ACID-BASE BALANCE AND ARTERIAL BLOOD GASES
PURPOSE

• Maintain a steady balance between acids and bases to achieve homeostasis

• Health problems lead to imbalance
  • Diabetes mellitus
  • Vomiting and diarrhea
  • Respiratory conditions
• Measure of $H^+$ ion concentration

• Blood is slightly alkaline at pH 7.35 to 7.45.
  • $<7.35$ is acidosis.
  • $>7.45$ is alkalosis.
Fig. 17-16. The normal range of plasma pH is 7.35 to 7.45. A normal pH is maintained by a ratio of 1 part carbonic acid to 20 parts bicarbonate.
REGULATORS OF ACID/BASE

- Metabolic processes produce acids that must be neutralized and excreted.

- Regulatory mechanisms
  - Buffers
  - Respiratory system
  - Renal system
REGULATORS OF ACID/BASE

- **Buffers**: Act chemically to neutralize acids or change strong acids to weak acids

  - Primary regulators
  - React immediately
  - Cannot maintain pH without adequate respiratory and renal function
REGULATORS OF ACID/BASE

• **Respiratory system**: Eliminates CO$_2$

  • Respiratory center in medulla controls breathing.
  • Responds within **minutes/hours** to changes in acid/base.
  • ↑respirations lead to ↑CO$_2$ elimination and ↓CO$_2$ in blood.
REGULATORS OF ACID/BASE

- **Renal system**: Eliminates $\text{H}^+$ and reabsorbs $\text{HCO}_3^-$

  - Reabsorption and secretion of electrolytes (e.g., $\text{Na}^+$, $\text{Cl}^-$)
  - Responds within *hours to days*
ALTERATIONS IN ACID-BASE BALANCE

• Imbalances occur when compensatory mechanisms fail.

• Classification:
  • **Respiratory**: Affect **carbonic acid** concentration
  • **Metabolic**: Affect **bicarbonate**
RESPIRATORY ACIDOSIS

- Carbonic acid excess caused by
  - Hypoventilation
  - Respiratory failure

- Compensation
  - Kidneys conserve $\text{HCO}_3^-$ and secrete $\text{H}^+$ into urine.
Fig. 17-17. Kinds of acid-base imbalances. **A**, Respiratory imbalances caused by carbonic acid (CA) excess and carbonic acid deficit. **B**, Metabolic imbalances caused by base bicarbonate (BB) deficit and base bicarbonate excess.
RESPIRATORY ALKALOSIS

• **Carbonic acid deficit** caused by
  • Hyperventilation
  • Hypoxemia from acute pulmonary disorders

• **Compensation**
  • Rarely occurs because of aggressive treatment of causes of hypoxemia
METABOLIC ACIDOSIS

• Base bicarbonate deficit caused by:
  • Ketoacidosis
  • Lactic acid accumulation (shock)
  • Severe diarrhea
  • Kidney disease

• Compensatory mechanisms:
  • Increased CO$_2$ excretion by lungs
  • Kussmaul respirations (deep and rapid)
  • Kidneys excrete acid
METABOLIC ALKALOSIS

• Base bicarbonate excess caused by
  • Prolonged vomiting or gastric suction
  • Gain of $\text{HCO}_3^-$

• Compensatory mechanisms
  • Decreased respiratory rate to increase plasma $\text{CO}_2$
  • Renal excretion of $\text{HCO}_3^-$
BLOOD GAS VALUES

- Arterial blood gas (ABG) values
  - Acid-base status
  - Underlying cause of imbalance
  - Body’s ability to regulate pH
  - Overall oxygen status
INTERPRETATION OF ABGS

• Diagnosis in six steps:

1. Evaluate pH.
2. Analyze PaCO₂.
3. Analyze HCO₃⁻.
4. Determine if CO₂ or HCO₃⁻ matches the alteration.
5. Decide if the body is attempting to compensate.
# NORMAL BLOOD GAS VALUES

## TABLE 17-15

**NORMAL ARTERIAL BLOOD GAS VALUES**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>REFERENCE INTERVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.35-7.45</td>
</tr>
<tr>
<td>PaCO₂</td>
<td>32-48 mm Hg</td>
</tr>
<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>22-26 mEq/L (mmol/L)</td>
</tr>
<tr>
<td>PaO₂†</td>
<td>80-100 mm Hg</td>
</tr>
<tr>
<td>SaO₂</td>
<td>&gt;95%</td>
</tr>
<tr>
<td>Base excess</td>
<td>±2.0 mEq/L</td>
</tr>
</tbody>
</table>

*PaCO₂*, Partial pressure of carbon dioxide in arterial blood; *PaO₂*, partial pressure of oxygen in arterial blood; *SaO₂*, arterial oxygen saturation.

*Venous blood gas reference intervals are listed in Table 26-1 on p. 501.

†Decreases above sea level and with increasing age.

Table 17-15. Normal Arterial Blood Gas Values *.

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## Table 17-16

### Arterial Blood Gas (ABG) Analysis

<table>
<thead>
<tr>
<th>ABG VALUES</th>
<th>ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH 7.30</td>
<td>1. pH &lt; 7.35 indicates acidosis.</td>
</tr>
<tr>
<td>PaCO₂ 25 mm Hg</td>
<td>2. PaCO₂ is low, indicating respiratory alkalosis.</td>
</tr>
<tr>
<td>HCO₃⁻ 16 mEq/L</td>
<td>3. HCO₃⁻ is low, indicating metabolic acidosis.</td>
</tr>
<tr>
<td></td>
<td>4. Metabolic acidosis matches the pH.</td>
</tr>
<tr>
<td></td>
<td>5. The CO₂ does not match, but is moving in the opposite direction, which indicates the lungs are attempting to compensate for the metabolic acidosis.</td>
</tr>
</tbody>
</table>

### Interpretation

This ABG is interpreted as metabolic acidosis with partial compensation. If the pH returns to the normal range, the patient is said to have full compensation.

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Table 17-16. Arterial Blood Gas (ABG) Analysis.
ACID-BASE MNEMONIC—ROME

- **R**espiratory
  - **O**pposite
    - Alkalosis $\uparrow$ pH $\downarrow$ PaCO$_2$
    - Acidosis $\downarrow$ pH $\uparrow$ PaCO$_2$
- **M**etabolic
  - **E**qual
    - Acidosis $\downarrow$ pH $\downarrow$ HCO$_3$
    - Alkalosis $\uparrow$ pH $\uparrow$ HCO$_3$
INTERPRETATION OF ABGS

- pH 7.36
- PaCO₂ 67 mm Hg
- PaO₂ 47 mm Hg
- HCO₃⁻ 37 mEq/L

- What is this?
INTERPRETATION OF ABGS

- pH 7.18
- \( \text{PaCO}_2 \) 38 mm Hg
- \( \text{PaO}_2 \) 70 mm Hg
- \( \text{HCO}_3^- \) 15 mEq/L
- What is this?
INTERPRETATION OF ABGS

- pH 7.60
- PaCO₂ 30 mm Hg
- PaO₂ 60 mm Hg
- HCO₃⁻ 22 mEq/L

- What is this?
INTERPRETATION OF ABGS

• pH 7.58
• PaCO₂ 35 mm Hg
• PaO₂ 75 mm Hg
• HCO₃⁻ 50 mEq/L

• What is this?
INTERPRETATION OF ABGS

• pH 7.28
• PaCO$_2$ 28 mm Hg
• PaO$_2$ 70 mm Hg
• HCO$_3^-$ 18 mEq/L

• What is this?
A patient with an acid-base imbalance has an altered potassium level. The nurse recognizes that the potassium level is altered because:

1. Potassium is returned to extracellular fluid when metabolic acidosis is corrected.
2. Hyperkalemia causes an alkalosis that results in potassium being shifted into the cells.
3. Acidosis causes hydrogen ions in the blood to be exchanged for potassium from the cells.
4. In alkalosis, potassium is shifted into extracellular fluid to bind excessive bicarbonate.
A patient has the following arterial blood gas (ABG) results: pH 7.48, PaO$_2$ 86 mm Hg, PaCO$_2$ 44 mm Hg, HCO$_3$ 29 mEq/L. When assessing the patient, the nurse would expect the patient to experience:

1. Warm, flushed skin.
2. Respiratory rate of 36.
4. Hypertonic muscles with cramping.
CASE STUDY 1: JERI

- Jeri’s been on a 3-day party binge.
- Friends are unable to awaken her.
- Assessment reveals level of consciousness difficult to arouse.
- Respiratory rate 8
- Shallow breathing pattern
- Diminished breath sounds
CASE STUDY 1: JERI

1. What ABGs do you expect?
2. What is your treatment?
CASE STUDY 2: MAYNA

- Presented to the ED after a sexual assault
- Examination reveals hysteria and emotional distress.
- Respiratory rate 38
- Lungs clear
- $O_2$ sat 96%
CASE STUDY 2: MAYNA

1. What ABGs do you expect?
2. What is your treatment?
CASE STUDY 3: GLEN

- History of fever, aches, and chills
- Generally feeling ill
- Cough productive of yellow, thick sputum for the past 4 days
- Examination reveals temp 38.4° C
- Respiratory rate 20
- Lungs with crackles in left lower lobes
CASE STUDY 3: GLEN

1. What ABGs do you expect?
2. What is your treatment?
CASE STUDY 4: ALAN

- 17 years old
- History of
  - Feeling bad
  - Fatigue
  - Constant thirst
  - Frequent urination

- Blood sugar is 484 mg/dL.
- Respirations are 28 and deep.
- Breath has a fruity odor.
- Lungs are clear.

CASE STUDY 4: ALAN

1. What ABGs do you expect?
2. What is your treatment?
CASE STUDY 5: ANTHONY

• History of nausea and vomiting for the past week

• Has been self-medicating himself with baking soda to control his abdominal discomfort
CASE STUDY 5: ANTHONY

1. What ABGs do you expect?
2. What is your treatment?
CASE STUDY 6: SUSAN

- ABG results are as follows:
  - pH 7.20
  - PaCO₂ 58 mm Hg
  - PaO₂ 59 mm Hg
  - HCO₃⁻ 24 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?
CASE STUDY 7: FERNANDO

- **ABG results are as follows:**
  - pH 7.39
  - PaCO$_2$ 38 mm Hg
  - PaO$_2$ 44 mm Hg
  - HCO$_3^-$ 24 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?
CASE STUDY 8: BRIANNA

• ABG results are as follows:
  • pH 7.36
  • PaCO₂ 58 mm Hg
  • PaO₂ 50 mm Hg
  • HCO₃⁻ 33 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?
CASE STUDY 9: MONICA

• ABG results are as follows:
  • pH 7.50
  • PaCO₂ 28 mm Hg
  • PaO₂ 85 mm Hg
  • HCO₃⁻ 24 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?
ABG results are as follows:
- pH 7.20
- \( \text{PaCO}_2 \) 28 mm Hg
- \( \text{PaO}_2 \) 81 mm Hg
- \( \text{HCO}_3^- \) 18 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?
CASE STUDY 11: JEREMY

ABG results are as follows:
- pH 7.57
- PaCO₂ 46 mm Hg
- PaO₂ 87 mm Hg
- HCO₃⁻ 38 mEq/L

1. Describe a patient who would have these ABGs, including history and assessment.

2. What is the treatment?