11

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.
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.

- 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.

Depending on the underlying problem the compensation mechanisms differ:

- Respiratory problem
  - Kidney can brings
  - Metabolic compensation

- Metabolic problem
  - Respiratory compensation (hypo/hyperventilation) +
  - Buffer system

Respiratory problem
Metabolic problem

Respiratory problem
Metabolic problem

Complete compensation: if the PH back into the normal limits.
Partial compensation: if the PH still outside the normal range.
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 HCO$_3^-$ drops below 22mEq/L.
- Diabetic ketoacidosis.
- Severe diarrhea (loss of HCO$_3$).
- Hypoaldosteronism.
- Acute renal failure (fail to excrete H$^+$).
- Accumulation of acids.

Compensation

Carbonic acid excess caused by blood levels of CO$_2$ above 45 mm Hg.
- Kidneys eliminate hydrogen ion and retain bicarbonate ion.
- Kidney also generates new bicarbonate.

Increased ventilation.
- 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).
Compensation

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

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)

Respiratory Alkalosis
- Kidneys conserve hydrogen ion
  - Excrete bicarbonate ion

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.
METABOLIC: ACIDOSIS AND ALKALOSIS

a) Metabolic balance before onset of acidosis

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

Primary change
pH — decreases
P_CO₂ — no change
HCO₃⁻ — decreases

b) Metabolic acidosis
HCO₃⁻ decreases because of excess presence of ketones, chloride, or organic acid ions

Primary change
pH — decreases
P_CO₂ — no change
HCO₃⁻ — decreases

Body's compensation

CO₂ + H₂O

Hyperactive breathing to "blow off" CO₂

Body's correction

HCO₃⁻ + H⁺

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

0.75 : 10

Acidic urine

Breathing suppressed to hold CO₂

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

1.25 : 30

Alkaline urine

d) Therapy required to restore metabolic balance

Lactate-containing solution

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

1 : 20

From Thibodeau GA, Patton KT. Anatomy & physiology, ed 5, St Louis, 2003, Mosby.
Mosby items and derived items copyright © 2004, 2000 by Mosby, Inc.
Diagnosis of Acid-Base Imbalances:
1) Note whether the pH is low (acidosis) or high (alkalosis).
2) Decide which value, pCO$_2$ or HCO$_3^-$, is outside the normal range and could be the cause of the problem.
   If the cause is a change in pCO$_2$, the problem is respiratory.
   If the cause is HCO$_3^-$, 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.

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.
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:

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

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:

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

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

(between 7.35-7.45) Compenstaed

If PCO2<35 Respiratory alkalosis

Uncompenstated

Hco3

If HCO3-< 22= Metabolic acidosis.

(<7.35 or >7.45) Uncompenstated

If HCO3-> 26 = metabolic alkalosis.

Above 7.4 alkalosis
<table>
<thead>
<tr>
<th>Questions</th>
<th>MCQs</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q1. Which of the following cause acidosis?</strong></td>
<td>A. Hyperaldosteronism</td>
<td>1.D</td>
</tr>
<tr>
<td>B. Sever vomiting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Hyperventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Sever diarrhea</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q2. How does the kidney compensate of respiratory acidosis?</strong></td>
<td>A. The kidney conserves H+ and excretes CHO-</td>
<td>2.A</td>
</tr>
<tr>
<td>B. K+ exchanges with excess H+ in ECF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Hyperventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. A+C</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q3. A patient is seen in the emergency department with following blood value PH=7.8, HCO3- =29, PCO2 =38 what is the acid-base disorder?</strong></td>
<td>A. Respiratory Acidosis</td>
<td>3.D</td>
</tr>
<tr>
<td>B. Respiratory Alkalosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Metabolic Acidosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Metabolic Alkalosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q4. In the conversion from acute to chronic respiratory alkalosis, what happen to blood PH?</strong></td>
<td>A. Increase</td>
<td>4.B</td>
</tr>
<tr>
<td>B. Decrease to normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Severe decreasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Constant</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q1. How does the kidney compensate of respiratory acidosis?</strong></td>
<td>Kidney will eliminate H+ ions and retain HCO3- ions, also generates new HCO3-</td>
<td></td>
</tr>
<tr>
<td><strong>Q2. What is the difference between vomiting and diarrhea an acid-base imbalance?</strong></td>
<td>Vomiting: is combined with excessive loose of acid.</td>
<td></td>
</tr>
<tr>
<td>Diarrhea: is combined with low absorption of HCO3- due to high flow fluid go out.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q3. What is “Anorexia nervosa”?</strong> An emotional disorder characterized by an obsessive desire to lose weight by refusing to eat, so it will cause alkalosis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Q4. 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?</strong></td>
<td>Respiratory alkalosis uncompensated</td>
<td></td>
</tr>
</tbody>
</table>