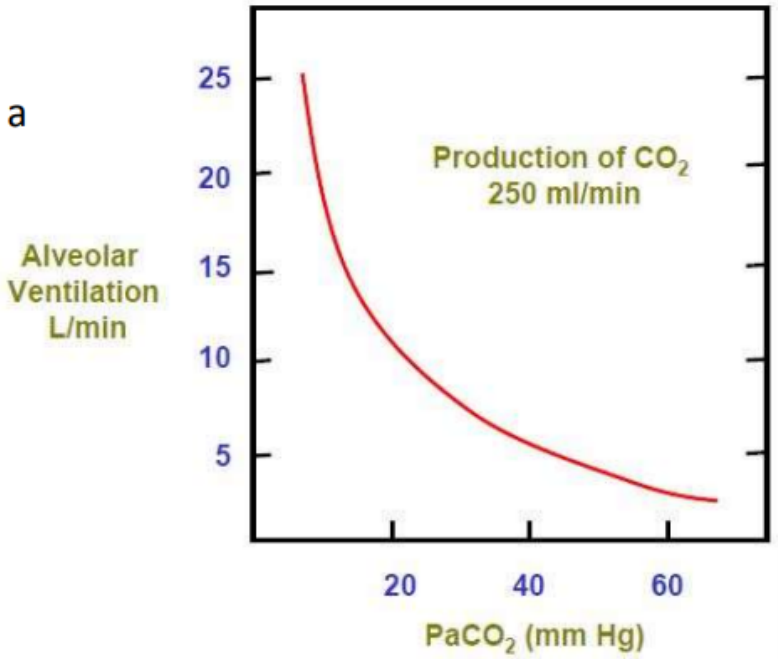
- ↑ in $PaCO_2$> 45 mmHg and pH <7.35
- due to inadequate alveolar ventilation.

Respiratory Acidosis:

From Brain to alveolus, many problems can cause hypoventilation ➔ ↑PaCO2 ➔ ↓pH (Respiratory acidosis)

- By far, most cases of respiratory acidosis reflect a decrease in alveolar ventilation.

- Overproduction of carbon dioxide is usually matched by increased excretion (due to increased alveolar ventilation) such that hypercapnia is prevented.



- **What are the cuases of acute respiratory acidosis?**

- **Alveolar hypoventilation**
- **Increased CO_2 production**

Respiratory Acidosis:

Brain	***Stroke*** ***Drug Intoxication***
Spinal Cord	***C spine injury,***
Peripheral Nerve	***Guillan Barre***
NeuroMuscular Junction	***Myasthenia Gravis***
Lung and Pleural disease	***Asthma, COPD, ARDS,*** etc

Alveolar hypoventilation

- Central nervous system depression
- Neuromuscular disorders
- Chest wall abnormalities
- Pleural abnormalities
- Airway obstruction
- Parenchymal lung disease
- Ventilator malfunction

Increased CO_2 production

- Large caloric loads
- Malignant hyperthermia
- Intensive shivering
- Prolonged seizure activity
- Thyroid storm
- Extensive thermal injury (burns)

- **What are clinical manifestations of respiratory acidosis?**

  - **Mainly NEUROMUSCULAR: CO_2 narcosis**

  - **Anxiety, Headache, Lethargy, Stupor, Focal Paresis, Tremors, Asterixis, Delirium, myoclonus, Seizures, Coma**

DIAGNOSIS…

- Requires the measurement of Pa_{CO_2} and arterial pH (ABG analysis).
- A detailed history and physical examination may indicate the cause.
- Pulmonary function studies including spirometry, diffusion capacity for CO, lung volumes and arterial Pa_{CO_2} and O_2 saturation helps if resp. acidosis is secondary to lung disease.
- For non-pulmonary causes, a detailed drug history, measurement of hematocrit, and assessment of upper airway, chest wall, pleura and neuromuscular function.

ARTERIAL FINDINGS IN RESP. ACIDOSIS…

- PCO_2 is always raised.
- In acute respiratory failure.
  - pH is low
  - HCO_3^- is high normal or slightly raised as compensatory changes take sometimes to occur.
- In chronic respiratory failure.
  - Ph is normal or low, depending on chronicity(time for compensation to occur)
  - HCO_3^- is raised

Sample problem

- *pH 7.36*
- *PCO2 62*
- *HCO3 34*
- *PO2 70*
- *O2 sat. 90%*

- *Respiratory acidosis*
- *Fully compensated*
- *E.g. COPD*

- **How to correct respiratory acidosis?**

MANAGEMENT…

- Primarily directed at the underlying disorder or patho-physiologic process.
- Caution should be exercised in the correction of chronic hypercapnia: too-rapid correction of the hypercapnia can result in metabolic alkalemia.
- Alkalization of the cerebrospinal fluid (CSF) can result in seizures.

- **Oxygen Therapy**
  - Because many patients with hypercapnia are also hypoxemic, oxygen therapy may be indicated.
  - Oxygen therapy is employed to prevent the sequelae of long-standing hypoxemia.
  - Hypercapnia is best avoided by titrating oxygen delivery to maintain oxygen saturation in the low 90% range and partial arterial pressure of oxygen (PaO_2) in the range of 60-65 mm Hg.
- **Ventilatory Support**
  - Therapeutic measures that may be lifesaving in severe hypercapnia and respiratory acidosis include endotracheal intubation with mechanical ventilation and noninvasive positive pressure ventilation (NIPPV)(they help improve PaO_2 and decrease the $PaCO_2$) techniques such as nasal continuous positive-pressure ventilation (NCPAP) and nasal bilevel ventilation.
  - Rapid correction of the hypercapnia by the application of external noninvasive positive-pressure ventilation or invasive mechanical ventilation can result in alkalemia and the development of sudden post- hypercapnic alkalosis with potential serious consequences.

Raspiratory alkalosis:

- **PaCO2 <35 mm Hg and pH>7.45,**
- **due to excessive alveolar ventilation.**

- **Define Respiratory alkalosis ?**

Respiratory alkalosis…

- Respiratory alkalosis is the acid-base disturbance initiated by a reduction in $PaCO_2$.
- This occurs when there is excessive loss of CO_2 by hyperventilation of lungs.
- Hypocapnia develops when a sufficiently strong ventilatory stimulus causes CO_2 output in the lungs to exceed its metabolic production by the tissues.
- As a result, partial pressure of CO_2 and H^+ conc. falls and so there is a decrease in bicarbonate levels.

- **What are the causes of respiratory alkalosis?**

Causes of Respiratory Alkalosis

CENTRAL RESPIRATORY STIMULATION

Structural Causes	Non Structural Causes
Head trauma	Pain
Brain tumor	Anxiety
CVA	Fever
	Voluntary

INTRATHORACIC STRUCTURAL CAUSES:

- ↓ movement of chest wall & diaphragm
- ↓ compliance of lungs
- Irritative lesions of conducting airways

OTHERS:

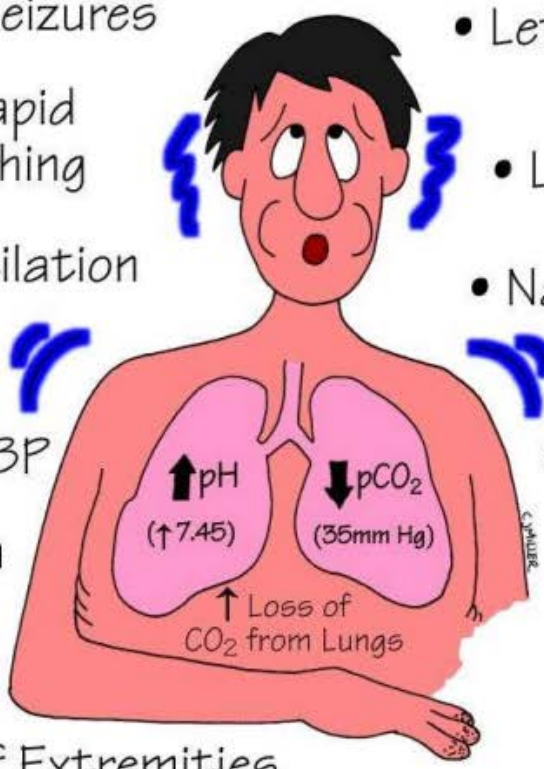
- Heat exposure, Sepsis, Pregnency, Mechanical ventilation

Manifestations of Respiratory Alkalosis

- **Mainly NEUROMUSCULAR:**
- **Lightheadedness, Confusion, Decreased intellectual function,**
- **Paraesthesias (circumoral, extremities)**
- **Muscle twitching, cramps, tetany, Hyperreflexia**
- **Syncope, Seizures**

RESPIRATORY ALKALOSIS

- Seizures
- Deep, Rapid Breathing
- Hyperventilation
- Tachycardia
- ↓or Normal BP
- Hypokalemia
- Numbness & Tingling of Extremities



- Lethargy & Confusion
- Light Headedness
- Nausea, Vomiting
- Causes:
  - Hyperventilation (Anxiety, PE, Fear)
  - Mechanical Ventilation

ARTERIAL FINDINGS IN RESP. ALKALOSIS…

- PCO_2 is always reduced.
- HCO_3^- is low normal or low.
- Ph is raised or normal.

Sample problem

- ***pH 7.42***
- ***PCO2 18***
- ***HCO3 11***
- ***PO2 150***
- ***O2 sat 99%***

- ***compensated respiratory alkalosis***
- ***This pt is hyperventilated for too long (blowing off CO2)***

TREATMENT…

- The treatment of respiratory alkalosis is primarily directed at correcting the underlying disorder. Respiratory alkalosis itself is rarely life threatening.
- Therefore, emergent treatment is usually not indicated unless the pH level is greater than 7.5. Because respiratory alkalosis usually occurs in response to some stimulus, treatment is usually unsuccessful unless the stimulus is controlled.
- If the $PaCO_2$ is corrected rapidly in patients with chronic respiratory alkalosis, metabolic acidosis may develop due to the renal compensatory drop in serum bicarbonate.
- In mechanically ventilated patients who have respiratory alkalosis, the tidal volume and/or respiratory rate may need to be decreased. Inadequate sedation and pain control may contribute to respiratory alkalosis in patients breathing over the set ventilator rate.

Renal & Respiratory Compensation:

Primary Disorder	Primary change	Predicted Compensatory Respons
Respiratory acidosis: Acute	↑PaCO2	1 meq ↑ HCO3 per 10 mm ↑PaCO2
Respiratory acidosis: Chronic	↑PaCO2	3.5 meq ↑ HCO3 per 10 mm ↑PaCO2
Respiratory alkalosis: Acute	↓PaCO2	2 meq ↓HCO3 per 10mm ↓ PaCO2
Respiratory alkalosis: Chronic	↓PaCO2	4 meq ↓HCO3 per 10mm ↓ PaCO2

Simple Acid-Base Disorders:

Type of Disorder	pH	$PaCO_2$	$[HCO_3]$
Metabolic Acidosis	↓	↓	↓
Metabolic Alkalosis	↑	↑	↑
Acute Respiratory Acidosis	↓	↑	↑
Chronic Respiratory Acidosis	↓	↑	↑↑
Acute Respiratory Alkalosis	↑	↓	↓
Chronic Respiratory Alkalosis	↑	↓	↓↓