Acid-base basics

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Learning objectives

- Understand the four basic acid base disorders
- Understand mixed disorders
- Stepwise approach to acid base analysis

Lecture outline

- Simplified physiology of acid base
- Stepwise approach to acid base analysis
- Questions
  - From simple acid base to the ultimate triple acid base disorder
  - See pdf file “Acid Base Q&A”

Definitions

- *AN "osis " means a process*
    - *Eg Acidosis.*
- *Alkalaemia means pH > 7.44*
- *Acidaemia means pH < 7.36*

Types of Acidosis

- Acidosis
  - Respiratory
  - Metabolic
    - Anion Gap
    - Non Anion Gap

Types of Alkalosis

Alkalosis

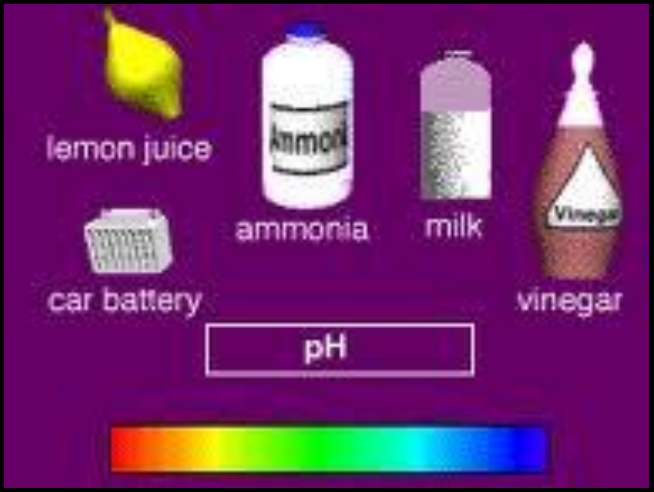
- Chloride Responsive
- Chloride non responsive

Definitions

- Respiratory means changes in PCO_2 values c.f. to expected/normal.
- Metabolic means changes in serum bicarbonate

Homeostasis

- Various buffers in the body
- HCO_3/CO_2 buffer system is clinically used.
- Other buffers are hemoglobin, bone, proteins



Homeostasis

- Body tries to keep the pH between 7.36-7.44
- Body tries to keep ratio of HCO_3/CO_2 fixed.

Basic disorders

- Metabolic acidosis
  - Decreased bicarbonate or tCO_2
- Metabolic alkalosis
  - Increased bicarbonate or tCO_2

Basic disorders

- Respiratory acidosis
  - Increased PCO_2
- Respiratory alkalosis
  - Decreased PCO_2

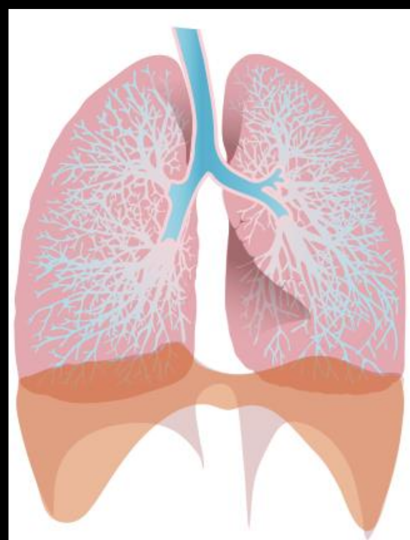
Compensation

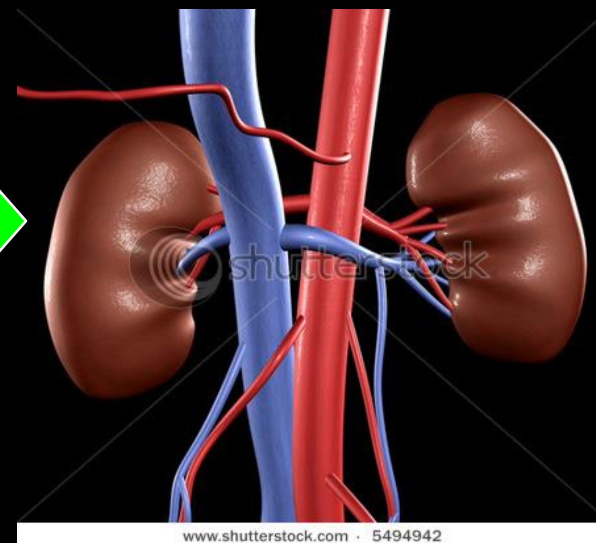
- HCO_3/CO_2 ratio
- Changes in one parameter are compensated by same direction changes in the other:
  - Increased HCO_3 leads to increased CO_2 etc

Compensation

- Lungs compensate for metabolic processes.
  - minutes to hours
- Kidneys compensate for respiratory processes.
  - hours to days

Compensation





Analysis of ABG

- Obtain ABG, chem 7.
- pH - alkalemic or acidaemic ?
- Check P_aCO_2 ; has it changed in direction to explain pH change ?

Analysis

- If P_aCO_2 has changed in appropriate direction, does it account for the whole change?

- Δ P_aCO_2 10 = Δ pH 0.08 acutely
- Δ P_aCO_2 10 = Δ pH 0.04 chronically

Analysis

- If answer is No to either of the previous two questions...
- Must be a metabolic acid base problem in addition

pH	PCO2	Interpretation
7.40	40	Normal
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

pH	PCO2	Interpretation
7.40	40	Normal
7.48	30	Respiratory alkalosis
7.56	20	Respiratory alkalosis
7.32	50	Respiratory acidosis
7.24	60	Respiratory acidosis
7.30	60	Respiratory acidosis + Metabolic alkalosis
7.48	20	Respiratory alkalosis + Metabolic acidosis

Analysis

- Is serum bicarbonate high or low ?
- If low, calculate the anion gap.
  - Na - Chloride - bicarbonate = AG

Analysis of gap acidosis

If there is an anion gap, then check:

- M Methanol
- U Uremia
- D DKA
- P Propylene glycol
- I Iron, infection
- L High lactate
- E Ethanol
- S Salicylate

Correction of AG for low albumin

- Low albumin hides a high anion gap

2.5 x (Normal albumin - measured albumin)

\+ Measured AG

= Corrected Anion gap

Analysis of delta gap

- If anion gap present analyze delta gap to look for second acidosis. In effect, correct the bicarbonate for the presence of the anion gap.

  - $HCO_{3(c)}$ = $HCO_{3\ (a)}$ + {Actual AG --normal AG}

  - E.g. = 8 +{34 -10} = 32

The delta gap.

- Tries to back track in time to when the patient did not have an anion gap that was high.

- Assumes that as AG increases, bicarbonate drops on a 1:1 ratio.

Analysis of delta gap.

- If ***corrected bicarbonate is higher*** than normal : implies ***metabolic alkalosis.***

- If ***corrected bicarbonate is lower*** than normal : implies ***non gap metabolic acidosis.***

Corrected bicarbonate

Anion gap 20
Bicarbonate 5

→ Metabolic gap acidosis

Delta (change) in AG
20-10 = 10

→ Corrected Bicarbonate
5 + 10 =15

Metabolic gap acidosis
+
Metabolic non gap acidosis

Corrected bicarbonate

Anion gap 30
Bicarbonate 10 → Metabolic gap acidosis

Delta (change) in AG
30-10 = 20 → Corrected Bicarbonate
10 + 20 =30

Metabolic gap acidosis
+
Metabolic alkalosis

Analysis of respiratory compensation

- Any metabolic acidosis (gap or non gap) - use ***Winter's*** formulae to assess respiratory compensation.

- $P_aCO_{2\ (e)} = \{HCO_3 \text{ x}1.5\} + 8 \pm 2$

Bicarbonate tCO_2	PCO2	Interpretation
24	40	Normal
10	21-25	Metabolic acidosis + appropriate respiratory compensation
10	30	Metabolic acidosis + Respiratory acidosis
10	15	Metabolic acidosis + Respiratory alkalosis

Analysis of respiratory compensation.

- If ***actual P_aCO_2 is higher than*** **$P_aCO_{2\,(e)}$,** then there is a ***respiratory acidosis*** (even if <40).

- If ***actual P_aCO_2 is lower than*** **$P_aCO_{2\,(e)}$,** then there is a **respiratory alkalosis** (even if > 40).

Analysis of non gap metabolic acidosis

- Whenever there is a non gap metabolic acidosis, calculate the urinary anion gap.
- UAG = Na + K - Chloride.

- Two types of non gap acidosis
  - Renal and non renal

Analysis of non gap metabolic acidosis

- If UAG is a positive value, implies renal source of non gap acidosis eg RTA.
- If UAG is a negative value, implies non renal source such as diarrhoea

Analysis of metabolic alkalosis

- Either adding bicarbonate and/or losing acid.
- Check urine chloride
- If low : implies chloride responsive
- If high : implies chloride unresponsive

Mixed disorders

- A normal pH may be normal

- A normal pH may be abnormal if
  - combined metabolic and alkalotic process.

Mixed disorders

- No way to have a combined respiratory acidosis and respiratory alkalosis.
- If *bicarbonate and* P_aCO_2 *have changed in opposite directions : a mixed disorder exists*

Mixed disorders

- Up to 3 at a time:
  - Metabolic gap acidosis, metabolic alkalosis and respiratory alkalosis
  - Metabolic gap acidosis, metabolic alkalosis and respiratory acidosis
  - Metabolic gap acidosis, metabolic non gap acidosis and respiratory acidosis e
  - And so on....

  - Which combination is not possible?

Some examples (without clinical context!) #1

- pH 7. 32, $PaC0_2$ 80
- Acute respiratory acidosis
- Plus metabolic alkalosis

2

- pH 7. 10, $PaCO_2$ 60
- Acute respiratory acidosis
- Plus metabolic acidosis
- Two disorders as pH is lower than a respiratory process could explain

3

- Bicarbonate 10
- AG 30
- Delta gap 20
- Corrected bicarbonate 30
- Metabolic gap acidosis
- Plus metabolic alkalosis

4

- Bicarbonate 5
- AG 18
- Delta gap 8
- Corrected bicarbonate 13
- Metabolic gap acidosis
- Plus metabolic non gap acidosis

5

- Bicarbonate 10
- $PaC0_2$ 25
- Appropriate respiratory compensation

6

- Bicarbonate 10
- $PaC0_2$ 40
- Inappropriate respiratory compensation
- Under compensated
- Respiratory acidosis and metabolic acidosis - May need intubation!!!

7

- Bicarbonate 10
- $PaC0_2$ 40
- Anion gap 40
- Metabolic acidosis gap
- Metabolic alkalosis
- Respiratory acidosis
- A triple disorder

Causes and Rx

- Metabolic gap acidosis
  - Salicylate - dialysis
  - Renal failure - renal Rx
  - Lactic acidosis - resuscitate
  - DKA - insulin, fluids, Rx trigger
  - Methanol OD - dialysis

Causes and Rx

- Metabolic non gap acidosis
  - Diarrhea - Rx the diarrhea
  - Renal tubular acidosis - Rx the cause
  - TPN - change to acetate salts of Na and K

Causes and Rx

- Metabolic alkalosis
  - NG suctioning - replace same fluid or stop suctioning
  - Vomiting - replace with NS

Causes and Rx

- Respiratory alkalosis
  - Head injury
  - Infection
  - Alcohol withdrawal
  - Anxiety
  - Pain

Causes and Rx

- Respiratory acidosis
  - Over sedation
  - COPD
  - Neuromuscular disease

Osmolar Gap > 10 mOsm/kg

Osmolar gap

Measured osmolarity - Calculated osmolarity

Causes :=

Ethanol, methanol, ethylene glycol, mannitol, propylene glycol

Osmolar gap calculation

Calculated = 2 Na
+ glucose/18
+ BUN/ 2.8
+ Glucose/189
+ Ethanol/4.6

- Sodium 140
- Potassium 4.0
- Chloride 100
- Bicarbonate 10

- BUN 28
- Glucose 180
- Measured osmolarity 350

What is the acid base interpretation?

Metabolic anion gap acidosis

What is the osmolar gap?

50

Osmolarity and US units

- Osmolarity units - osmoles per liter
- US units - mg/deciliter (1/10th of liter)
- SI units moles/liter
- In USA
  - Osmolarity = (concentration mg/dL X 10) / molecular weight

  - Ethanol is C_2H_5 OH = 46 molecular weight

Osmolar and US units.
http://www.scymed.com/en/smnxps/psmcf770.htm

- Going back to question, osmolar gap was 50
- Assuming this was all due to ethanol what is the equivalent ethanol concentration in mg/dL?
    - Osmolarity = (concentration mg/dL X 10) / molecular weight
    - Concentration mg/dL = Osmolarity X molecular weight / 10
    - 50 x 4.6 = 230 mg/dL of ethanol