Team Medicine

Acid-Base Balance

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Introduction:

- Normal values that you must be familiar with:

pH= 7.35 - 7.45	pCO2= 35 - 45	Serum HCO3= 22 - 26	Anion gap= 8 - 16

- Primary disorders:

Primary disorder	Problem	pH	HCO3	PaCO2
Metabolic acidosis	Gain of H+ or loss of HCO3	↓	↓	↓
Metabolic alkalosis	Gain of HCO3 or loss of H+	↑	↑	↑
Respiratory acidosis	Hypoventilation	↓	↑	↑
Respiratory alkalosis	Hyperventilation	↑	↓	↓

1- Respiratory Alkalosis:

- Primary mechanism: Hyperventilation (if you try to hyperventilate now, you will feel dizzy and you might feel numbness, treatment for it, so simple, is to breath in a bag so that you inhale back the CO2)
- Causes includes:
  - Pain
  - Drugs
  - Sepsis
  - Fever
  - Thyrotoxicosis
  - Pregnancy
  - Overaggressive mechanical ventilation
  - Hepatic failure
  - Anxiety
  - Hypoxemia
  - Restrictive lung disease
  - Severe congestive heart failure
  - Pulmonary emboli (hypoxia > hyperventilation)
  - Bronchial asthma at the beginning (hyperventilation)

2- Respiratory Acidosis

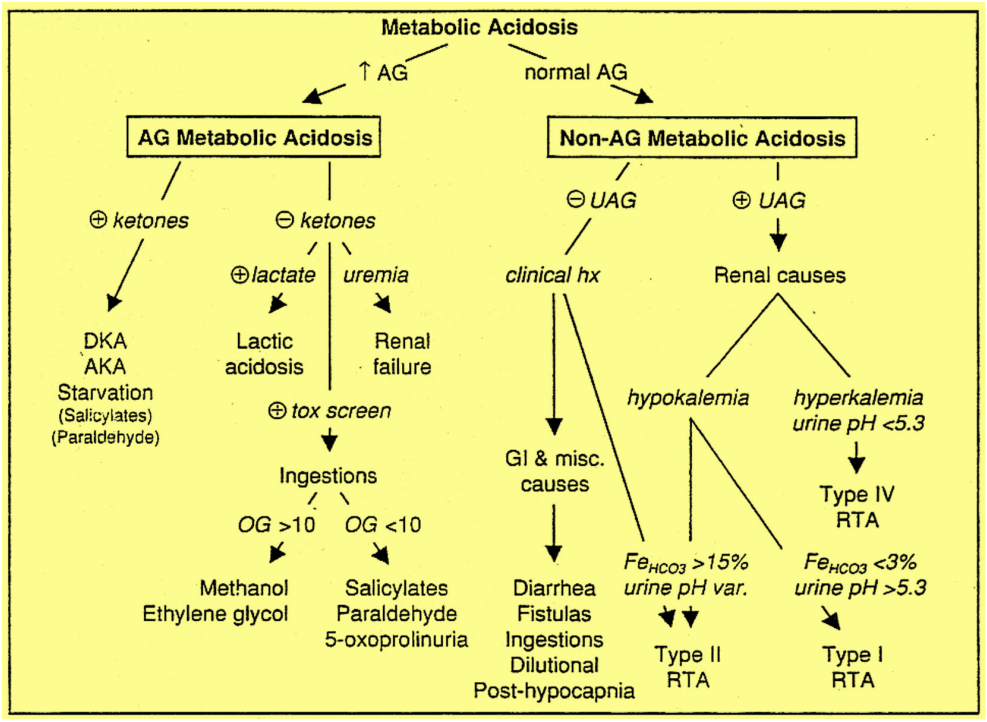
- Primary mechanism: Hypoventilation
- Causes, by location:
  - CNS. Respiratory center damage: Injury to brainstem, Trauma, Stroke, drugs, Hemorrhage...
  - Peripheral nerve. Guillain-Barré Syndrome
  - Neuromuscular junction. Mysthenia Gravis
  - Chest wall. Muscle Dystrophy, deformities
  - Bronchial tree. COPD

Acute respiratory acidosis	Chronic respiratory acidosis

• Respiratory pathophysiology
  ○ Airway obstruction
  ○ Severe pneumonia
  ○ Chest trauma
  ○ Pneumothorax
• Acute drug intoxication (narcotics, sedatives)
• Residual neuromuscular blockade
• CNS disease (head trauma)
	• Chronic lung disease (COPD)
	• Neuromuscular disease
	• Extreme obesity
	• Chest wall deformity
	- In chronic case: paCO2 is high and PH is in the acceptable range.
	
	-Renal mechanisms increase the excretion of H+ within 24 hours and may correct the resulting acidosis caused by chronic retention of CO2 to a certain extent
	(there is compensation through retaining HCO3 by the kidneys)

3- Metabolic Acidosis

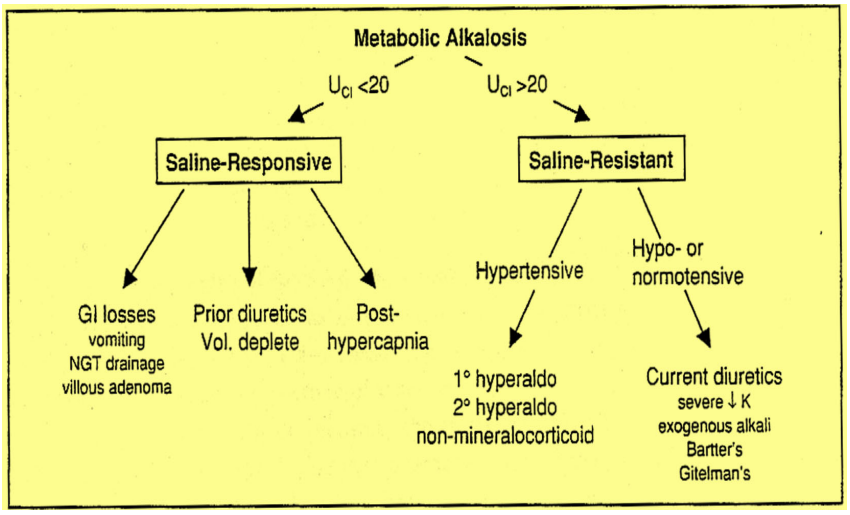
- Primary mechanism:
  - Increase acid production
  - Decrease acid secretion
  - Loss of bicarbonate
  - Due to gaining of acid from inside or outside the body, or by losing bicarbonate. Patient will have low pH, low bicarbonate and low pCO2 (due to hyperventilation as a compensatory mechanism)
- To differentiate between the causes. You have to measure the anion gap:
  - Anion gap = [Sodium] - ([Chloride] + [Bicarbonate]) Or
    AG = $[Na^+]$ - ($[Cl^-]$ + $[HCO_3^-]$)
  - Anion gap = positives(cations) – negatives (anions)
  - Normal AG= 8-16
    (If the anion gap is normal the cause is either diarrhea or renal tubular acidosis and if it's high it could be one those causes: Methanol other alcohols, and ethylene glycol intoxication, Uremia (renal failure), Lactic acidosis, Ethanol, Paraldehyde and other drugs, Aspirin, Ketones (starvation, alcoholic and diabetic ketoacidosis))
  - Serum Osmolality = (2 x (Na + K)) + (BUN) + (glucose) to differentiate between internal or external acid gaining



No need to memorize the details of RTA types.
You should know that you develop metabolic acidosis generally by:
1- Losing bicarbonate: in diarrhea or renal tubular acidosis
2- Gaining acid, either internally such as lactic acidosis, ketoacidosis or externally i.e. aspirin overdose, excessive alcohol intake.
3- Osmolar gap (OG) is to know if there are substances contributes to the osmolality such as alcohol or salicylates

4- Metabolic alkalosis:

Causes:
Saline responsive: (GI loss of H+: vomiting, NGT drainage, villous adenoma), Diuretic use, posthypercapina.
Saline resistant: Adrenal disorders, Cushing's, sever hypokalemia….etc



- Steps to analyze the disorder:

1- **Acidemic or Alkalemic?**
(Acidemic: pH < 7.35
Alkalemic: pH > 7.45)

2- **Is the primary disturbance respiratory or metabolic?**
(Respiratory disturbances alter the arterial PaCO2 (normal value 35-45)
Metabolic disturbances alter the serum HCO3-(normal value 22-26))

3- **Is there appropriate compensation for the primary disorder?**
(If PH is normal it is compensated details in step 4 and 6)

4- **Is the respiratory disturbance acute or chronic?**
(Acute respiratory acidosis:
–HCO3-increase by 1 mEq/l for every 10 mmHg increase inPaCO2
•Chronic respiratory acidosis:
–HCO3-increase by 3-3.5 mEq/l for every 10 mmHg increase inPaCO2
•Acute respiratory alkalosis:
–HCO3-decrease by 2 mEq/l for every 10 mmHg decrease inPaCO2
•Chronic respiratory alkalosis:
–HCO3-decrease by 4-5 mEq/l for every 10 mmHg decrease inPaCO2)

5- **For a metabolic acidosis, is there an increased anion gap?**
(Anion gap = [Sodium] - ([Chloride] + [Bicarbonate]) Or AG = [Na+] - ([Cl-] + [HCO3-]).
Normal AG= 8-16)

6- **Is the respiratory system compensating adequately for a metabolic disturbance?**
   - Metabolic acidosis:
     - PCO2 decreases by 1 mmHg for every 1 mEq/l decrease in HCO3
     - OR PCO2 = [1.5 x (serum HCO3)] + 8 (±2)
   - Metabolic alkalosis:
     - PCO2 increases by 0.6 mmHg for every 1 mEq/l increases in HCO3
     - OR ↑ PCO2 = 0.6 x ↑ HCO3 (±2)

➢ **CASE 1**

- A 22 year-old woman presents with 4 hours of numbness in both hands and SOB. ABG: pH=7.48, pCO2=30 mmHg, pO2=86 mmHg. Na=140, Cl=110, HCO3=22

1- Alkalemia
2- Respiratory alkalosis (young women, most likely pregnancy or anxiety)
3- In Respiratory alkalosis, for every ↓pCO2 10, there will be ↓HCO3 by 2 (acute) or 4-5 (chronic). So in this case it is Acute because pCO2 is 30 (decreased by 10) and HCO3 is 22 (decreased by 2)

➢ **CASE 2**

- **pH =7.2, pCO2 = 60, HCO3 = 24**

Answer:

1- Acidemia
2- Respiratory (pCO2 is elevated)
3- Since the pH didn't return to normal range, it is uncompensated. In this case pCO2 is increased by 20 (normal mid-range is 40) so in order to say compensated in this case, we have to have normal pH with an increase of HCO3 by 2 (acute) or by 6-7 (chronic)
"I.e. If it was chronic compensated pH =7.4, pCO2 = 60, HCO3 = 30 ... if there is an acute on top of chronic, the pH will be low and pCO2 will be very high i.e. pH=7.2, pCO2=80, HCO3=32"
4- It is most likely acute because there are no chronic underlying diseases such as COPD, the pH didn't get back to normal, and the HCO3 didn't even begin to increase.

This is acute uncompensated respiratory acidosis

➢ **CASE 3**

- **What do you expect the ABG in the following patients to be:**

1- 24 Year-old male with acute SOB, and wheezes for 2 days and has a history of a bronchial asthma?

- He might have either respiratory alkalosis or acidosis or normal depending on the severity
- Remember! Asthma patient start with alkalosis due hyperventilation then will be normal when the respiratory muscles starts to get fatigued then shifts to acidosis finally if left untreated

2- 67 years old women, HTN, DMII, COPD presenting with cough and SOB?

- Most likely it will fit into acute or acute on top of chronic respiratory acidosis.

➢ **CASE 4**

- **pH =7.25, pCO2 = 52, HCO3 = 20**

Answer:

1-Acidemia
2-Respiratory is the primary cause
3-Uncompensated
4-Metabolic acidosis (HCO3 should increase by 1 above the normal (24) but in this case it is lower than normal)

➢ **CASE 5**

- **A man with kyphoscoliosis, ABG: pH:7.32 - pCO2: 55 - HCO3: 19**

Answer:

1- Acidemia
2- Respiratory is the primary cause due to his chest wall deformity
3- Uncompensated (pH is abnormal)
4- Chronic (chest wall deformity)
5- Metabolic acidosis as well (in this case, HCO3 should increase by 1.5 above the normal (24) but in this case it is even lower than normal)

➢ **CASE 6**

- A 70 year-old smoker presents with an acute onset of shortness of breath. ABG: pH 7.30, pCO2 = 60 mmHg, pO2 60 mmHg Na 135, Cl 100, HCO3 30

1. Acidosis
2. Respiratory
3. Acute on top of chronic. pCO2 increased by 20, therefore the HCO3 should increase by 2 if acute and 8 if chronic. Because the HCO3 increased from 24 to 30 (6), an acute on chronic respiratory acidosis is present. Also, notice that the chronic type of respiratory acidosis is usually compensated (means normal pH) but if you calculate and it appears to be chronic plus you see the pH is low, consider an acute on top of chronic.

➢ **Case 7**

- 32 year old man with depression and alcohol abuse presents with altered mental status. ABG: pH=6.9, pCO2=29, pO2=100
- Na=140, Cl= 101, HCO3= 5

1. Acidemia
2. Metabolic
3. In order to know if respiratory compensation is there:
   - pCO2 = 1.5(HCO3) + 8 = 15, but the patient's pCO2 is higher than 15±2 Therefore, a respiratory acidosis is also present, possibly secondary to CNS depression.
4. Step 4: AG = 140 – (101 + 5) = 34, means high anion gap metabolic acidosis

- **Case 8**
  - 32 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
  - Na 135, Cl 108, HCO3 18

1. Acidemia
2. Metabolic
3. In order to know if respiratory compensation is there:
   - pCO2 = 1.5(HCO3) + 8 ±2 = 35 ±2, and the patient pCO2 is roughly the same (no concomitant respiratory acidosis).
   - If you apply the other easy calculation: HCO3 is decreased by 6 in this case, so pCO2 should be decreased by around 6 as well and it is
4. AG = 135 – (108 + 18) = 9, means normal anion gap metabolic acidosis
5. Aetiology: diarrhea or RTA. The history obviously will guide you (diarrhea)

- **Case 9**
  - 32 y/o male present w/ 2d Hx of intractable vomiting. ; pH 7.51, pCO_2= 41
  - Na132, Cl=90 32 K=3.4 HCO3= 33 creatinine1.6

1. Alkalemia (high pH)
2. Metabolic (high HCO3 and normal pCO2)
3. In order to know if respiratory compensation is there:
   ↑pCO2 = 0.6(↑HCO3) ±2 = 5.4 ±2, and pCO2 is clearly not elevated above normal by 5.4 ±2. The doctor said we take 40 as a midrange of the normal value (35-45) so pCO2 should be 40 + (5.4 +/-2) so it should be 43.4 - 47.4 to say it is compensated and no other concomitant disturbance. But in this case, respiratory alkalosis is present as well.
4. AG = 135 – (108 + 18) = 9, means normal anion gap metabolic acidosis
5. Metabolic alkalosis due to vomiting, treatment is fluids (isotonic saline)

Additional cases:

- **Case 10**
  - 56 yo M with Hx of COPD is admitted with 1-wk Hx of dyspnea, productive cough and diarrhea
    (Na) 125, (Cl) 103 , (BUN) 42, (Glucose) 100, (K) 3.5, (HCO3-) 10, (Creat) 1.4
  - ABG: PH= 7.14, pCO_2 =30, pO_2 =50

1. Acidemia (low pH)
2. Metabolic
3. Respiratory compensation?
   - Applying the simple calculation, 1 decrease in pCO2 for every 1 decrease in HCO3
   - 24-10 = 14 decrease in HCO3 | 40-30 = 10 decrease in pCO2
   - still not enough decrease in pCO2 which indicates an underlying primary respiratory acidosis, suggested by the Hx (lungs are not compensating properly)
   - AG= 125-(103+10) = 12, normal anion gap > diarrhea

- **Case 11**
  - A 58- year old man presents to the Emergency Department with abdominal pain and hypotension. Investigation reveal the following:
  - Na=140, K=4, Cl=90, HCO3 =5, pH=6.8 PCO2=36, pO2=7

1. Acidemia
2. Metabolic
3. Respiratory compensation?
   - Applying the simple calculation, 1 decrease in pCO2 for every 1 decrease in HCO3
   - 24-5 = 19 decrease in HCO3 | 40-36 = 4 decrease in pCO2
   - still not enough decrease in pCO2 which indicates an underlying respiratory acidosis
   - AG= 140-(90+5) = 45, high anion gap > most likely lactic acidosis due to hypotension. But we should ask for alcohol

QUIZ:

1	pH	pCO2	HCO3	Interpretation
2	7.41	40	24	normal
3	7.5	42	35	**metabolic alkalosis**
4	6.72	40	5	**metabolic acidosis**
5	7.26	63	25	**respiratory acidosis**
6	7.52	18	25	**respiratory alkalosis**