Lecture# 7
semester# 1

Acid Base Balance

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Introduction

- The major function of the **pulmonary system** (lungs and pulmonary circulation) is to deliver oxygen to cells and remove carbon dioxide from the cells.
- If the patient's history and physical **examination reveal evidence of respiratory dysfunction**, **diagnostic test will help** identify and evaluate the dysfunction.
- **ABG analysis** is one of the first tests ordered to assess respiratory status because it helps evaluate gas exchange in the lungs.
- Acid Base Controlled by the **lungs, kidneys, and buffers**.
- Disrupted by **vomiting**, **diarrhea**, **respiratory failure**, **kidney failure**, **infections** and **ingestions**

Principles of Acid-Base Disorders

Plasma pH is an indicator of **hydrogen ion (H+) concentration** and measures the acidity or alkalinity of the blood. **Homeostatic mechanisms** keep **pH within a normal range (7.35 to 7.45).**

The H+ concentration is extremely important: The **greater** the concentration, **the more acidic** the solution and **the lower the pH**.

Blood pH is determined by the ratio of **serum bicarbonate** concentration ($[HCO_3^-]$) and **partial pressure of CO_2 (Pa_{CO2})**

Principles of Acid-Base Disorders

- Metabolic acid-base disorders alter $[HCO_3^-]$
- Respiratory acid-base disorders alter (Pa_{CO2})

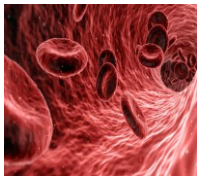
Principles of Acid-Base Disorders

- Acidemia: serum pH < 7.35
- Alkalemia: serum pH > 7.45
- Acidosis: pathologic process that lowers [HCO_3^-] or raises Pa_{CO2}
- Alkalosis: pathologic process that raises [HCO_3^-] or lowers Pa_{CO2}

Buffers

- extracellular
  - carbonic acid / bicarbonate (H_2CO_3 / HCO_3^-)
  - haemoglobin
- intracellular
  - proteins
  - phosphoric acid / hydrogen phosphate (H_3PO_4 / $H_2PO_4^-$ + HPO_4^{2-})

Organs act as acid base balancer



- Equilibrium with plasma
- High buffer capacity Haemoglobin – main buffer for CO_2

- Excretion of CO_2 by alveolar ventilation: minimally 12,000 mmol/day

- Reabsorption of filtered bicarbonate: 4,000 to 5,000 mmol/day
- Excretion of the fixed acids (acid anion and associated H^+): about 100 mmol/day

Assessment of Acid Base balance

	Arterial blood		Mixed venous blood	
		range		range
pH	7.40	7.35-7.45	pH	7.33-7.43
pCO	40 mmHg	35 – 45	pCO_2	41 – 51
pO_2	95 mmHg	80 – 100	pO_2	35 – 49
Saturation	95 %	95 – 100	Saturation	70 – 75
HCO_3^-	24 mEq/l	22 - 26	HCO_3^-	24 - 28

Acid Base Disorders

Disorder	pH	[H+]	Primary disturbance	Secondary response
Metabolic acidosis	↓	↑	**↓ [HCO3-]**	**↓ pCO2**
Metabolic alkalosis	↑	↓	**↑[HCO3-]**	**↑ pCO2**
Respiratory acidosis	↓	↑	**↑ pCO2**	**↑[HCO3-]**
Respiratory alkalosis	↑	↓	**↓ pCO2**	**↓[HCO3-]**

Respiratory Acidosis

- Airway
  - Obstruction, aspiration
- Drug-induced CNS depression
  - Alcohol, narcotics, IV sedation
- CNS origin
  - Myasthenia gravis, CNS injury, Guillain-Barré
- Pulmonary disease
  - Pneumonia, edema, COPD/emphysema

a. Respiratory acidosis

Phase	PH	PaCO2	HCO3
UNCOMPENSATED	↓	↑	------

Because there is no response from the kidneys yet to acidosis the HCO3 will remain normal

Phase	PH	PaCO2	HCO3
PARTIAL COMPENSATED	↓	↑	↑

The kidneys start to respond to the acidosis by increasing the amount of circulating HCO3

Phase	PH	PaCO2	HCO3
FULL COMPENSATED	N	↑	↑

PH return to normal PaCO2 & HCO3 levels are still high to correct acidosis

Management

- Correct the ventilation
  - Establish airway
  - Re-expand the lung
  - Correct the CNS disease
  - Bronchodilators
  - Antibiotics

Practice1

- 25 year-old male, heroin overdose
  - pH 7.10 Pa_{CO2} 80 HCO_3– 24
  - Acidemic, Pa_{CO2} is elevated, acute change
  - Acute respiratory acidosis ([HCO_3^-] unchanged)

Practice2

- 55 year-old man with COPD
  - pH 7.32 Pa_{CO2} 70 HCO_3^- 35
  - Acidemic, Pa_{CO2} is elevated → respiratory acidosis

Respiratory alkalosis

- Hypoxia-mediated hyperventilation
  - High altitude, severe anemia, ventilation-perfusion mismatch
- CNS mediated
  - Psychogenic, CVA, increased ICP (tumor/trauma)
- Pharmacologic
  - Salicylates, caffeine, vasopressors, thyroxine
- Pulmonary
  - Pneumonia, PE, mechanical hyperventilation
- Hepatic
  - Encephalopathy

B. Respiratory alkalosis

Phase	PH	PaCO2	HCO3
UNCOMPENSATED	↑	↓	------

Because there is no response from the kidneys yet to acidosis the HCO3 will remain normal

Phase	PH	PaCO2	HCO3
PARTIAL COMPENSATED	↑	↓	↓

The kidneys start to respond to the alkalosis by decreasing the amount of circulating HCO3

Phase	PH	PaCO2	HCO3
FULL COMPENSATED	N	↓	↓

PH return to normal PaCO2 & HCO3 levels are still low to correct alkalosis

Practice 1

- pH 7.46 Pa_{CO2} 20 HCO_3^- 14
- Alkalemic, Pa_{CO2} is decreased → respiratory alkalosis

Metabolic acidosis

- Acidemia created by increase in $[H^+]$ or decrease in $[HCO_3^-]$
- Compensated by hyperventilation to reduce Pa_{CO2}
- Treatment
  - Treat the underlying condition and the pH will gradually normalize

C. Metabolic acidosis

Phase	PH	PaCO2	HCO3
UNCOMPENSATED	↓	-------	↓

Because there is no response from the lungs yet to acidosis the PaCO2 will remain normal

Phase	PH	PaCO2	HCO3
PARTIAL COMPENSATED	↓	↓	↓

The lungs start to respond to the acidosis by decreasing the amount of circulating PaCO2

Phase	PH	PaCO2	HCO3
FULL COMPENSATED	N	↓	↓

PH return to normal PaCO2 & HCO3 levels are still low to correct acidosis

Practice 1

- 23 year-old woman with seizure for 90 minutes.
  - pH 7.24 Pa_{CO2} 36 HCO_3^- 14
  - Acidemic, Pa_{CO2} is decreased → metabolic acidosis

Metabolic alkalosis

- Volume-Contracted
  - Vomiting/gastric suction
  - Diuretics
- Normal Volume / Volume-Expanded
  - Severe potassium depletion
  - Hyperaldosteronism
  - Cushing's syndrome

D. Metabolic alkalosis

Phase	PH	PaCO2	HCO3
UNCOMPENSATED	↑	-------	↑

Because there is no response from the lungs yet to alkalosis the PaCO2 will remain normal

Phase	PH	PaCO2	HCO3
PARTIAL COMPENSATED	↑	↑	↑

The lungs start to respond to the alkalosis by increasing the amount of circulating PaCO2

Phase	PH	PaCO2	HCO3
FULL COMPENSATED	N	↑	↑

PH return to normal PaCO2 & HCO3 levels are still high to correct alkalosis

Practice1

- 29 year-old pregnant woman who is vomiting.
  - pH 7.58 Pa_{CO2} 48 HCO_3^- 40
  - Alkalemic, Pa_{CO2} is increased → metabolic alkalosis

Additional Tutorial

Example 1

Jane Doe is a 45-year-old female admitted to the nursing unit with a severe asthma attack. She has been experiencing increasing shortness of breath since admission three hours ago. Her arterial blood gas result is as follows

Clinical Laboratory:

pH 7.22

PaCO2 55

HCO3 25

Follow the steps:

- **1. Assess the pH. It is low therefore, we have acidosis.**
- **2. Assess the PaCO2. It is high and in the opposite direction of the pH.**
- **3. Assess the HCO3. It has remained within the normal range (22-26).**

Acidosis is present (decreased pH) with the PaCO2being increased, reflecting a primary respiratory problem. For this patient, we need to improve the ventilation status by providing oxygen therapy, mechanical ventilation or by administering bronchodilators.

Example 2

John Doe is a 55-year-old male admitted with a recurring bowel obstruction. He has been experiencing intractable vomiting for the last several hours, Here is his arterial blood gas result:

Clinical Laboratory:

pH 7.50

PaCO2 42

HCO3 33

Follow the steps again:

- **1. Assess the pH. It is high (normal 7.35-7.45), therefore, indicating alkalosis.**

2. Assess the PaCO2. It is within the normal range (normal 35-45).

3. Assess the HCO3. It is high (normal 22-26) and moving in the same direction as the pH.

Alkalosis is present (increased pH) with the HCO3 increased, reflecting

a primary metabolic problem. Treatment of this patient might include administration of I.V. fluids and measures to reduce the excess base.