ACID-BASE DISORDERS MADE SO EASY
EVEN A CAVEMAN CAN DO IT

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I. LEARNING OBJECTIVES

The clinician after participating in the roundtable will be able to:

1) Indicate whether the pH level indicates acidosis or alkalosis.
2) State whether the cause of the pH imbalance is respiratory or metabolic.
3) Identify if there is any compensation for the acid-base imbalance.

II. INTRODUCTION

Acid-Base balance is an intricate concept which requires an intimate and detailed knowledge of the body's metabolic pathways used to eliminate the H^+ ion. Clinicians may find it daunting to understand when first introduced to the subject. This roundtable session will demonstrate how to analyze blood gas levels in a very elementary manner so as to diagnose any acid-base disorder in a matter of minutes.

The body is in a constant state of flux delicately stabilizing the pH so as to maintain its normalcy. In order to prevent untoward effects of alkalosis or acidosis the body has three major buffering systems that it uses to adjust the pH. They are:

1) Plasma protein ($Prot^-$)
2) Plasma hemoglobin (Hb^-)
3) Bicarbonate ($HCO3^-$)

The Bicarbonate-Carbonic acid system is the most dominate buffering system and controls the majority of the hydrogen ion (H^+) equilibrium. Maintaining homeostasis when these acid-base shifts occur is vital to survival. Metabolic and respiratory processes work in unison to keep the H^+ normal and static.

II. ACID-BASE ABNORMALITIES

The four principal acid-base imbalances are illustrated in Table 1. as well as possible causes for each condition. The H^+ ion concentration is reflected in the serum pH value. Normal pH levels range from 7.35 to 7.45 and are slightly alkaline. Elevated levels indicate alkalosis (decreased H^+ ion concentration) caused by excess alkaline agents or a reduced amount of acidic components while lowered values reflect acidosis (increased H^+ ion concentration) resulting from excessive acidic substances or a lessened quantity of alkaline elements.

TABLE 1. ACID-BASE DISORDER ETIOLOGIES

METABOLIC ACIDOSIS

Excess Production of Organic Acids
1) Ketoacidosis
   - a. Uncontrolled Diabetes Mellitus
   - b. Alcoholic
   - c. Starvation
   - d. Reduced CHO Intake
   - e. Violent Convulsions
   - f. Extreme and/or Prolonged Exercise
   - g. Prolonged Exposure to Severe Cold
2) Lactic acidosis
   - a. Severe Hypoxemia
   - b. Underutilization of Lactic Acid

Excessive Ingestion of Exogenous Toxins
1) Aspirin
2) Methanol Alcohol
3) Ethylene Glycol Antifreeze
4) toluene

Excess Loss of HCO3-
1) Diarrhea
2) Intestinal or Biliary Intubation
3) Addison's Disease
4) Pancreatic, Biliary or Intestinal Fistula

Retention of Organic Acis
   Renal Insufficiency of Any Cause

Carbonic Anyhydrase Inhibitors
1) Diuretics
2) Azides, Sulfides, Cyanide Acetazolamide

Hyperchloremic Acidosis (Normal Anion Gap)
High Anion Gap Acidosis (Normal Cl- Level)

METABOLIC ALKALOSIS

HCl Loss
1) Stomach
   - a. Vomiting
   - b. Nasogastric Suctioning
2) Intestinal Fistulae

Excessive Administration of HCO3-
(or Prescursors: Lactate, Acetate, Citrate)
1) Oral
2) PN with Excessive Acetate
3) Bicarbonate Therapy in Metabolic Acidosis
4) Ringer's Lactate or Citrated Blood
5) Milk-Alkali Syndrome

Hypokalemia

Rapid Contraction of Extracellular Volume
(Hypovolemia)
1) Loop Diuretics (Furosemide)
2) Thiazide Diuretics (Hydrochlorothiazide)
3) Dehydration

Increased Renal Excretion of Acid
1) Diuretic Therapy
2) Exogenous Mineralocorticoids
3) Hyperaldosteronism
4) K+ Depletion
5) High pCO2
6) Secondary Hypoparathyroidism

RESPIRATORY ACIDOSIS

Airway Obstruction
1) Emesis with Aspiration
2) Bronchospasm
3) Larygngospasm
4) COPD

Respiratory Center Depression
1) General Anesthesia
2) Sedative or Narcotic Overdose
3) head Injury
4) Obesity (Pickwickian Syndrome)
5) Brain Tumor

Circulatory Collapse
1) Cardiac Arrest
2) Pulmonary Edema

Neurogenic Causes
1) Cervical Spine Injury
2) Guillain-Barre Syndrome
3) Myasthenic Crisis
4) Drugs (Paralytic Agents, Organophosphates)
5) Multiple Sclerosis
6) Muscular Dystrophy
7) Amyotrophic Lateral Scleosis
8) Myxedema
9) Post-traumatic Diaphragmatic Paralysis
10) Phrenic Nerve Injury

Restrictive Effects
1) Hemothroax/Pneumothorax
2) ARDS
3) Hydrothorax
4) Ascites
5) Obesity

RESPIRATORY ALKALOSIS

Lack of O2/Hypoxia: Living at High Altitudes

Lung Disease
1) Pneumonia
2) Pulmonary Embolism

CNS - Respiratory Stimulation
1) Cerebral Vascular Accident (Stroke)
2) Fever
3) Liver Disease
4) Anxiety-Hyperventilation Syndrome
5) Pregnancy
6) Drugs and Toxins
   - a. Progesterone Derivatives
   - b. Salicylate Intoxication
7) Hyperthyroidism
8) Delerium Tremors

Congestive Heart Failure
Hepatic Insufficiency
Sepsis
Mechanical Ventilation
Peritonitis

More specifically, with regards to the respiratory system, CO_2 levels affect the pH. The carbon dioxide is referred to as an acid due to the fact that it combines with water in the blood to form carbonic acid. Blood gas levels of $PaCO_2$, the partial pressure of CO_2, are normal when the levels range between 35 to 45 mmHg. Increased levels noted in respiratory acidosis i.e., COPD cause the pH to drop whereas elevated levels produce a respiratory alkalosis as seen in hyperventilation.

Metabolically, the alkaline constituent in HCO_3^- or bicarbonate, bonds with available H^+ to balance its concentration. Normal HCO_3^- ranges are 22-26 mmHG. Hyperalkinemia as evidenced in vomiting causes the pH to rise in a metabolic alkalosis state. Conversely, a metabolic acidosis creates a pH below acceptable ranges in renal patients.

ACID-BASE NORMAL VALUES			
	ACID	**NORMAL**	**ALKALINE**
pH	< 7.35	7.35 – 7.45	> 7.45
pCO_2	> 45	35 – 45	< 35
HCO_3^-	< 22	22 – 26	> 26

III. DETERMINING ACID-BASE IMBALANCES FROM ABGs (Arterial Blood Gases) USING THE TIC-TAC-TAC GRID

Sorting of the pH, pCO_2, and HCO_3^- in a generic chart similar to that of a tic-tac-toe game can easily decipher what kind of condition exists, if its origin is respiratory or metabolic, and if any compensation from either system has occurred.

A primer for using the Tic-Tac-Toe method to determine acid-base balances:

- The column that the pH is in tells whether the patient has acidosis or alkalosis.
- The position of the pCO_2, and HCO_3^- reveals the origin of any acid-base balance.
- If the pH and the HCO_3^- fall in the same column, the problem is metabolic.
- If the pH and the pCO_2 fall in the same column – other than normal – the problem is respiratory.
- If the parameter that is NOT associated with the pH is normal, then there has been no metabolic compensation and vice versa.
- If the parameter that is NOT associated with the pH is abnormal and falls in the category opposite of the existing acidosis or

A. UNCOMPENSATED METABOLIC ACIDOSIS

CASE STUDY:

Ms Doe, a 75 year old diabetic, has a long history of non-compliance with her insulin. She was recently admitted to the hospital with the following ABG results:

pH	**7.26**
PCO_2	**42**
$HCO3^-$	**17**

Step I. Refer to the chart above listing the normals for pH. Since the pH falls within the acid range, place the acronym ‘pH’ into the Acid column as shown below:

ACID	NORMAL	ALKALINE
pH		

Step II. Again, referring to the chart of normals, the pCO_2 is found to be in the normal range and is placed under the NORMAL column below:

ACID	NORMAL	ALKALINE
pH	pCO_2	

Step III. The HCO_3^- value is acidic so it is placed in the ACID column.

ACID	NORMAL	ALKALINE
pH	pCO_2	
HCO_3^-		

DISCUSSION:

- Since the pH and the HCO_3^- both fall under the ACID column (three in a row), Ms Doe has Metabolic Acidosis.
- The pCO_2 is normal designating that no respiratory compensation has occurred. Thus Ms Doe has Uncompensated Metabolic Acidosis.

B. METABOLIC ACIDOSIS WITH PARTIAL COMPENSATION

If Ms Doe presented with the following ABGs

pH	**7.26**
PCO_2	**32**
HCO_3^-	**17**

then her tic-tac-toe grid would appear as below:

ACID	NORMAL	ALKALINE
pH		pCO_2
HCO_3^-		

DISCUSSION:

- Because the pCO_2 was alkaline instead of normal, it is placed under the ALKALINE column.
- This reflects that the respiratory system (pCO_2) has begun to compensate for the metabolic acidosis (HCO_3^-) with a resulting respiratory alkalosis.
- Therefore, with these values, Ms Doe's diagnosis is now a Metabolic Acidosis with Partial Compensation.

C. METABOLIC ACIDOSIS WITH COMPLETE COMPENSATION

If Ms Doe presented with the following ABGs

pH	**7.35**
PCO_2	**32**
HCO_3^-	**17**

then her graph would appear as below:

ACID	NORMAL	ALKALINE
pH-ADJ	pH-WNL	pCO_2
HCO_3^-		

DISCUSSION:

- First, her normal pH will be designated pH-WNL and placed in the NORMAL column.
- Secondly, to determine her diagnosis, the origin of the normal pH needs to be determined. To accomplish this, find the median value of the normal pH range of 7.35 – 7.45; which is 7.4. Since Ms Doe's value is less than 7.4 and therefore acidic, this value is named pH-ADJ (Adjusted) and placed in the ACID column.
- The pH-ADJ and the HCO_3^- are both in the ACID column indicating a Metabolic Acidosis.
- The pCO_2 is Alkaline showing partial Respiratory Compensation. However, since the actual pH (designated as pH-WNL) is normal, the diagnosis is Metabolic Acidosis with Complete (Respiratory) Compensation.

D. CONCLUSION

During the Focused Learning Session the basic types of acidosis and alkalosis scenarios will be shown in the method described above. The clinician, by the end of the roundtable, will be able to analyze ABGs with ease and label what type of acid-base disturbance is present. This ability will further help clinicians grasp the acid-base concept and therefore, improve the quality of care given to their patients.

E. REFERENCES

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