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ACID-BASE DISORDERS

Renal Block
OBJECTIVES

I. To explain the principles of blood gas and acid-base analysis.
II. To interpret blood gas analysis and diagnose various acid base disorders.
III. Describe causes of acid base disorders.
IV. Understand use of acid base nomograms.
- **PCO2** = 35-45 mmHg
- If the problem in the **PCO2**, it is respiratory acidosis or alkalosis.
- **HCO3-** = 22-26 mEq/L
- If the problem in the **HCO3**, it is metabolic acidosis or alkalosis.

**Compensation: The body response to acid-base imbalance**

**Complete compensation:** if the PH back into the normal limits.

**Partial compensation:** if the PH still outside the normal range.

Depending on the underlying problem the compensation mechanisms differ:

- **Respiratory problem**
  - Kidney can brings
  - Metabolic compensation

- **Metabolic problem**
  - Respiratory compensation (hypo/hyperventilation)
  - Buffer system
ACID-BASE IMBALANCE: ACIDOSIS

Causes

A- Respiratory:
- CNS depression (anaesthesia).
- Resp muscle paralysis/ diaphragm paralysis, rib fractures, etc..
- Obstructive lung diseases e.g. Emphysema.
- Pulmonary edema.

B- Metabolic:
Bicarbonate deficit: blood conc. of HCO3- drops below 22mEq/L.
- Diabetic ketoacidosis.
- Severe diarrhea (loss of HCO3).
- Hypoaldosteronism.
- Acute renal failure (fail to excrete H+).
- Accumulation of acids.

Compensation

Carbonic acid excess caused by blood levels of CO₂ above 45 mm Hg.
- Increased ventilation.
- Kidneys eliminate hydrogen ion and retain bicarbonate ion.
- Kidney also generates new bicarbonate.

Renal excretion of hydrogen ions if possible.
- K+ exchanges with excess H+ in ECF (H+ into cells, K+ out of cells).
ACID-BASE IMBALANCE: ALKALOSIS

**Causes**

**A- Respiratory:**
Carbonic acid deficit: $pCO_2$ is <35mmHg (hypocapnea).
Most common acid-base imbalance.
- Hyperventilation:
- High altitude (Oxygen deficiency).
- Hysterical.
- Anorexia nervosa.
- Early salicylate intoxication.

**B. Metabolic:**
Blood conc. of HCO3 is > 26mEq/L.
- Severe vomiting = loss of stomach acid or heavy ingestion of antacids.
- Severe dehydration.
- Excess antacids & alkaline drugs.
- Hyperaldosteronism.(endocrine disorders).

**Compensation**

- Conditions that stimulate respiratory center and wash out CO2 (Hyperventilation):
- Kidneys conserve hydrogen ion.
- Excrete bicarbonate ion.
- Kidney excretes alkaline urine and retain H+.
- Respiratory compensation difficult (hypoventilation limited by hypoxia).
Respiratory Acidosis

- Kidneys eliminate hydrogen ion and retain bicarbonate ion.
- Kidney also generates new bicarbonate.

Respiratory Alkalosis

Kidneys conserve hydrogen ion
Excrete bicarbonate ion

Metabolic Acidosis

- Increased ventilation
- Renal excretion of hydrogen ions if possible
- K+ exchanges with excess H+ in ECF
  - (H+ into cells, K+ out of cells)

Metabolic Alkalosis

- Kidney excretes alkaline urine and retain H+
- Respiratory compensation difficult – hypoventilation limited by hypoxia
# Effects of acidosis

- **Principal effect of acidosis:**
  - Depression of the CNS through ↓ of synaptic transmission.
  - Generalized weakness.
  - Deranged CNS function the greatest threat.

*Severe acidosis causes:*
  - Disorientation.
  - Coma.
  - Death.

# Effects of alkalosis

- **Alkalosis causes over excitability of the central and peripheral nervous systems.**
  - Numbness.
  - Lightheadedness.
  - It can cause:
    - Nervousness.
    - Muscle spasms or tetany.
    - Convulsions.
    - Loss of consciousness.
    - Death.

*Almost always the causes of acidosis or alkalosis are respiratory or metabolic.*
RESPIRATORY: ALKALOSIS AND ACIDOSIS

a) Metabolic balance before onset of acidosis

H₂CO₃ : Carbonic acid
HCO₃⁻ : Bicarbonate ion
(Na⁺ • HCO₃⁻)
(K⁺ • HCO₃⁻)
(Mg²⁺ • HCO₃⁻)
(Ca²⁺ • HCO₃⁻)

1 : 20

b) Respiratory acidosis

Breathing is suppressed, holding CO₂ in body

\[ \text{CO}_2 \rightarrow \text{CO}_3^- + \text{H}_2\text{O} \]

Hyperactive breathing "blows off" CO₂

Primary change
pH — decreases
PcO₂ — increases
HCO₃⁻ — no change

0.5 : 20

c) Body's compensation

Kidneys conserve HCO₃⁻ ions and eliminate H⁺ ions in acidic urine

Acidic urine

2 : 30

Body's correction

\[ \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+ \]

Lactate solution used in therapy is converted to bicarbonate ions in the liver

Lactate-containing solution

2 : 20

d) Therapy required to restore metabolic balance

Lactate solution

0.5 : 10

Kidneys conserve H⁺ ions and eliminate HCO₃⁻ in alkaline urine

Alkaline urine

0.5 : 15

Kidneys conserve H⁺ ions and eliminate HCO₃⁻ in alkaline urine

HCO₃⁻ ions are replaced by Cl⁻ ions


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METABOLIC: ACIDOSIS AND ALKALOSIS

a) Metabolic balance before onset of acidosis

\[ \frac{1}{20} \]

\[ \begin{align*}
\text{H}_2\text{CO}_3 : \text{Carbonic acid} \\
\text{HCO}_3^- : \text{Bicarbonate ion} \\
(\text{Na}^+ \cdot \text{HCO}_3^-) \\
(\text{K}^+ \cdot \text{HCO}_3^-) \\
(\text{Mg}^{2+} \cdot \text{HCO}_3^-) \\
(\text{Ca}^{2+} \cdot \text{HCO}_3^-)
\end{align*} \]

b) Metabolic acidosis

\[ \frac{1}{10} \]

HCO$_3^-$ decreases because of excess presence of ketones, chloride, or organic acid ions

Primary change

\[ \begin{align*}
\text{pH} — \text{decreases} \\
P_{\text{CO}_2} — \text{no change} \\
\text{HCO}_3^- — \text{decreases}
\end{align*} \]

c) Body's compensation

Hyperactive breathing to "blow off" CO$_2$

Kidneys conserve HCO$_3^-$ and eliminate H$^+$ ions in acidic urine

\[ \frac{0.75}{10} \]

d) Therapy required to restore metabolic balance

Lactate solution used in therapy is converted to bicarbonate ions in the liver

\[ \frac{1}{20} \]

\[ \begin{align*}
\text{H}_2\text{CO}_3 \quad \text{HCO}_3^- \\
\text{Lactate-containing solution}
\end{align*} \]


The difference between diarrhea and vomiting:
In diarrhea: cause metabolic acidosis due to loss of bicarbonate from intestine so the PH will decrease.
In vomiting: cause metabolic alkalosis due to loss of HCL so the PH will increase.

Diagnosis of Acid-Base Imbalances:
1) Note whether the pH is low (acidosis) or high (alkalosis)
2) Decide which value, pCO₂ or HCO₃⁻, is outside the normal range and could be the cause of the problem.
If the cause is a change in pCO₂, the problem is respiratory.
If the cause is HCO₃⁻, the problem is metabolic.

The change in PH:
If pH is normal (between 7.35-7.45) Compenstaed
If pH is abnormal (<7.35 or >7.45) uncompenstated.

Is the cause Respiratory or metabolic?
If PCO₂>45 = Respiratory acidosis
If PCO₂<35= Respiratory alkalosis
If HCO₃< 22 = Metabolic acidosis.
If HCO₃> 26 = metabolic alkalosis.
**Example 1:**
A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample:

\[ \text{pH} = 7.21, \text{ PCO}_2 = 42, \text{ HCO}_3^- = 12 \]

To answer it List the condition
First : acidosis or alkalosis,
Second : metabolic or respiratory
Third : compensated or uncompensated?

**The answer:** Metabolic acidosis, uncompensated

**Example 1:**
A 50 year-old man with history of type 2 diabetes was admitted to the emergency department with history of polyuria. On examination he had rapid and deep breathing. Blood analysis showed glucose level of 400 mg/dl.

The following is the arterial blood analysis report of this patient:

\[ \text{pH} = 7.1, \text{ PCO}_2 = 40 \text{ mmHg and HCO}_3^- = 18 \text{ mmol/L} \]

**The answer:** Metabolic acidosis, uncompensated
Example 2:

\[ \text{pH} = 7.36, \text{PCO}_2 = 54, \text{HCO}_3^- = 32: \]

the answer: respiratory, acidosis, compensated

Example 3:

\[ \text{pH} = 7.38, \text{PCO}_2 = 38, \text{HCO}_3^- = 25: \]

The answer: normal
How to diagnosis?

PH

Lower 7.4 Acidosis

Pco

If PCO2 > 45
Respiratory Acidosis

If PCO2 < 35
Respiratory alkalosis

(between 7.35-7.45)
Compenstaed

Hco3

If HCO3 < 22=
Metabolic acidosis.

If HCO3 > 26 =
Metabolic alkalosis.

Above 7.4 alkalosis

Compenstated

Uncompenstated
<table>
<thead>
<tr>
<th>Questions</th>
<th>Answers</th>
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| **Q1.** Which of the following cause acidosis? | A. Hyperaldosteronism  
B. Severe vomiting  
C. Hyperventilation  
D. Severe diarrhea | Ans: **1.D** |
| **Q2.** How does the kidney compensate of respiratory acidosis? | **A.** The kidney conserves H+ and excretes CHO-  
**B.** K+ exchanges with excess H+ in ECF  
**C.** Hyperventilation  
**D.** A+C | Ans: **2.A 3.D** |
| **Q3.** What is “Anorexia nervosa”? | An emotional disorder characterized by an obsessive desire to lose weight by refusing to eat, so it will cause alkalosis. |
| **Q4.** How does the kidney compensate alkalosis? | A. Increase  
**B.** Decrease to normal  
**C.** Severe decreasing  
**D.** Constant | Ans: **2.B** |
| **Q4.** In the conversion from acute to chronic respiratory alkalosis, what happen to blood PH? | A. Increase  
**B.** Decrease to normal  
**C.** Severe decreasing  
**D.** Constant | Ans: **2.B** |
| **Q5.** a patient is in ER because she travels to high altitude for 5hrs. The report as following.  
PH=7.49  
PCO2=25  
PHCO3=21  
What is the diagnosis? | Respiratory alkalosis uncompensated |