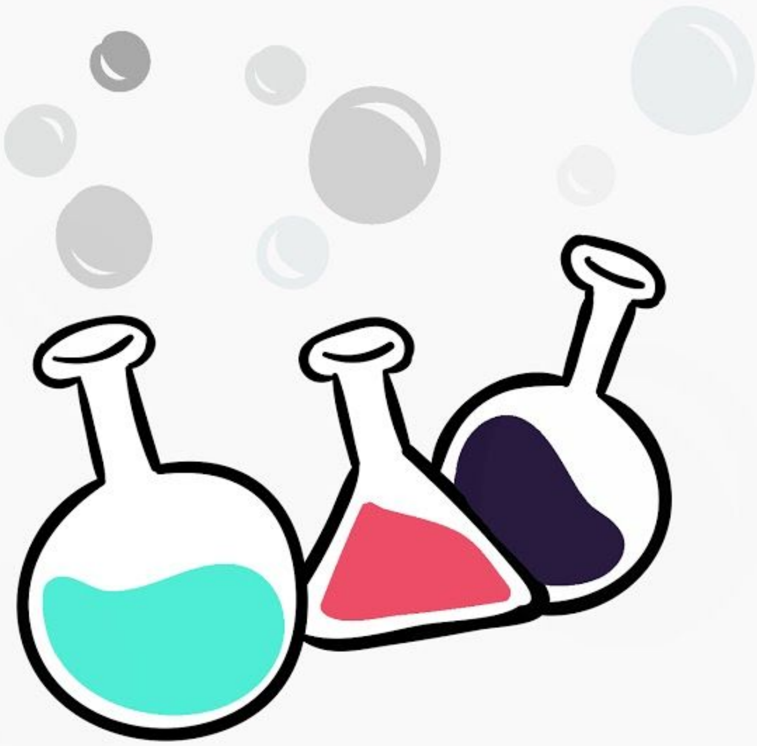

Acid Base Disorders

Objectives:

- To provide a simple, systematic approach to interpreting arterial blood gas (ABG) samples..

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[Color index : Important | Notes | Extra | Editing file]

Note: there won't be calculations in the exam so focus more on the theory part. SUMMARY

Acid Base Disorders

- Getting in the routine of performing these steps on each patient in which an ABG and electrolytes are performed will help decrease the rate of missed complex acid-base disturbances and hopefully improve patient care.

Five Steps of Acid-Base Analysis 1-5 (Understand the steps memorise none)

-Step 1: Acidemia (pH <7.38) or alkalemia (pH >7.42)

Acidosis is the process that induce academia, alkalosis is the process that induce alkalemia

Can a patient have acidosis without acidemia, how ?

yes. when the patient has a mix acid-base disorder he can present with normal pH and still has acidosis, and here the cause of normal PH is not compensation but the mix acid-base disorder so you can't trust the numbers, and follow the steps. compensation can make PH normal only in one case: **chronic respiratory alkalosis**

-Step 2: **Primary** respiratory or metabolic disturbance? Look at PCO2 and pH.

-If pH and PCO2 going in same direction (both increase or decrease) = Metabolic

-If pH and PCO2 not going in same direction = Respiratory

-Step 3: Is there appropriate compensation for the primary disorder?

-Metabolic acidosis: $PCO_2=[1.5 \times (\text{serum } HCO_3)] + 8\ (\pm 2)$

Winter's formula/expected PCO2:

calculated PCO2 = the patient PCO2 → appropriate response (compensation)

calculated PCO2 ↓ than the patient PCO2 → respiratory acidosis

calculated PCO2 ↑than the patient PCO2 → respiratory alkalosis

-Metabolic alkalosis: $\uparrow PCO_2 = 0.6 \times \uparrow HCO_3\ (\pm 2)$

-Respiratory acidosis: $\uparrow PCO_2$ 10, $\uparrow HCO_3$ by 1 (acute) or 4 (chronic)

-Respiratory alkalosis: $\downarrow PCO_2$ 10, $\downarrow HCO_3$ by 2 (acute) or 5 (chronic)

-Step 4: Is there an anion gap metabolic acidosis (AGMA)?

$AG = Na - (HCO_3 + Cl)$. If > 12, an AGMA is present (AKA high anion gap).

you do step 4 for all types, not only metabolic acidosis, because there might be metabolic acidosis blunted by a stronger disturbance

-Step 5: If metabolic acidosis, is there another concomitant metabolic disturbance?

If AGMA, then calculate $\Delta Gap = \Delta AG - \Delta HCO_3 = (AG - 12) - (24 - HCO_3)$

-If the ΔGap is > 6, there is a combined AGMA and metabolic alkalosis.

-If the ΔGap is < -6, there is a combined AGMA and NAGMA.

- If between -6 and 6, there is only AGMA

If NAGMA, for every 1 mEq/L ↑ Cl, there should be a 1 mEq/L ↓ HCO3 (+ 5).

-If HCO3 decrease is less than predicted, then NAGMA and metabolic alkalosis.

Metabolic Acidosis

-In the presence of a pH < 7.38, metabolic acidosis is diagnosed as a primary condition when the pCO_2 is < 40 mmHg or the bicarbonate is < 24 mEq/L.

-Metabolic acidosis can be further classified based on the presence of an anion gap. The anion gap reflects the balance between positively and negatively charged particles in the blood.

-Sodium is the only significant positively charged particle that is measured, while the measured anions are chloride and bicarbonate.Therefore, the anion gap is calculated by the formula: Na – (Cl + HCO_3).

k isn't used in the formula, if used the normal AG value is 20 instead of 12

-One potential pitfall in the measurement of the anion gap is patients with low albumin.

-Albumin has several negative charges on it and therefore, in a patient with a low albumin level, their "normal" anion gap might be much lower than 12.

-For every 1 gram drop in serum albumin level, the anion gap decreases by 2.5.

-A patient with a calculated anion gap of 10 and a 2 gram drop in their albumin may actually have an anion gap metabolic acidosis(recalculated AG 15).

- Detection of an AGMA is important because only a few conditions commonly cause it.

-In addition, in mixed acid-base disorders, an elevation in the anion gap may be the only signal that a metabolic acidosis is present.

-The causes of an AGMA are divided into four main categories:

- renal failure.
- ketoacidosis.
- lactic acidosis.
- toxins. toxic alcohols : Ethylene glycol, methanol.

Metabolic acidosis causes:

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-Analgesics (massive NSAID such as ASPIRIN , acetaminophen). Aspirin causes both metabolic acidosis (AGMA) and respiratory alkalosis, except in children, there respiratory center isn't well developed yet so they present with only AGMA.

-Cyanide, Carbon monoxide

-Arsenic, Alcoholic ketoacidosis.

-Toluene

- Methanol, Metformin

-Uremia

- Diabetic ketoacidosis

-Paraldehyde, Phenformin

-Iron, Isoniazid

-Lactic acidosis

-Ethylene glycol

In any patient with an AGMA, calculate an osmol gap:

-Osmol gaps are a clue to a potentially life-threatening toxic alcohol ingestion (ie. ethylene glycol and methanol).

-The osmol gap is determined by subtracting the calculated osmolality from the measured osmolality.

Calculated osmolality = 2(Na) + Glc/18 + BUN/2.4 + **ETOH/4.6**

2 Na + Glucose + Urea (all in mmol/L). if more than 10 > high osmolar gap

Example:

-32 year old man with depression and alcohol abuse presents with altered mental status.

-ABG: pH 6.9, pCO2 29, pO2 100

-Metabolic panel: Na 140, Cl 101, HCO3 5

-Step 1: Acidosis

-Step 2: Metabolic

-Step 3: pCO2 = 1.5(HCO3) + 8 = 15, but the patient's pCO2 is higher than 15. Therefore, a respiratory acidosis is also present, possibly secondary to CNS depression.

-Step 4: AG = 140 − (101 + 5) = 34 > AGMA

-Step 5: Delta gap = (34-12) − (24-5) = 3. between 6 and -6 just AGMA No additional metabolic disorders other than AGMA.

-**Answer: Anion gap metabolic acidosis and respiratory acidosis. The patient had an osmol gap of 174 and a methanol level of 510 mg/dL.**

Non-Anion Gap Metabolic Acidosis (NAGMA)

-A NAGMA is due to either GI or renal losses of bicarbonate.

-If desired, GI mediated and renally mediated losses can be distinguished by obtaining urine electrolytes (ie. Na, K, and Cl) and calculating the urine anion gap.

-The urine anion gap : Na + K - Cl

-The urine anion gap is the difference between the spot urine positive ions and spot urine negative ions.

-If an excess of negatively charged ions is present, the acidemia is due to the kidney

-**Causes : renal tubular acidosis, Vesicoenteric fistulas, Diarrhea**

Example:

-A 68 year old man who recently took antibiotics for a skin infection presents with 10 episodes of watery diarrhea per day for the last 5 days.

-ABG: pH 7.34, pCO2 34, pO2 80

-Metabolic panel: Na 135, Cl 108, HCO3 18

-Step 1: Acidosis

-Step 2: Metabolic

-Step 3: pCO2 = 1.5(HCO3) + 8 = 35 > matches the patient pco2 (±2) > no other respiratory disorder

-Step 4: AG = 135 − (108 + 18) = 9 > NAGMA

-Step 5: Cl ↑ by 8 and HCO3 ↓ by 6; therefore there is no metabolic alkalosis.

-**Answer: NAGMA due to diarrhea**

Respiratory acidosis

-Respiratory acidosis is characterized by an elevation in the pCO_2 and a decrease in blood pH due most commonly to hypoventilation.
-It results from conditions that decrease the ability of the lungs to excrete carbon dioxide at a rate to keep up with the body's production.
-The kidney compensates for primary respiratory acidosis by retaining bicarbonate.
-This compensation occurs over hours to days and is generally at a maximum within four days.
-The rate of onset of respiratory acidosis can be determined by the degree of renal compensation (increase in HCO_3) as listed above in step 3.
-Alternatively, the chronicity of the respiratory acidosis can be predicted by the change in the pH:

- In **acute** respiratory acidosis, the **pH decreases by 0.08 units** for each increase of 10 mmHg in the pCO_2 from its baseline of 40 mmHg.
- **Chronic** respiratory acidosis is marked by a **decrease in the pH of 0.03 units** for every increase of 10 mmHg in the pCO_2.
- Acute on top of chronic

-Differentiating acute from chronic respiratory conditions can have important clinical implications that may alert the clinician to a patient that is rapidly spiraling downward and might require emergent intubation, from a patient who has chronic disease, but is in less danger of imminent decompensation
examples of chronic respiratory acidosis are smoking and COPD > no need for urgent Rx

Differential diagnosis includes:

-Central nervous system depression (sedatives, CNS disease, sleep apnea)
-Pleural disease (large pneumothorax or pleural effusion)
-Lung disease (ARDS, COPD, pulmonary edema, severe pneumonia)
-Acute airway obstruction (laryngospasm, sleep apnea)
-Neuromuscular disorders (GBS, myasthenia gravis, botulism)
-Thoracic cage injury (flail chest)
-Ventilator dysfunction

Example:
-A 70 year-old smoker presents with an acute onset of shortness of breath.
-ABG: pH 7.30, pCO_2 = 60 mmHg, pO_2 60 mmHg
-Metabolic panel: Na 135, Cl 100, HCO_3 30
-Step 1: Acidosis
-Step 2: Respiratory
-Step 3: Acute on chronic. pCO_2 increased by 20, therefore the HCO_3 should increase by 2 if acute and 8 if chronic. Because the HCO_3 increased from 24 to 30 (6), an acute on chronic respiratory acidosis is present.
-Step 4: AG = 135-(100+26) = 9. No anion gap metabolic acidosis
-Step 5: XX
-Answer: Acute on chronic respiratory acidosis due to COPD exacerbation.

Metabolic alkalosis

Metabolic alkalosis is characterized by an increase in the serum bicarbonate concentration.

The causes of metabolic alkalosis:

-Volume contraction (vomiting, NG suction, loop or thiazide diuretics).

-Excess glucocorticoids or mineralocorticoids (eg, Cushing's syndrome).

-Hypokalemia

-Bartter's syndrome.

-Alkali ingestion/infusion.

-Post-hypercapnic alkalosis

To differentiate the most common cause of metabolic alkalosis which is volume depletion from other causes you need to measure urine chloride.

- If urine chloride less than 10 this due to volume depletion (saline response)
- If urine chloride more than 10 this due to other causes (saline resistance)

Example:

-A 20 year old student presents with excessive vomiting after binge drinking.

-ABG: pH 7.50, pCO2 44, pO2 100

-Metabolic panel: Na 138, Cl 100, HCO3 30

-Step 1: Alkalosis

-Step 2: Metabolic both ph and pco2 high - metabolic

-Step 3: Increase in pCO2 should equal 0.6 multiplied by the elevation of the HCO3 ±2. The increase of the pCO2 of 4 is within two of 6(0.6) or 3.6; therefore there is appropriate compensation.

-Step 4: AG = 138 – (100 + 30) = 8 here we stop, only metabolic alkalosis cause we have normal AG

-Step 5: XX

-Answer: Metabolic alkalosis secondary to vomiting

Respiratory alkalosis

-Respiratory alkalosis is characterized by a decrease in the pCO2 and an elevation in the blood pH.

-The pO2 can be used to distinguish between disease of the lungs and other causes of hyperpnea (eg, fever)

Causes of a primary respiratory alkalosis :

-CNS disease (CVA)

- Toxins (Salicylates)

-High altitude

-Severe anemia

-Pregnancy

-Lung disease/hypoxia (asthma, pneumonia, PE, pulmonary edema, pulmonary fibrosis)

-Anxiety

- Cirrhosis of the liver

- Fever (Sepsis)

- Ventilator dysfunction

Example:

-A 22 year-old woman presents with 4 hours of numbness in both hands. typical of previous episodes of anxiety.

-ABG: pH 7.48, pCO2 30 mmHg, pO2 86 mmHg

-Metabolic panel: Na 140, Cl 110, HCO3 22

-Step 1: Alkalosis

-Step 2: Respiratory

-Step 3: Acute. Drop in the pCO2 by 10 corresponds to a drop in the HCO3 by 2 if acute and 5 if chronic. 24-22 = 2 and therefore, as would be expected by the clinical history, an acute disorder is diagnosed.

-Step 4: AG 140-(110+22) = 8

-Step 5: XX

-Answer: Acute respiratory alkalosis secondary to a panic attack

Practice Cases

CASE 1

-A diabetic presents with diarrhea and cough. CXR reveals an infiltrate.

-pH 7.31; pCO2 10

-Na 123; Cl 99; HCO3 5

ANS: Primary AGMA (DKA), respiratory alkalosis (pneumonia), NAGMA (diarrhea)

CASE 2

-An alcoholic presents with vomiting.

-pH 7.20; pCO2 25

-Na 130; Cl 80; HCO3 10

ANS: Primary AGMA (alcoholic ketoacidosis), metabolic alkalosis (vomiting)

CASE 3

-A man with arthritis presents with confusion, shortness of breath, and diaphoresis.

-pH 7.30; pCO2 18

-Na 147; Cl 108; HCO3 16

ANS: Primary AGMA and respiratory alkalosis (Salicylate toxicity—107 mg/dl)

CASE 4

-A patient with COPD presents with shortness of breath.

-pH 7.18; pCO2 80

-Na 135; Cl 93; HCO3 30

ANS: Primary respiratory acidosis—acute-on-chronic (COPD exacerbation)

CASE 5

-A woman with Crohn's disease presents with fever, vomiting, and diarrhea.

-pH 7.36; pCO2 22

-Na 147; Cl 121; HCO3 14

ANS: Primary NAGMA (diarrhea), respiratory alkalosis (fever), metabolic alkalosis (vomiting)

CASE 6

-A noncompliant patient with diabetes and cirrhosis presents with vomiting.

-pH 7.46; pCO2 17

-Na 133; Cl 84; HCO3 15

ANS:Primary chronic respiratory alkalosis (cirrhosis), AGMA (DKA), metabolic alkalosis

CASE 1:

step 1 : acidosis low PH

step 2 : metabolic why ? both PH and Pco2 ↓

step 3 : (1.5 x 5) + 8 = 15.5 (respiratory alkalosis) the patient's pCO2 is lower than 15.5 Therefore, a respiratory alkalosis

step 4 : AG = 123 - (99+5) = 19 (AGMA) more than 12

step 5 : (19-12) - (24-5) = -12 (AGMA + NAGMA) If the ΔGap is < -6, there is a combined AGMA and NAGMA.

CASE 2:

step 1 : acidosis low PH

step 2 : metabolic both PH and Pco2 ↓

step 3 : (1.5 x 10) + 8 = 23 there is appropriate compensation.

step 4 : AG = 130 - (80+10)= 40 (AGMA) more than 12

step 5 : (40-12) - (24-10) = 8 If the ΔGap is > 6, there is a combined AGMA and metabolic alkalosis.

CASE 3:

step 1 : acidosis low PH

step 2 : metabolic both PH and Pco2 ↓

step 3 : (1.5 x 16) + 8 = 32 (respiratory alkalosis) the patient's pCO2 is lower than 32 Therefore, a respiratory alkalosis

step 4 : AG = 147 - (108 + 16) = 23 (AGMA) more than 12

step 5 : (23-12) - (24-16) = -1 between 6 and -6 no more acid-base disorder

CASE 4:

step 1 : acidosis low PH

step 2 : respiratory. why ? PH low and Pco2 high

step 3 : Pco2 80 and Hco3 30. ↑ PCO2 10, ↑ HCO3 by 1 (acute) or 4 (chronic) . the patient is acute on chronic

step 4 : AG = 135 - (93 + 30) = 12 NAGMA

CASE 5:

step 1 : acidosis low PH

step 2 : metabolic both PH and Pco2 ↓

step 3 : (1.5 x 14) +8 = 29 (respiratory alkalosis) the patient's pCO2 is lower than 29 Therefore, a respiratory alkalosis.

step 4 : AG = 147 - (121 + 14) = 12 NAGMA

step 5 : If NAGMA, for every 1 mEq/L ↑ Cl, there should be a 1 mEq/L ↓ HCO3 (±5).

If HCO3 decrease is less than predicted, then NAGMA and metabolic alkalosis.

CASE 6:

step 1 : alkalosis high PH

step 2 : respiratory PH high and Pco2 low

step 3 : Pco2 17 Hco3 15 (chronic)

step 4 : AG = 133 - (84 + 15) = 34 (AGMA) more than 12

step 5 : (34 - 12) - (24 - 15) = 13 (AGMA - metabolic alkalosis) more that 6.

SUMMARY of most important causes of acid-base disturbance:

	Acidosis		Alkalosis
Metabolic	AGMA: - Renal failure. - Ketoacidosis (diabetic/ alcoholic: methanol & ethylene glycol) - Lactic acidosis - Aspirin - Sepsis	NAGMA: - renal tubular acidosis, - Vesicoenteric fistulas, - Diarrhea	Metabolic Alkalosis: - vomiting
Respiratory	Respiratory acidosis: - Hypoventilation - Chronic = smoking or COPD - Acute on chronic = COPD exacerbation		Respiratory Alkalosis: - Acute = Hyperventilation e.g. Panic attack, fever (sepsis) - Chronic = cirrhosis - Aspirin