pH Cases

David- Brett-Augusta-Vivian
Clinical Case #1

15-year-old girl with cystic fibrosis has complained of an increased cough productive of green sputum over the last week. She also complained of being increasingly short of breath, and she is noticeably wheezing on physical examination. Arterial blood was drawn and sampled, revealing the following values:

\[
\begin{align*}
\text{pH} & \quad 7.30 \\
p\text{CO}_2 & \quad 50 \text{ mm Hg} \\
p\text{O}_2 & \quad 55 \text{ mm Hg} \\
\text{Hemoglobin O}_2 & \quad 45\% \\
\text{HCO}_3 & \quad 24 \text{ meq / liter}
\end{align*}
\]

*Cystic fibrosis is a genetic disease that causes thick, sticky mucus to build up in the lungs, digestive tract, and other areas of the body. It is one of the most common chronic lung diseases in children and young adults. The thick mucus is difficult to clear from the respiratory tract, and it provides a nutrient-rich breeding ground for bacteria. Individuals with CF are therefore subjected to repeated bouts of lower respiratory tract infections.*
Clinical Case #1

15-year-old girl with cystic fibrosis...

How would you classify this girl's acid base status?

*Answer:* patient has respiratory acidosis, as is evident from her ↓ arterial blood pH, ↑ arterial blood pCO2, and normal arterial HCO3- concentration.

How does cystic fibrosis cause this acid-base imbalance?

*Answer:* The pooling of excessively thick mucus obstructs the small and large airways. This reduces the patient's minute ventilation, causing hypoventilation. As she hypoventilates, the pCO2 level rises and the excess CO2 reacts with H2O in the bloodstream to produce carbonic acid (H2CO3), which dissociates into H+ ions and HCO3- ions, lowering the pH of the blood.

Can you think of other causes of this type of acid-base disturbance?

*Answer:* Other causes of respiratory acidosis include asthma, chronic bronchitis, emphysema, muscular dystrophy, myasthenia gravis, amyotrophic lateral sclerosis, poliomyelitis, and morphine overdosing.
Clinical Case #2

A 27-year-old woman has been sick with the flu for the past week, vomiting several times every day. She is having a difficult time keeping solids and liquids down, and has become severely dehydrated. After fainting at work, she was taken to a walk-in clinic, where an IV was placed to help rehydrate her. Arterial blood was drawn first, revealing the following:

- **pH**: 7.50
- **pCO2**: 40 mm Hg
- **pO2**: 95 mm Hg
- **Hemoglobin - O2**: 97%
- **HCO3**: 32 meq / liter

How would you classify the patient’s acid base status?

**Answer:** An ↑ arterial blood pH in combination with a normal arterial pCO2 and ↑ arterial HCO3- concentration suggests that this woman has metabolic alkalosis.

Why might excessive vomiting cause her acid-base imbalance?

**Answer:** Gastric secretions in the stomach are very acidic - pH can be below 1.0. If patient is vomiting a lot, there is a net loss of H+ ions from the stomach lumen and ultimately from the bloodstream. This ↑ her arterial blood pH and causes a metabolic alkalosis.

*It should be noted that in severe vomiting the loss of alkaline bile and pancreatic secretions into the vomit can actually cause a metabolic acidosis.*
Clinical Case #3

A 76-year-old man at home experienced the ff:
- severe sub-sternal chest pains that radiated the inside of his left arm
- he collapsed on the living room floor
- paramedics found him unresponsive, not breathing, and without a pulse
- CPR and AED shock were required to start his heart beating again
- In ER the man regained consciousness & complained of severe dyspnea and continued chest pain. Vital signs were as follows:

  *Systemic blood pressure* 85 mmHg / 50 mm Hg
  *HR* 175 BPM
  *Respiratory rate* 32 breaths / minute
  *Temperature* 99.2

Arterial blood tests revealed the following:
- pH 7.22
- pCO2 30 mm Hg
- pO2 70 mm Hg
- Hemoglobin - O2 88%
- HCO3- 2 meq / liter

What is your diagnosis of the patient?

*Answer: heart attack evident by radiating chest pain, sudden collapse, elevated HR etc suggest this diagnosis.*
Clinical Case #3

76-year-old man with myo infarction...

How would you classify his acid-base status? What specifically caused this acid-base disturbance?

Answer: patient has lower-than-normal arterial pH and HCO3- levels, in combination with a lower-than-normal arterial pCO2 level. This indicates that he is in a state of metabolic acidosis. When his heart stopped beating, blood flow to organs stopped. Hence, tissues were forced to continue to work w/o oxygen (anaerobically). A by-product of anaerobic respiration is lactic acid- when lactic acid ↑ in tissues/bloodstream, it ↓ the blood pH, a condition known as lactic acidosis. Even after his heart started beating again, it takes several minutes to hours to flush the excess acid out of the bloodstream.

How has his body started to compensate for this acid-base imbalance?

Answer: patient hyperventilation is driving the arterial pCO2 downward and causing more production of carbonic acid. This carbonic acid is then converted to CO2 and H2O, the former being excreted through the lungs. The net effect of this process is to remove some of the excess H+ ions from the bloodstream, thus helping to correct the metabolic acidosis.
An 80 year old homeless man presents with nausea, vomiting and poor oral intake 2 days prior to admission. The patient reports a 3 day history of binge drinking prior to symptoms.

Arterial Blood Gas (ABG)

- pH = 7.30
- PaCO2 = 29
- HC03- = 16
- P02 = 92
- Na+ = 132
- Cl- = 104
Acid-Base Disturbance | pH 7.35-7.45 | Pco2 35-45mm HG | HCO3- 22-26mEq/L
--- | --- | --- | ---
Respiratory Acidosis | ↓ | ↑ | ↑ if compensating
Respiratory Alkalosis | ↑ | ↓ | ↓ if compensating
Metabolic Acidosis | ↓ | ↓ if compensating | ↓
Metabolic Alkalosis | ↑ | ↑ if compensating | ↑

Is the patient ACIDEMIC or ALKALEMIC? **↓ ACIDEMIC!**

Is the PCO2 normal, increased or decreased? **↓ DECREASED!**

Is the HCO3- normal, increased or decreased? **↓ DECREASED!**

What acid/base order exists in this scenario? Metabolic Acidosis with respiratory compensation
**ANION GAP FORMULA**

\[ [\text{Na}^+] - ([\text{Cl}^-] + [\text{HCO}_3^-]) \]

Normal Anion Gap Range = 10-14

**Arterial Blood Gas (ABG)**

- pH = 7.30
- PaCO2 = 29
- HC03- = 16
- P02 = 92
- Na+ = 132
- Cl- = 104

\[ 132 - (104 + 16) = 12 \]

\[ \uparrow \quad \uparrow \quad \uparrow \]

Na+  Cl-  HCo3-

= NORMAL AG
Mr. Williams is a 24 year old college student who is complaining of a four day history of bloody-watery diarrhea.

**Arterial Blood Gas (ABG)**

- $\text{pH} = 7.28$
- $\text{PaCO}_2 = 43$
- $\text{HCO}_3^- = 20$
- $\text{P}O_2 = 88$
- $\text{Na}^+ = 138$
- $\text{Cl}^- = 108$
### Acid-Base Disturbance

<table>
<thead>
<tr>
<th>Acid-Base Disturbance</th>
<th>pH 7.35-7.45</th>
<th>Pco2 35-45mm HG</th>
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</tr>
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<tr>
<td>Respiratory Acidosis</td>
<td>↓</td>
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### Arterial Blood Gas (ABG)

- pH = 7.28
- PaCO2 = 43
- HC03- = 20
- P02 = 88
- Na+ = 138
- Cl- = 108

**Is the patient ACIDEMIC or ALKALEMIC?**  
ACIDEMIC!

**Is the PCo2 normal, increased or decreased?**  
NORMAL

**Is the HCo3- normal, increased or decreased?**  
DECREASED!

**What acid/base order exists in this scenario?**  
Metabolic Acidosis
ANION GAP FORMULA

\[ [\text{Na}^+] - ([\text{Cl}^-] + [\text{HCO}_3^-]) \]

Normal Anion Gap Range = 10 – 14

Arterial Blood Gas (ABG)

- pH = 7.28
- PaCO2 = 43
- HCO3- = 20
- PO2 = 88
- Na+ = 138
- Cl- = 108

\[ 138 - (108 + 20) \uparrow \]

\[ \uparrow \text{Na} \]

\[ \uparrow \text{Cl}^- \]

\[ \uparrow \text{HCO}_3^- \]

\[ \cong 10 \]

\[ = \text{NORMAL AG} \]
Possible Causes of Metabolic Acidosis

- Severe diarrhea
- Renal Disease
- Untreated diabetes
- Starvation
- Excess alcohol digestion
- High potassium concentration
Acid Base Imbalance
The human body has many different intricate systems that keep us living, and we have the blood pH.

The blood pH is a very important measurement of the blood stream, and has a number associated with it from 0-14. It measures the concentration of hydrogen in a solution or substance.

If the pH is at 7.0 it's said to be neutral, higher numbers are considered alkali or base and lower numbers are considered acids.

The blood pH is important because it controls the body's biomechanical responses by controlling enzyme activity and the speed of electricity through the body. The higher the pH (alkali) equals more resistance.

Now let's look at what happens when numbers constitute an imbalance.
### Normal Ranges

<table>
<thead>
<tr>
<th>Test</th>
<th>Normal Range</th>
<th>Down Value</th>
<th>Up Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.35-7.45</td>
<td>Acidosis</td>
<td>Alkalosis</td>
</tr>
<tr>
<td>pCO₂</td>
<td>35-45</td>
<td>Alkalosis</td>
<td>Acidosis</td>
</tr>
<tr>
<td>HCO₃</td>
<td>22-26</td>
<td>Acidosis</td>
<td>Alkalosis</td>
</tr>
<tr>
<td>pO₂</td>
<td>80-100</td>
<td>Hypoxemia</td>
<td>O₂ Therapy</td>
</tr>
<tr>
<td>SaO₂</td>
<td>95-100%</td>
<td>Hypoxemia</td>
<td>-----------</td>
</tr>
<tr>
<td>Anion Gap</td>
<td>10-14</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

pCO₂ deals with respiratory
HCO₃ deals with (renal) metabolic
Metabolic acidosis (body builds up too much acid, & kidneys can't remove it fast enough w/ bicarbonate HC03)

Metabolic alkalosis (body builds up too much HCO3, and acid can't neutralize it)

Respiratory acidosis (body builds up too much CO2 in the blood) shallow breaths hypoventilation

Respiratory alkalosis (CO2 is eliminated faster than produced) hyperventilation
Diagnosis

Anion Gap formula \((\text{Na}^+ - \text{Cl}^- + \text{HCO}_3^-)\)

We use the anion gap any time we diagnose a patient with metabolic acidosis. The anion gap calculation allows us to differentiate cases of metabolic acidosis.

Also whenever we have a respiratory acidosis or alkalosis we also tend to look at whether or not it is acute or chronic problems

When the body goes through these imbalances it tends to compensate
Mixed acid-base disorder is one in which two different primary conditions are acting at the same time. Mixed disorders can be a combination of metabolic and respiratory disorders or a combination of different metabolic disorders.

The expected compensatory response does not occur. Compensatory response occurs, but level of compensation is inadequate or too extreme.

pH is normal but PCO2 or HCO3- is abnormal.
A 26-year-old woman is undergoing treatment for frequent panic attacks. The attacks are accompanied by hyperventilation, a racing heartbeat (tachycardia), dizziness, feelings of “unreality” and tingling in the hands. In one particularly severe attack, when taken to the emergency department, an arterial blood-gas sample was taken, which revealed the following:

- pH 7.52
- PCO2 26 mm Hg
- HCO3 22 mEq/L
The pH of the arterial blood gas identifies it as alkalemic. Also the numbers indicate the primary disturbance is respiratory, because the PCO2 being lowered primarily. In our case an arterial PCO2 shifted by 0.086 pH for each PCO2 shift of 10 mm. This means that the respiratory disturbance is acute. The renal system compensates bicarbonate ion levels fall as kidneys eliminate more HCO3 because they can't secrete it or reclaim.

**DIAGNOSIS**: Acute Respiratory Alkalosis from Hyperventilation due to Panic Attack
A 31 year old man presents with lethargy, weakness, labored respiration, and confusion. He has had diabetes for 15 years, and has been suffering from the “intestinal flu” so he has been avoiding food to help prevent vomiting. Since he stopped eating, he thought that it would be a good idea to stop taking his insulin. The following arterial blood gas data was obtained:

- pH 7.27
- PCO2 23 mm Hg
- Na+ 132 mEq/L
- Cl- 83 mEq/L
- HCO3 10 mEq/L
- Glucose 345 mg/dL
The pH is 7.27, which is considerably less than normal (7.35-7.45), so the patient is acidemic. The PCO2 is low, so the respiratory system is not causing the acidosis; rather, the drop in PCO2 must be a compensatory process. The bicarbonate is low, which indicates that a metabolic acidosis is present. The anion gap \(= [\text{Na}^+] - [\text{Cl}^-] - [\text{HCO}_3^-] = [132] - [83] - [10] = 39\). The anion gap is obviously elevated. This means that the metabolic acidosis is of the elevated anion gap type.

Diagnosis Elevated Anion Gap Metabolic Acidosis
Central Sleep Apnea
Characterized by...

- Periods of absent airflow due to lack of respiratory effort
- Inhibitory input to the respiratory center of the brain exceeds excitatory input
Occurs if...

- Arterial pCO2 is lowered below a highly sensitive apneic threshold
Hyperventilation

• Central sleep apnea can be induced by hyperventilation
  – Hypernea occurs (ex. Hypoxia due to poor lung function)
  – Hypernea leads to hypocapnia (low CO2) which induces central apnea
  – Central apnea causes pCO2 to rise creating a respiratory alkolosis
Central Apnea in Healthy Individuals

• This occurs at the onset of sleep
• During this time pCO2 levels are at or below apneic threshold
• Once sleep begins wakefulness related excitatory input is lost and a central apnea results
Treatment

- Continuous Positive Airway Pressure
- Supplemental oxygen
- Trials are being done on Acetazolamide, a diuretic which causes a mild metabolic acidosis
Ethylene Glycol Toxicity

- Generally a result of ingesting antifreeze, fairly common poison used
- LETHAL!
Anion Gap

- A profound anion gap occurs with ingestion of ethylene glycol
- There is an accumulation of toxic acid metabolites
- Bicarbonate levels decrease
Symptoms

- Abdominal pain
- Hematuria (RBCs in urine)
- Coma
- Seizures
- Hyperpnea
- Hypotension
Treatment

• Administer sodium bicarbonate
• Inhibit alcohol dehydrogenase
• Hemodialysis
Diabetic Ketoacidosis (DKA)

- Characterized by triad of hyperglycemia, anion gap metabolic acidosis, and ketonemia
Anion Gap

• Reduction in bicarbonate concentration leads to elevated anion gap metabolic acidosis

• A compensatory hyperventilation results to decrease the pCO2
Arterial pH

- pH values in DKA are less than 7.3 and can even be lower than 6.9 in severe cases
Treatment

• Insulin therapy
  – Lowers glucose concentration
  – Diminishes ketone production

• Correction of fluid and electrolyte imbalances
  – Avg fluid loss in DKA is 3-6 liters!
  – Isotonic saline is used as fluid replacement