ABG
(Arterial Blood Gas)

DR SUDHIR KUMAR SINGH
The basic physiology of acid–base balance

- Our body functions in a relatively narrow alkaline environment
  - pH: 7.35-7.45
- Normal physiologic function = the maintenance of pH within this range.
- Two main mechanisms – Respiratory and Metabolic.
- If pH <7.35, the blood is said to be acidic.
- If pH >7.45, the blood is said to be alkalotic.
The respiratory buffer response

- Carbon dioxide (CO2) is a normal by-product of cellular metabolism.
- Partial pressure of CO2 in arterial blood (paCO2) is determined by alveolar ventilation.
- The excess CO2 combines with water to form carbonic acid.
- The blood pH changes according to
  - Amount of carbonic acid in the body i.e. the depth and rate of ventilation.
- As blood pH decreases (acidosis), CO2 is exhaled (alkalosis as compensation).
- As blood pH increases (alkalosis), CO2 is retained (acidosis as compensation).
- The respiratory response is fast and activated within minutes.
The renal buffer response

- The kidneys secrete Hydrogen ion (H+) and reabsorbs bicarbonate.
- In response to **metabolic acid** formation.
- Bicarbonate is a metabolic component and considered a base.
- As blood pH decreases (acidosis), the body retains bicarbonate (a base).
- As blood pH rises (alkalosis), the body excretes bicarbonate (a base) in urine.
- This compensation is slow and **takes hours to days** to get activated.
The acid-base control

• The pH is dependent on the \( \text{paCO2} / \text{HCO}_3^- \) (bicarbonate) ratio.

• A change in CO2 \( \rightarrow \) compensated by a change in \( \text{HCO}_3^- \) and vice versa.

• The initial change is called the primary disorder.

• The secondary response is called the compensatory disorder.
Basic facts to remember

• CO₂ is a respiratory component and considered a respiratory acid.
• Moves opposite to the direction of pH and is visualized as a see-saw
Basic facts to remember……..

• Bicarbonate - A metabolic component and considered a base.
• It moves in the same direction as pH and is visualized as an elevator.
Basic facts to remember........

• If CO2 and HCO3- move in the **same direction**, it is considered a **primary disorder**.
  • For example, if there is respiratory acidosis in body (CO2 retention), the bicarbonate levels increase as a compensation (metabolic alkalosis). The direction of both CO2 and HCO3- are the same in this case.

• If CO2 and HCO3- move in **opposite directions**, it is considered a **mixed disorder**.
  • For example, mixed disorder in the case of salicylate poisoning: Primary respiratory alkalosis due to salicylate-induced hyperventilation and a primary metabolic acidosis due to salicylate toxicity.
Conditions causing acid-base imbalance

- Respiratory acidosis
  - Any condition causing the accumulation of CO2 in the body.
  - Central nervous system (CNS) depression due to head injury
  - Sedation, coma
  - Chest wall injury, flail chest
  - Respiratory obstruction/foreign body

- Respiratory alkalosis
  - Due to decrease in CO2.
    Hyperventilation occurs and CO2 is washed out causing alkalosis.
  - Psychological: Anxiety, fear
  - Pain
  - Fever, sepsis, pregnancy, severe anemia.
Conditions causing acid-base imbalance

- Metabolic acidosis - due to excess of acids or deficit of base.
  - Increased acids
    - Lactic acidosis (shock, haemorrhage, sepsis)
    - Diabetic ketoacidosis
    - Renal failure
  - Deficit of base
    - Severe diarrhoea
    - Intestinal fistulas.

- Metabolic alkalosis - caused by excess base or deficit of acids.
  - Acid Deficit:
    - Prolonged vomiting, nasogastric suction, diuretics
  - Excess base:
    - Excess consumption of diuretics and antacids
    - Massive blood transfusion (citrate metabolized to bicarbonate).
Arterial blood gas analysis

• Important routine investigation to monitor
  ➢ the acid-base balance of patients
  ➢ effectiveness of gas exchange

• A vital role in monitoring of
  ➢ Postoperative patients,
  ➢ Patients receiving oxygen therapy,
  ➢ Those on intensive support,
  ➢ Patients with significant blood loss, sepsis, and comorbid conditions like diabetes, kidney disorders,
  ➢ Cardiovascular system (CVS) conditions
Why do we order a blood gas analysis?

- Aids in establishing diagnosis
- Guides treatment plan
- Improvement in the management of acid/base; allows for optimal function of medications
- Acid/base status may alter levels of electrolytes critical to the status of a patient.

- Limitations of blood gas analysis
  
  - Can not yield a specific diagnosis. (e.g. A patient with asthma may have similar values to another patient with pneumonia).

  - Does not reflect the degree to which an abnormality actually affects a patient.

  - Cannot be used as a screening test for early pulmonary disease.
Arterial vs Venous blood gas analysis

- Arterial blood → paO₂, paCO₂, and pH measurements.
- Best indicator → How well the lungs are oxygenating.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺</td>
<td>Hydrogen ions, inversely proportional to pH</td>
<td>35-45 mmol/L</td>
</tr>
<tr>
<td>pH</td>
<td>Acidity/alkalinity</td>
<td>7.35-7.45</td>
</tr>
<tr>
<td>paO₂</td>
<td>Partial pressure of oxygen in arterial blood</td>
<td>80-100 mmHg</td>
</tr>
<tr>
<td>SaO₂</td>
<td>Arterial oxygen saturation</td>
<td>95-100%</td>
</tr>
<tr>
<td>paCO₂</td>
<td>Partial pressure of CO₂ in arterial blood</td>
<td>35-45 mm Hg</td>
</tr>
<tr>
<td>HCO³⁻</td>
<td>Bicarbonate in blood</td>
<td>22-26 mEq/L</td>
</tr>
<tr>
<td>BE</td>
<td>Base excess (amount of excess or insufficient amount of base in blood)</td>
<td>-2 to +2 mmol/L</td>
</tr>
<tr>
<td></td>
<td>-ve in acidosis, +ve in alkalosis</td>
<td></td>
</tr>
</tbody>
</table>

CO₂: Carbon dioxide
Arterial vs Venous blood gas analysis

• If the venous sample is obtained
  ➢ Values compared and interpreted keeping in consideration.

<table>
<thead>
<tr>
<th>Value</th>
<th>Arterial blood</th>
<th>Mixed venous</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.40 (7.35-7.45)</td>
<td>7.36 (7.31-7.41)</td>
</tr>
<tr>
<td>( \text{paO}_2 )</td>
<td>80-100 mmHg</td>
<td>35-40 mmHg</td>
</tr>
<tr>
<td>( \text{O}_2 ) saturation</td>
<td>95%</td>
<td>70-75%</td>
</tr>
<tr>
<td>( \text{PaCO}_2 )</td>
<td>35-45 mmHg</td>
<td>41-51 mmHg</td>
</tr>
<tr>
<td>( \text{HCO}_3^- )</td>
<td>22-26 mEqL(^{-1})</td>
<td>22-26 mEqL(^{-1})</td>
</tr>
<tr>
<td>BE</td>
<td>-2 to +2</td>
<td>-2 to +2</td>
</tr>
</tbody>
</table>

(Table adapted from\(^3\); \( \text{O}_2 \): Oxygen, \( \text{paO}_2 \): Partial pressure of oxygen in arterial blood, pH: Acidity/alkalinity, \( \text{PaCO}_2 \): Partial pressure of oxygen in arterial blood, \( \text{HCO}_3^- \): Bicarbonate in blood, BE: Base excess)

➢ Significance in hemodynamically unstable patients and should not be discarded.
Obtaining an arterial sample

• Order of preference:
  ➢ Radial > brachial > femoral artery.

• Radial artery is preferred:
  ➢ ease of palpation and access
  ➢ good collateral supply.

• Collateral supply to the hand:
  ➢ Confirmed by the modified Allen’s test
Modified Allen's test

• Ask the patient to make a tight fist.

• Apply pressure to the wrist:
  ➢ Using the middle and index fingers of both hands
  ➢ Compress the radial and ulnar arteries at the same time

• While maintaining pressure:
  ➢ ask the patient to open the hand slowly.
  ➢ Lower the hand and release pressure on the ulnar artery only.

• Positive test:
  ➢ The hand flushes pink or returns to normal color within 15 seconds

• Negative test:
  ➢ The hand does not flush pink or return to normal color within 15 seconds
  ➢ indicating a disruption of blood flow from the ulnar artery to the hand
  ➢ radial artery should not be used.
Sampling

- Arm of the patient
  - palm up on a flat surface
  - wrist dorsiflexed at 45°.

- Puncture site:
  - cleaned with alcohol or iodine
  - allow the alcohol to dry before puncture, as the alcohol can cause arteriospasm
  - local anesthetic (such as 2% lignocaine)

- Radial artery should be palpated for a pulse

- A preheparinised syringe with a 23/25 gauge needle should be inserted at an angle just distal to the palpated pulse.

- After the puncture, sterile gauze should be placed firmly over the site and direct pressure applied for several minutes to obtain hemostasis.
Errors

• Allow a steady state after initiation or change in oxygen therapy before obtaining a sample
  • a steady state is reached between 3 and 10 minutes.
  • in patients with chronic airway obstruction, it takes about 20-30 minutes.

• Always note the percentage of inspired air (FiO2) and condition of the patient

• Do not use excess heparin as
  • it causes sample dilution
  • Excess of heparin may affect the pH.

• Avoid air bubbles in syringe.

• Avoid delay in sample processing.
  • As blood is a living tissue, O2 is being consumed and CO2 is produced in the blood sample.
  • In case of delay, the sample should be placed in ice and such iced samples can be processed for up to two hours without affecting the blood gas values.

• Accidental venous sampling. The venous sample report should not be discarded and can provide sufficient information.
Steps of interpretation

• **Step 1:** Anticipate the disorder
  • keeping in mind the clinical settings and the condition of the patient
  • e.g., the patient may present with a history of insulin-dependent diabetes mellitus (IDDM), which may contribute to a metabolic acidosis

• **Step 2:** Check the pH.
  • pH < 7.35: Acidosis
  • pH > 7.45: Alkalosis
  • pH = 7.40: Normal/mixed disorder/fully compensated disorder
    • (Note: If mixed disorder, pH indicates stronger component)
Steps of interpretation…………….  

**Step 3**: Check SaO2 /paO2

- SaO2 is a more reliable indicator as it depicts the saturation of hemoglobin in arterial blood.

<table>
<thead>
<tr>
<th>Mild hypoxemia</th>
<th>SaO2 %</th>
<th>paO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate hypoxemia</td>
<td>75-89</td>
<td>40-59 mmHg</td>
</tr>
<tr>
<td>Severe hypoxemia</td>
<td>&lt;75</td>
<td>&lt;40 mmHg</td>
</tr>
</tbody>
</table>

- Note: Always compare the SaO2 with FiO2
  - the SaO2 could be within normal range but still much less than FiO2 if the patient is on supplemental oxygen (difference should be less than 10)
Steps of interpretation..........

• Step 4: Check CO2 and HCO3 - (bicarbonate) levels-
  ➢ Identify the culprit

<table>
<thead>
<tr>
<th>Condition</th>
<th>Disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased CO(_2) (&gt;40 mmHg)</td>
<td>Respiratory acidosis</td>
</tr>
<tr>
<td>Decreased CO(_2) (&lt;40 mmHg)</td>
<td>Respiratory alkalosis</td>
</tr>
<tr>
<td>Increased HCO(_3^-) (&gt;24 mEq/L)</td>
<td>Metabolic alkalosis</td>
</tr>
<tr>
<td>Decreased HCO(_3^-) (&lt;24 mEq/L)</td>
<td>Metabolic acidosis</td>
</tr>
</tbody>
</table>

➢ Is it a respiratory/metabolic/mixed disorder?
Steps of interpretation

• **Step 5**: Check base excess (BE).
  
  - Defined as amount of base required to return the pH to a normal range.
  
  - If it is positive, the metabolic picture is of alkalosis.
  
  - If it is negative, the metabolic picture is of acidosis.

• Either of bicarbonate ions/base excess can be used to interpret metabolic acidosis/alkalosis.
Interpretation of arterial blood gas report on the basis of using BE as a metabolic index
Steps of interpretation

• **Step 6**: Check for compensation.

• Is there a compensatory response with respect to the primary change?
  • If yes: Compensated
  • if no: Uncompensated.

• In case of compensation, does it bring the pH to a normal range?
  • If yes: Fully compensated
  • if no: Partially compensated.
Example: 1

- If pH is 7.21, HCO3- is 14, and CO2 is 40.
  - CO2 is normal
  - HCO3- is decreased
Example: 1

• If pH is 7.21, HCO₃⁻ is 14, and CO₂ is 40.
  • CO₂ is normal
  • HCO₃⁻ is decreased

• A case of metabolic acidosis.

• Expected compensation would be a decrease in CO₂ causing respiratory alkalosis.

• Now consider this table ---

<table>
<thead>
<tr>
<th>pH</th>
<th>HCO₃⁻</th>
<th>pCO₂</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.21</td>
<td>14</td>
<td>40</td>
<td>Uncompensated</td>
</tr>
<tr>
<td>7.21</td>
<td>14</td>
<td>30 ↓</td>
<td>Partially compensated</td>
</tr>
<tr>
<td>7.37</td>
<td>14</td>
<td>20 ↓↓</td>
<td>Fully compensated</td>
</tr>
</tbody>
</table>
Example: 2

- **pH**: 7.55, **paCO2**: 49.0, **HCO3**: 48.2
  - pH: 7.55       alkalosis      ↑
  - paCO2: 49.0    increased      ↑
  - HCO3: 48.2     increased      ↑

- paCO2 is increased - retention of CO2 causes acidosis
- HCO3 is increased - increased base causes alkalosis
- So, the primary disorder is metabolic alkalosis.

- CO2 is being retained to compensate for the same-
  - the pH has still not returned to a normal range.

- So, the interpretation - **Partially Compensated Metabolic Alkalosis**
Example 3

- **pH: 7.34, paCO2 40.3, HCO3 : 20.4.**
  - The pH is acidic
  - paCO2 is normal
  - Bicarbonate is decreased.

- Primary disorder is metabolic acidosis

- but no compensatory response as the paCO2 is normal.

- Interpretation - Uncompensated Metabolic Acidosis
Example 4

• pH: 7.52, paCO2 : 31.0, HCO3 : 29.4
  • pH is alkalotic
  • paCO2 is decreased (alkalosis)
  • Bicarbonate is increased (alkalosis).

• As the directions of paCO2 and bicarbonate are opposite and both are causing alkalosis.

• The picture is suggestive of a mixed disorder.

• Interpretation - Combined Alkalosis
THANKS