Lecture 12 : Exercise Calculation of Anion Gap and Osmolar Gap

Objectives

1. Describe the physiology involved in the acid/base balance of the body.
2. Compare the roles of PaO_2, pH, $PaCO_2$ and Bicarbonate in maintaining acid/base balance.
3. Review causes and treatments* of Respiratory Acidosis, Respiratory Alkalosis, Metabolic Acidosis and Metabolic Alkalosis.
4. Identify normal arterial blood gas values and interpret the meaning of abnormal values.
5. Interpret the results of various arterial blood gas samples.

*For the treatments it's preferred that you go back to (L15: Acid base balance) in Medicine lectures .

Introduction

- Venous blood gas analysis is an essential part of diagnosing and managing a patient's acid-base balance.

- The usefulness of this diagnostic tool is dependent on being able to correctly interpret the results.

- in This presentation we will examine the components of venous blood gas and what each component represents and interpret these values in order to determine the patient's condition and treatment.

pH		CO_2		HCO_3	
< 7.35:	Acidosis	> 45:	Acidosis	< 22:	Acidosis
7.35-7.45:	Normal Range	35-45:	Normal Range	22-26:	Normal Range
>7.45:	Alkalosis	< 35:	Alkalosis	> 26:	Alkalosis

Acid Base Balance

- The pH is a measurement of the acidity or alkalinity of the blood.
- It is inversely proportional to the number of hydrogen ions (H+) in the blood.
- The more H+ present, the lower the pH will be. Likewise, the fewer H+ present, the higher the pH will be.
- The normal blood pH range is 7.35 to 7.45. In order for normal metabolism to take place, the body must maintain this narrow range at all times.

When the pH of the blood is <7.35 it is acidic:

- Changes in body system functions include:
    1. A decrease in the force of cardiac contractions (negative inotropic effect)
    2. A decrease in the vascular response to catecholamines. *

When the pH of the blood is >7.45 it is alkalotic:

- An alkalotic state interferes with tissue oxygenation and normal neurological and muscular functioning.

- **Significant changes in the blood pH >7.8 or <6.8 will interfere with cellular function, and if uncorrected, will lead to death .**
- **the only indication for NaCho3 is severe acidosis Ph < 6.8 because it's a highly concentrated solution and may case brain edema in young patients.**

* this Results in hypotension and in response to that the body will produce even more catecholamines, the blood vessels do not respond to it so, the patient will continue to be hypotensive .
** Alkalosis shifts the (Oxygen–hemoglobin dissociation curve) to the left= increases oxygen's affinity for hemoglobin = less oxygen is released.

Buffer Responses

Respiratory:

- **CO_2** is carried in the blood to the lungs, where excess CO_2 combines with water (H_2O) to form carbonic acid (H_2CO_3).
- The blood pH will change according to the level of carbonic acid present.
- This triggers the lungs to either increase or decrease the rate and depth of ventilation until the appropriate amount of CO_2 has been re-established.
- Activation of the lungs to compensate for an imbalance starts to occur within 1 to 3 minutes.

Renal:

- As the blood pH decreases, the kidneys will compensate by retaining **HCO_3^-** and as the pH rises, the kidneys excrete HCO_3^- through the urine.
- It takes hours to days.

Acid-Base Disorders

	Respiratory Acidosis*	Respiratory Alkalosis
Definition	pH <7.35 with a $PaCO_2$ >45 mm Hg.	pH >7.45 with a $PaCO_2$ <35 mm Hg.
Causes	**1- CNS depression** related to head injury, or to medications such as narcotics, sedatives, or anesthesia **2- Impaired respiratory muscle function** related to spinal cord injury, neuromuscular diseases, or neuromuscular blocking drugs **3- Pulmonary disorders** such as atelectasis, pneumonia, pneumothorax, pulmonary edema, or bronchial obstruction **4- Massive PE** **5- Hypoventilation** due to pain, chest wall injury/deformity, or abdominal distension .	Any condition causing **hyperventilation,** including: **1- Psychological responses**, such as anxiety or fear **2- Pain** **3- Increased metabolic demands**, such as fever, sepsis, pregnancy, or thyrotoxicosis **4- Medications**, such as respiratory stimulants **5- CNS lesions**
Signs & Symptoms	**a) Pulmonary:** Dyspnea, respiratory distress, and/or shallow respirations. **b) Nervous system:** Headache, restlessness, and confusion. If CO_2 levels become extremely high, drowsiness and unresponsiveness* may be coma. **c) Cardiovascular:** Tachycardia and dysrrhythmias	**a) Nervous system:** Light-headedness, numbness and tingling, confusion, inability to concentrate, and blurred vision **b) Cardiovascular:** Dysrhythmias and palpitations **c) Other:** Dry mouth, diaphoresis, and tetanic spasms of the arms and legs (**Carpopedal spasms)****.

***Acidosis is caused by an accumulation of CO2 which combines with water in the body to produce carbonic acid, thus, lowering the pH of the blood.**

**** due to decreased levels of ionized calcium (but total number of calcium is normal), secondary to alkalosis.**

Acid-Base Disorders

	Metabolic Acidosis	Metabolic Alkalosis
Definition	A bicarbonate level of <22 mEq/L with a pH <7.35	A bicarbonate level >26 mEq/liter with a pH >7.45
Causes	**1- A deficit of base** in the bloodstream (e.g. because of diarrhea or intestinal fistulas) **2- An excess of acids**	**1- Excess Base:** Occurs from ingestion of antacids, excess use of bicarbonate, or use of lactate in dialysis **2- Loss of acids:** can occur secondary to protracted vomiting, gastric suction, hypochloremia, excess administration of diuretics, or high levels of aldosterone
Signs & Symptoms	**a) Nervous system :** Headache, confusion, and restlessness progressing to lethargy, then stupor or coma. **b) Cardiac** dysrhythmias c) Kussmaul respirations* d) Warm, flushed skin e) Nausea, vomiting	

*** deep and labored breathing pattern**

Metabolic Acidosis: The Anion Gap [AG = Na – (Cl + HCO3)]

MUDPILES

Methanol
Uremia
Diabetic ketoacidosis*
Parakdehyde, phenformin
Iron, isoniazid, inhalants
Lactic acidosis
Ethylene glycol, ethanol (alcoholic ketoacidosis)
Salicylates, solvents, starvation ketosis

Normal Anion Gap Metabolic Acidosis

HARDUP

Hyperelemintation TPN
Acetazolamide
Renal tubular acidosis types 1, 2, and 4
Diarrhea
Uretroentestinal fistula
Pancraeticoduodenal fistula

*In managing cases of DKA the anion gap is the most important thing. The pH may be corrected and the anion gap is still high so you will continue giving the iv insulin until its back to normal.

Components of Blood Gas

pH: Measurement of acidity or alkalinity, based on the H^+ ions present. The normal range is 7.35-7.45

PO2: The partial pressure of oxygen that is dissolved in arterial blood. The normal range is 80-100 mm Hg.

SaO2: The arterial oxygen saturation. The normal range is 95% - 100%

PaCO2: The amount of carbon dioxide dissolved in arterial blood. The normal range is 35-45 mmHg.

HCO3: The calculated value of the amount of bicarbonate in the bloodstream. The normal range is 22-26 mEq/liter

B.E: The base excess indicates the amount of excess or insufficient level of bicarbonate in the system. The normal range is –2 to +2 mEq/liter

Steps to an Arterial Blood Gas Interpretation

Step 1

Assess the pH to determine if the blood is within normal range, alkalotic or acidotic.

Step 2

If the blood is alkalotic or acidotic, we now need to determine if it is caused primarily by a respiratory or metabolic problem. To do this, **assess the $PaCO_2$ level**.

Step 3

Assess the **HCO_3 value.**

Steps 4-5

Is there appropriate **compensation**? Is it chronic or acute?

Step 6 *

Assess the PaO_2. A value below **80** mm Hg can indicate hypoxemia, depending on the age of the patient.

***Correction of a patient's blood oxygenation level may be accomplished through a combination of augmenting the means of oxygen delivery and correcting existing conditions that are shifting the oxyhemoglobin curve.**

Remember that….

with a respiratory problem, as the pH decreases below 7.35, the PaCO2 should rise. If the pH rises above 7.45, the PaCO2 should fall.
Compare the pH and the PaCO2 values. If pH and PaCO2 are indeed moving in **opposite directions**, then the problem is primarily **respiratory** in nature.

with a metabolic problem, normally as the pH increases, the HCO3 should also increase. Likewise, as the pH decreases, so should the HCO3.
Compare the two values. If they are moving in the **same direction**, then the problem is primarily metabolic in nature.

What disorder is present?	pH	pCO2 or HCO3
Respiratory Acidosis	pH low ⇩	pCO2 high ⇧
Metabolic Acidosis	pH low ⇩	HCO3 low ⇩
Respiratory Alkalosis	pH high ⇧	pCO2 low ⇩
Metabolic Alkalosis	pH high ⇧	HCO3 high ⇧

Is there appropriate compensation ? Is it chronic or acute?

Respiratory Acidosis	• **Acute:** for every **10** increase in pCO_2 ➡ HCO_3 increases by **1** and there is a decrease of **0.08*** in pH • **Chronic:** for every **10** increase in pCO_2 ➡ HCO_3 increases by **4** and there is a decrease of **0.03*** in pH
Respiratory Alkalosis	• **Acute:** for every **10** decrease in pCO_2 ➡ HCO_3 decreases by **2** and there is a increase of **0.08*** in PH • **Chronic:** for every **10** decrease in pCO_2 ➡ HCO_3 decreases by **5** and there is a increase of **0.03*** in PH
Metabolic Acidosis	• **Winter's formula**: $pCO_2 = 1.5[HCO_3] + 8 \pm 2$ • If serum pCO_2 > expected pCO2 , additional respiratory acidosis.
Metabolic Alkalosis	• For every **10** increase in HCO_3 ➡ pCO_2 increases by **6**

MEMORIZE IT !!!!!

* If it change of the pH is different, thus you face a mixed disorder.

Examples :

Follow the steps:
1. Assess the pH. **(normal 7.35-7.45).**
2. Assess the PaCO2. **(normal 35-45).**
3. Assess the HCO3. **(normal 22-26).**

Example 1

Sultana is a 45-year-old female admitted to the nursing unit with a severe asthma attack. She has been experiencing increasing shortness of breath since admission three hours ago.
Her arterial blood gas result is as follows:

pH = 7.22 ↓
PaCO2 = 5 ↓
HCO3 = 18

Same direction = Metabolic Acidosis → Winter's formula ($pCO_2 = 1.5[18] + 8 \pm 2$) = 33 – 37 [paco2 should be in that range].
Pco2 is low = 5 (improper compensation)
because the patient has also Respiratory Alkalosis (severe attack of bronchial asthma) .

*very helpful video (3 minutes): https://youtu.be/nq0xSUJJf-4

Example 2

Amjad is a 55-year-old male admitted to your DEM with a recurring bowel obstruction. He has been experiencing intractable vomiting for the last several hours despite the use of antiemetics. Here is his arterial blood gas result:

pH = 7.50 ↑
PaCO2 = 51 ↑
HCO3 = 33 ↑

Same direction = Metabolic Alkalosis
(45 + 6 = 51) √ Normal compensation (but still not compensated because the pH is not normal yet).
Here the Hco3 is increased by 10 because the lower limit of normal range is 22 so the Paco2 should increase by 6.

Example 3

Adel is admitted to the hospital. He is a kidney dialysis patient * who has missed his last two appointments at the dialysis center. His arterial blood gas values are reported as follows:

pH = 7.32 ↓

PaCO2 = 35 ↓

HCO3 = 18

Same direction = Metabolic Acidosis → Winter's formula ($pCO_2 = 1.5[18] + 8 \pm 2$) = 33 – 37 [paco2 should be in that range].
Pco2 = 35 (so it's a normal compensation)

*From the scenario we can guess that the patient probably have (high anion gap metabolic acidosis)

Example 4

SARA is a patient with chronic COPD being admitted for surgery. Her admission lab work reveals an arterial blood gas with the following values:

pH = 7.27 ↓

PaCO2= 55 ↑

HCO3 = 30

opposite direction = Respiratory acidosis
COPD is a chronic condition so for every 10 increase in pCO_2 , HCO_3 should increases by 4.
Paco2 is 55 (45+10) and Hco3 is 30 (26+4) so it's a normal compensation.

Example 5

Abdullah is a trauma patient with an altered mental status. His initial arterial blood gas result is as follows:

pH =7.20 ↓

PaC02 =62 ↑

HC03 =28

opposite direction = Respiratory acidosis
Trauma is an acute condition so for every for every 10 increase in pCO2 , HCO3 should increases by 1.
Paco2 is 62 (almost increased by 20) and Hco3 is 28 (26+1+1) so it's a normal compensation.

Example 6

LAMA is a 54-year-old female admitted for an ileus. She had been experiencing nausea and vomiting. An NG tube has been in place for the last 24 hours. Here are the last ABG results:

pH = 7.46 ↑

PaC02 = 48 ↑

HC03 = 36

Same direction = metabolic Alkalosis

For every 10 increase in HCO_3 , pCO_2 should increases by 6.

The range of Paco2 is 35-45 **so we could say** (42+6 = 48) **and the rang of Hco3 is** 22-26, (36-10=26) **so, it's a normal compensation.**

Calculate the anion gap :

AG = Na - (Cl + HCO3)

"the normal value AG is 10-14"

Na = 135
HCO3 = 12
Cl = 92
PH = 7.1
paCO2 = 22

135 – (92+12) = **31**

The patient has high anion gap > look for the cause [MUDPILES]

If you have any questions You can always contact us at : forensic433@gmail.com

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