MED439
KING SAUD UNIVERSITY

Physiology Team 439

Revised & Approved by:
Shayma Abdullah Alghanoum
Faisal Alotaibi

PHYSIOLOGY

ACID-BASE DISORDERS

Objectives

To explain the principle of blood gas and acid base analysis.

To interpret blood gas analysis and diagnose various acid base disorders.

Describe causes of acid base disorders.

Understand use of acid base nomograms.

Black: in male AND female slides
Red : important
Pink: in female slides only
Blue: in male slides only
Green: Notes
Gray: extra information

Editing file

Abnormalities in Acid-Base Balance

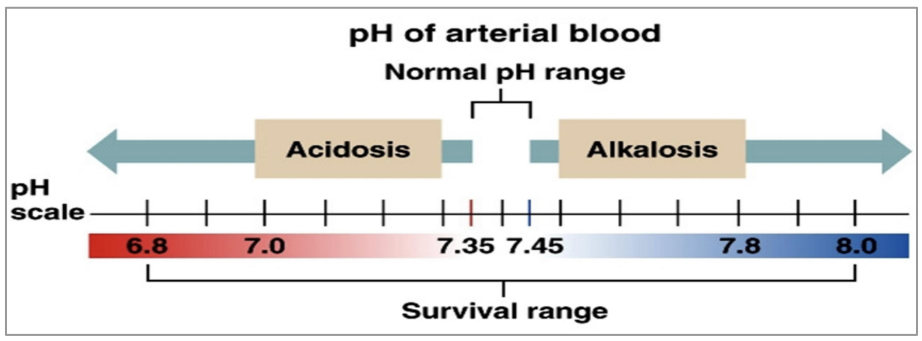
Many critical illnesses can disturb acid-base balance

Acid-base disturbances may indicate an underlying disease or organ damage

Accurate interpretation of acid-base disturbances requires the following:

- Arterial blood gases.
- Plasma electrolytes.
- Knowledge of the compensatory physiologic mechanisms.

Acidosis and alkalosis describe the abnormal conditions that result from an imbalance in the pH of the blood caused by an excess of acid or alkali (base). This imbalance is typically caused by some underlying condition or disease.
Normal blood pH must be maintained within a narrow range, typically 7.35-7.45, to ensure the proper functioning of metabolic processes and the delivery of the right amount of oxygen to tissues.



Fundamentals in Acid-Base Disorders

Acid-base disorders are classified by changes in pH, PCO_2 and HCO_3^-

There are **4 primary acid-base disorders:**

1. **Respiratory acidosis** ↑ PCO_2
2. **Respiratory alkalosis** ↓ PCO_2
3. **Metabolic acidosis** ↓ HCO_3^-
4. **Metabolic alkalosis** ↑ HCO_3^-

The kidney will compensate "Renal compensation"

The lung will compensates "Respiratory compensation"

If a person develops any of these disorders, What will the body try to do?

The body normally attempts to correct the primary acid- base disturbances by a **secondary** or **compensatory** response trying to restore pH towards normal.

Disorder	PH	[H□]	Primary disturbance	Secondary response
Metabolic Acidosis	↓	↑	↓ $[HCO_3^-]$	↓ PCO_2
Metabolic Alkalosis	↑	↓	↑ $[HCO_3^-]$	↑ PCO_2
Respiratory Acidosis	↓	↑	↑ PCO_2	↑ $[HCO_3^-]$
Respiratory Alkalosis	↑	↓	↓ PCO_2	↓ $[HCO_3^-]$

From female slides

Primary Acid-Base Disturbances

Acidosis

PH^+ ↓
Acidemia

Respiratory
$PCO2↑$ $HCO_3↑$

Decreased ventilation

- Inhibition of respiratory center: (opioid , sleeping dose and narcotic ingestion).
- Airway obstruction.
- Lung disease:

COPD
Pneumonia
Pulmonary edema

Metabolic
$PCO2↓$ $HCO_3↓$

- Excessive alkali ingestion (antacide)
- H^+loss (vomiting)
- Diuretics except CAI Hyperaldosteronism

Gain of acids:

↑acid production:
Lactic acidosis .
Diabetic ketoacidosis
Salicylate poisoning Starvation
↓ acid elimination:
Renal failure

Loss of HCO_3:

Through kidneys:
RTA (Renal tubular acidosis)
CAI
Aldosterone deficiency
Through GIT:
Diarrhea

Alkalosis

PH^+ ↑
Alkalemia

Respiratory
$PCO2↓$ $HCO_3↓$

Increase ventilation

- Psychoneurosis:

They breathing on a paper bag why? Because they will inhale again that air they exhaled it and thus Decreases respiratory alkalosis.

- High altitude
- Mechanical
- overventilation Pregnancy:

The expanding of uterus Causes the space of lung to expand will decreases

- Anxiety

Metabolic
$PCO2↑$ $HCO_3↑$

- Renal tubular acidosis

It can be Acquired or hereditary
The kidney doesn't secrete H^+which lead to accumulate in body or it can't reabsorb HCO_3

- Diabetes (most common cause)

If they forget insulin they can't utilise glucose as energy so will start utilise other compound for energy like breakdown of fat will come out "aceto acetate" then will be **keto acidosis** which lead to metabolic acidosis.

- Diarrhea
- Ingestion of acids (alcohol or aspirin)
- Chronic renal failure
- Diabetic ketoacidosis
- Lactic acidosis
- ethylene glycol or salicylates poisoning

Loss of acids:

Vomiting gastric contents.
Loop & thiazide diuretics Hyperaldosteronism.

Gain of HCO_3:

Ingestion or administration of alkaline products.

From boys slides

Simple Acid-Base Disturbances

Respiratory Acidosis

Uncompensated	Compensated
$H^+ \uparrow$	$H^+ \uparrow$
pH ↓	pH ↓
$CO_2 \uparrow$	$CO_2 \uparrow$
HCO_3^- NORMAL	**$HCO_3^- \uparrow$**

Respiratory Alkalosis

Uncompensated	Compensated
$H^+ \downarrow$	$H^+ \downarrow$
pH ↑	pH ↑
$CO_2 \downarrow$	$CO_2 \downarrow$
HCO_3^- NORMAL	**$HCO_3^- \downarrow$**

Metabolic Acidosis

Uncompensated	Compensated
$H^+ \uparrow$	$H^+ \uparrow$
pH ↓	pH ↓
CO_2 NORMAL	**$CO_2 \downarrow$**
$HCO_3^- \downarrow$	$HCO_3^- \downarrow$

Metabolic Alkalosis

Uncompensated	Compensated
$H^+ \downarrow$	$H^+ \downarrow$
pH ↑	pH ↑
CO_2 NORMAL	**$CO_2 \uparrow$**
$HCO_3^- \uparrow$	$HCO_3^- \uparrow$

- In any of the previous disturbances; the body's normal pH is not returned to normal even with the compensation. it gets close to normal.
- The primary disorder is not treated or healed, it is just about increasing the antagonist of the increased acid or alkaline.
- If the disturbance origin was metabolic; the respiratory system will compensate, and vice versa. (Mainly)

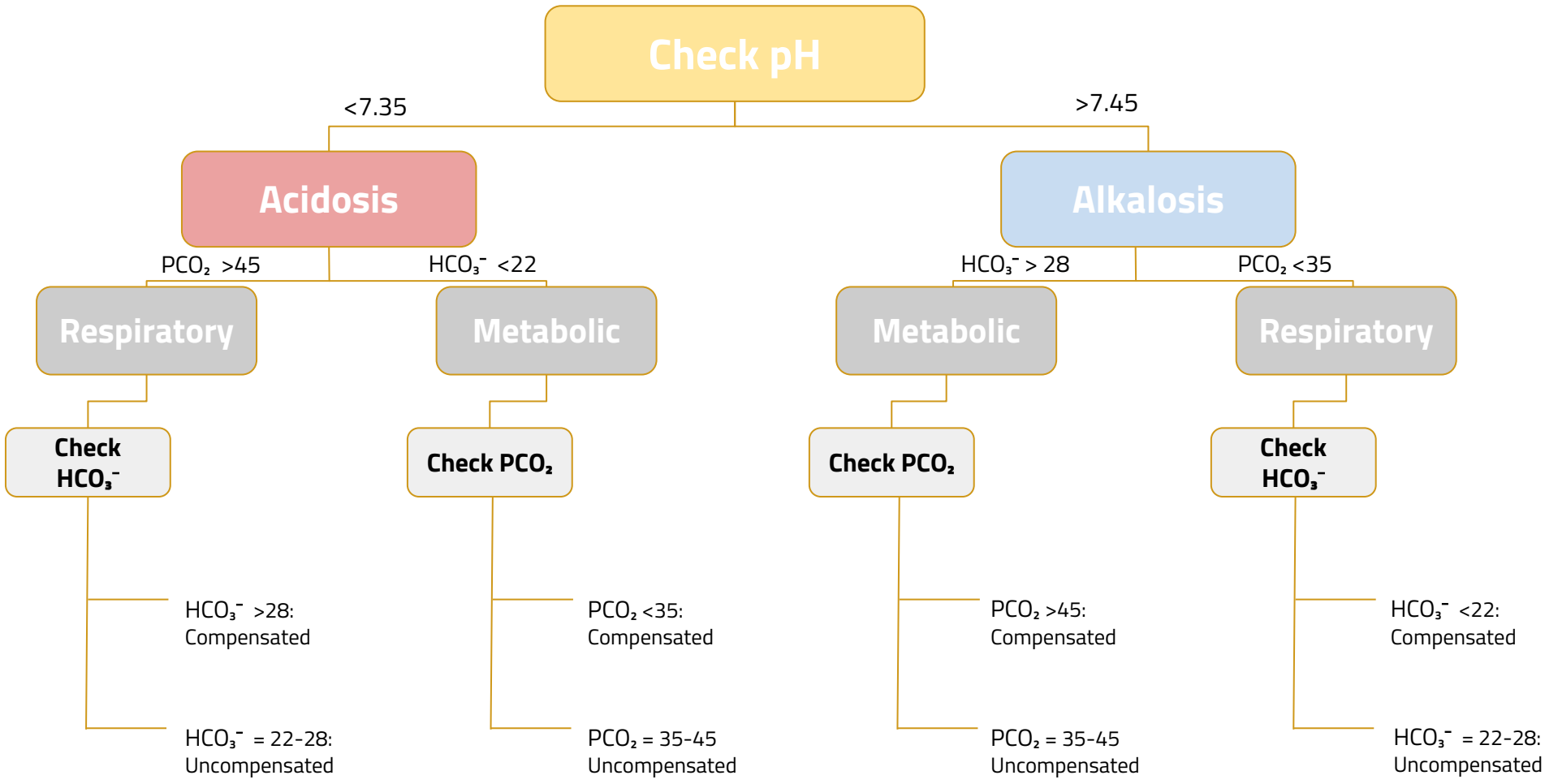
From boys slides

Normal Values (arterial blood analysis)

"We won't ask you about values in kpa"

ANALYTE	REF. RANGE
pH	7.4 ± 0.05
PO2	75-100 mmHg (10.0-13.3 kpa)
PCO2	36.0-46.0 mmHg (4.8-6.1 kpa)
*HCO3-	22.0-26.0 mmol/L
O_2 Saturation	95-100 %
Base Excess	± 2.5 (Normal)

The diagnosis of simple acid base disorders involves several steps:



From female slides

Other Acid-Base Disorders

Simple acid-base disorders
(we have already discussed it)

Result from a **single primary** abnormality **with appropriate** physiologic **compensation**.

Mixed acid-base disorders

- Result from multiple primary processes.
- Occurs when a patient has more than one primary acid base disorder that occur at the same time

Examples:

1. Respiratory alkalosis/acidosis along with a metabolic acidosis/alkalosis.
2. Two metabolic acid-base disorders occurring simultaneously.

Clinical example from Guyton: patient with acute HCO3– loss from the gastrointestinal tract because of diarrhea (metabolic acidosis) and emphysema (respiratory acidosis).

From boys slides

Plasma or Extracellular Fluid Factors That Increase or Decrease H+ Secretion and HCO_3^- Reabsorption by the Renal Tubules:

Increased H^+ secretion and HCO_3^- reabsorption	Decreased H^+ secretion and HCO_3^- reabsorption
↑ PCO_2	↓ PCO_2
↑H^+ , ↓HCO_3^-	↓H^+ , ↑HCO_3^-
↓ Extracellular fluid	↑ Extracellular fluid
↑ Angiotensin II	↓ Angiotensin II
↑ Aldosteron	↓ Aldosteron
Hypokalemia	Hyperkalemia

Some drugs (such as antihypertensive) can affect the acid base balance; because of their effect on angiotensin for example. (Acid base balance isn't affected only by PCO2, H+, or HCO3-)

Body's Response to Acidosis
(Titles from slides, info from Guyton)

In respiratory acidosis, the compensatory response is an increase in plasma HCO_3^-, caused by addition of new HCO_3^- to the extracellular fluid by the kidney

In metabolic acidosis, there is also a decrease in pH and a rise in extracellular fluid H+ concentration. However, in this case, the primary abnormality is a decrease in plasma HCO3–. The primary compensations include increased ventilation rate, which reduces PCO2, and renal compensation, which, by adding new HCO3– to the extracellular fluid, helps minimize the initial fall in extracellular HCO3– concentration.

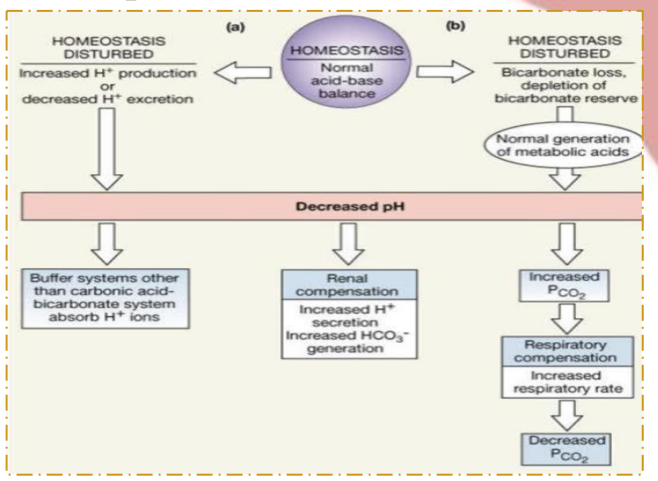
with chronic acidosis, regardless of whether it is respiratory or metabolic, there is an increase in the production of NH4+, which further contributes to the excretion of H+ and the addition of new HCO3– to the extracellular fluid

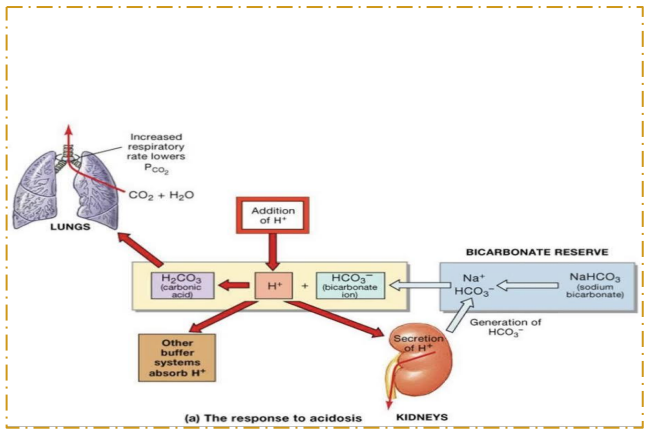
"To acidosis caused by the metabolism of food, there are 3 lines of defense:

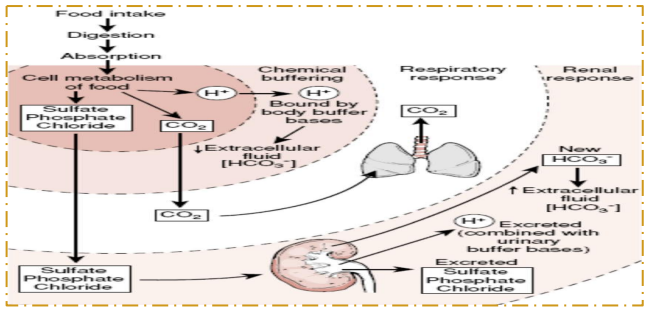
1st: non volatile acids: they are dealt with by the buffer system

2nd: volatile gases are dealt with by the respiratory system

3rd: excessive amounts of non volatile gases are dealt with by the renal system" says doctor.



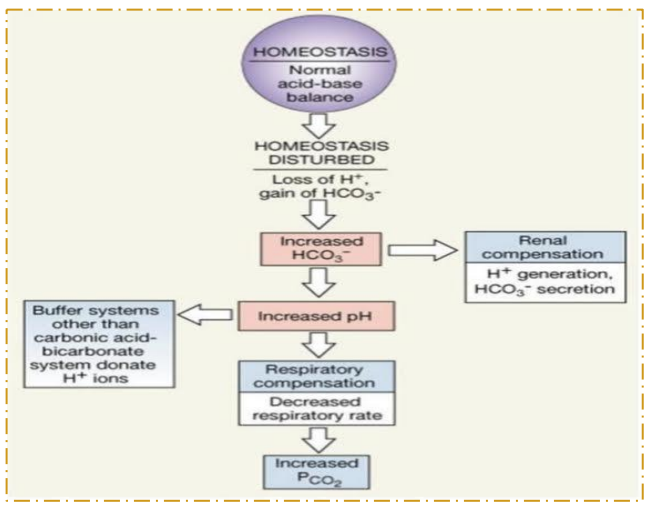


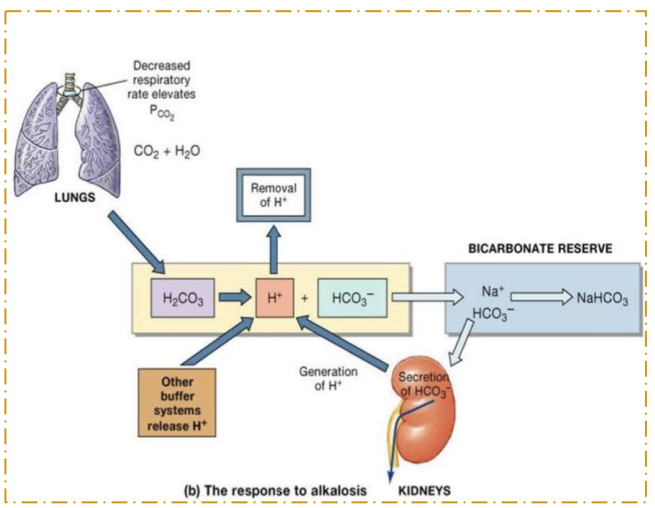


Body's Response to Alkalosis

In respiratory alkalosis the cause of the alkalosis is decreased plasma PCO2, caused by hyperventilation. therefore, the compensatory response to a primary reduction in PCO2 in respiratory alkalosis is a reduction in plasma HCO3– concentration, caused by increased renal excretion of HCO3–.

In metabolic alkalosis, there is also decreased plasma H+ concentration and increased pH. The cause of metabolic alkalosis, however, is a rise in the extracellular fluid HCO3– concentration. This rise is partly compensated for by a reduction in the respiration rate, which increases PCO2 and helps return the extracellular fluid pH toward normal. In addition, increased HCO3– concentration in the extracellular fluid increases the filtered load of HCO3–, which, in turn, causes excess HCO3– over H+ secreted in the renal tubular fluid. The excess HCO3– in the tubular fluid fails to be reabsorbed because there is no H+ to react with, and it is excreted in the urine. In metabolic alkalosis, the primary compensations are decreased ventilation, which raises PCO2, and increased renal HCO3– excretion, which helps compensate for the initial rise in extracellular fluid HCO3– concentration.

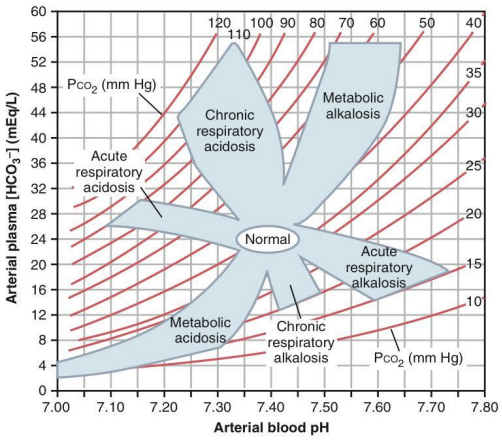




From boys slides

Acid-Base nomograms

(it is one of the objectives, text from Guyton)



A convenient way to diagnose acid-base disorders is to use an acid-base nomogram. ***This diagram can be used to determine the type of acidosis or alkalosis, as well as its severity***. In this acid-base diagram, pH, HCO3– concentration, and PCO2 values intersect according to the Henderson-Hasselbalch equation. The shaded areas of the diagram show the 95 percent confidence limits for the normal compensations to simple metabolic and respiratory disorders. When using this diagram, one must assume that sufficient time has elapsed for a full compensatory response, which is 6 to 12 hours for the ventilatory compensations in primary metabolic disorders and 3 to 5 days for the metabolic compensations in primary respiratory disorders. If a value is within the shaded area, this suggests that there is a simple acid-base disturbance. Conversely, if the values for pH, bicarbonate, or PCO2 lie outside the shaded area, this suggests that the patient may have a mixed acid-base disorder.

It is important to recognize that an acid-base value within the shaded area does not always mean that a simple acid-base disorder is present. With this reservation in mind, the acid-base diagrams can be used as a quick means of determining the specific type and severity of an acid- base disorder.

Anion Gap

The concentrations of anions and cations in plasma must be equal to maintain electrical neutrality. therefore, there is no real "anion gap" in the plasma. However, only certain cations and anions are routinely measured in the clinical laboratory.

The "anion gap" (which is only a diagnostic concept) is the difference between ***unmeasured*** anions and unmeasured cations and is estimated as:

$[Na^+] - ([Cl^-] + [HCO_3^-]) = 8\text{-}12$ mmol/L

High AG metabolic acidosis (MUD PILES)
• Methanol • Uremia • Diabetic ketoacidosis • Paraldehyde • Iron, isoniazid (INH) • Lactic acid • Ethanol, ethylene glycol • Salicylates (Aspirin)
Normal AG metabolic acidosis (USED CARP)
• Ureterostomy • Small bowel fistula • Extra Chloride • Diarrhea • Carbonic anhydrase inhibitors (acetazolamide) • Adrenal insufficiency • Renal tubular acidosis (RTA) • Pancreatic fistula

From female slides

Cases study

How i do analyze this acid-base disorder by doing something called ABG (Arterial Blood Gases)
What do ABG measure ? It measure pH&PCO2&HCO3

questions that help to answer the case:
1- is it acid-base Disturbances or not ?
2- what is the primary acid-base Disturbances? Is it respiratory alkalosis , acidosis or metabolic alkalosis , acidosis
3-Is it Compensated or not ? The kidneys compensate for primary respiratory and lungs compensate for primary metabolic

Steps to solve the case:
1-Look at the pH to determine if it is acidosis or alkalosis
2-Look at CO_2 and HCO_3

primary disorder يكون pH اللي ماشي مع
compensatory or secondary disorder يكون pH اللي عكس

You need to memorize the normal value of pH, PCO_2, and HCO_3^-

Case 1

A patient known to have COPD presented with 3-day history of fever, SOB and cough productive of yellowish sputum. His ABGs showed: ▪ pH = 7.25 ▪ PCO2 = 80 mmHg. ▪ [HCO3 -] = 34 mEq/L

pH^+ ↓(acidosis) PCO_2↑(acidosis) HCO_3↑(alkalosis)

Compensated Respiratory Acidosis

هنا ال PCO_2 ماشي مع الpH

Case 2

A 21 year old man with IDDM presents to ER with mental status changes, nausea, vomiting abdominal pain and rapid respirations. His ABGs showed: ▪ pH = 7.2 ▪ PCO2 = 20 mmHg ▪ [HCO3 -] = 8 mEq/l

pH^+ ↓(acidosis) PCO2↓(alkalosis) HCO_3↓(acidosis)

Compensated Metabolic Acidosis

هنا ال HCO_3ماشي مع الpH

Case 3

A 2-year old child who is lethargic and dehydrated has a 3-day history of vomiting.
His ABGs showed: ▪ pH = 7.56 ▪ PCO2 = 44 mmHg ▪ [HCO3 -] = 37 mEq/l

pH^+ ↑(alkalosis) PCO2 Normal , HCO_3↑(alkalosis)

Uncompensated Metabolic Alkalosis

هنا ال HCO_3ماشي مع الpH

Case 4

A 20-year old student suffered a panic attack while awaiting an exam.
Her ABGs showed: ▪pH = 7.6 ▪ PCO2 = 24 mmHg. ▪ [HCO3 -] = 23 mEq/L.

pH^+ ↑ (alkalosis) PCO2↓(alkalosis) HCO_3 Normal

Uncompensated Respiratory Alkalosis

هنا ال PCO_2 ماشي مع الpH

Case 5

A 69 year old patient known to have COPD presented with a 3-day history of abdominal pain and diarrhea. His ABGs showed; ▪ pH = 6.96 ▪ PCO2 = 55mmHg ▪ [HCO3 -] = 12 mmol/L

pH^+ ↓(acidosis) PCO2↑(acidosis) HCO_3↓(acidosis)

Mixed Disorder, (Respiratory +Metabolic) Acidosis

هنا ال PCO_2و HCO_3 كلهم ماشين مع الpH يعني تكون mixed

When you diagnosis don't look to the numbers only
Always link the result with case

Summary

- Explain the principle of blood gas and acid base analysis
- A sample taken from arterial blood is analyzed by special machine, by which; we can determine all the arterial blood parameters and make diagnosis
- Interpret blood gas analysis and diagnose various acid base disorders?
- By knowing the normal values of ABG and comparing it to the patient's values, we can confirm our diagnosis, like hypoxia, acidosis, and alkalosis. Acid-Base disorders can be diagnosed by knowing the concentration of bicarbonate, pH, and PCO2. + see slide 5
- Describe the causes of acid base disorders .
- Plenty. See slide No. 3
- what is the use of acid base nomograms ?
- It can be used to determine the type of acidosis or alkalosis, as well as it's severity

MCQ & SAQ

Q1: A 55 years old man was brought to the ER with muscle twitching, tremors, and confusion. ABG analysis confirmed that the patient is alkalotic. Which of the following is most probably the value of HCO3- in his blood:

A. 21 mmol/L
B. 24 mmol/L
C. 26.5 mmol/L
D. 29 mmol/L

Q2: In uncompensated respiratory alkalosis; CO2 level is:

A. Normal
B. Elevated
C. Decreased
D. None of these

Q3: In compensated respiratory acidosis; pH is:

A. Decreased
B. Elevated
C. Normal
D. Slightly decreased

Q4: Which of the following conditions will cause low PCO2 alkalosis:
A. COPD
B. Diabetic ketoacidosis
C. Vomiting
D. Pregnancy

Q5: Based on the following pH=7.5, HCO3-= 40, PCO2=55, what is the diagnosis:
A. Metabolic acidosis
B. Metabolic alkalosis
C. Respiratory acidosis
D. Respiratory alkalosis

Q6: A diabetic patient with COPD had the following, what is your diagnosis:
A. Mixed alkalosis
B. Mixed acidosis
C. Compensatory respiratory acidosis
D. Compensatory respiratory alkalosis

answer key:
1: D
2: C
3: D
4: D
5: B
6: B

1- list 2 examples for mixed acid base disorders

2- Talk about the body's response to acidosis caused by the ingestion of acidic food

3- What happens in Respiratory Acidosis & Metabolic Alkalosis?

4- what is the normal range of arterial blood PH ?

A1: Respiratory alkalosis/acidosis along with a metabolic acidosis/alkalosis, Two metabolic acid-base disorders occurring simultaneously.

A2::1- buffer system for nonvolatile acids 2- respiratory excretion for volatile acids 3- renal excretion for excessive amounts of nonvolatile acids.

A3: In Respiratory Acidosis↑↑ PCO2 while in metabolic alkalosis↑↑ HCO3

A4: It is between 7.35-7.45

Team Leaders

Albandari Alanazi **Abdulaziz Alsuhaim**

Team Sub-Leaders

Sara Alharbi **Fahad Al-Ajmi**

Organized and reviewed by:

- **Mohammed Beyari**

Members:

- **Omar Alhalabi**
- **Yara Alasmari**

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