Acid-base disturbances

4th years

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Outlines

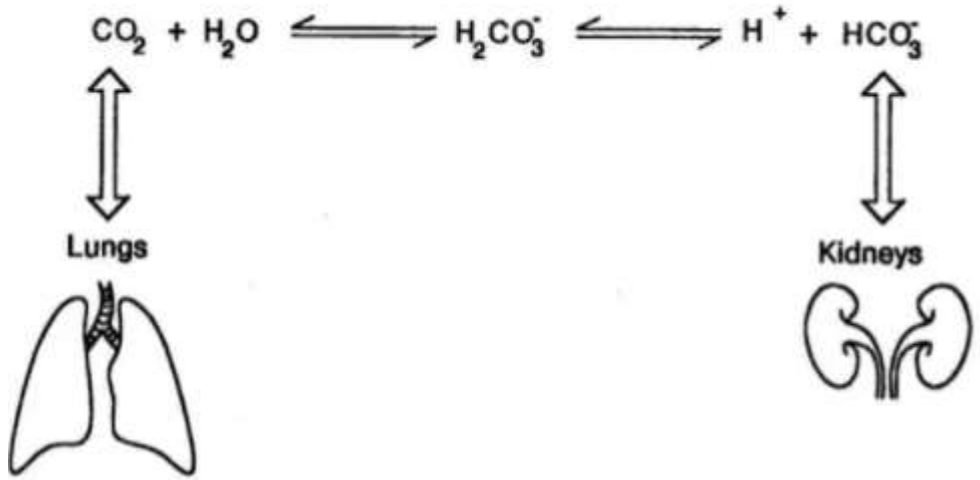
- Basics and terminology
- Acid base regulation
- Respiratory acidosis and alkalosis
- Metabolic acidosis: AGMA and NAGMA
- Metabolic alkalosis
- 7 steps approach

pH

- Each solution has pH which affect the characteristic of this solution
- "potential of Hydrogen" or "power of hydrogen“
- the decimal logarithm of the reciprocal of the H+ activity
- pH = - log (H+)

Henderson-Hasselbalch equation:

other molecules (CO2, HCO3)
CO2 + H2O ⇔ H2CO3⇔ H + HCO3
pH = HCO3/CO2 of H+ = 24 X CO2/HCO3



Terminology

- Acid: hydrogen-containing substance that is capable of donating a proton (hydrogen ion) to another substance.
- Base: a molecule or ion able to accept a hydrogen ion from an acid.
- Acidosis: process in crease the amount of proton H+
- Alkalosis: process decrease the amount of proton H+
- Acidemia: the pH of the blood lower than normal < 7.35
- Alkalemia: the pH pf the blood greater than normal > 7.45

ACID-BASE REGULATION

- Maintenance of an acceptable pH range in the extracellular fluids is accomplished by three mechanisms:

1- Chemical Buffers: Phosphate Buffer Protein Buffer Bicarbonate Buffer System

- React very rapidly (less than a second)

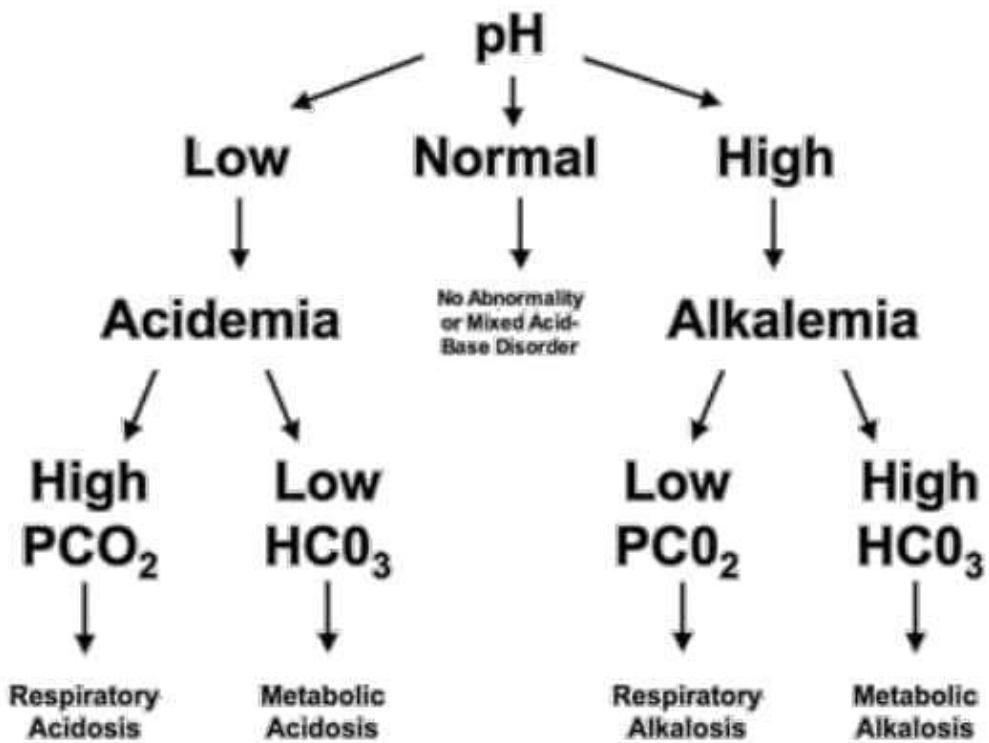
2- Respiratory Regulation: Hyperventilation Hypoventilation

- Reacts rapidly (seconds to minutes)

3- Renal Regulation: reabsorption or excretion of filtered (HCO_3^-). Formation of titratable acid. Excretion of NH_4^+ in the urine.

- Reacts slowly (minutes to hours)

Figure 1: Identifying the Primary Process

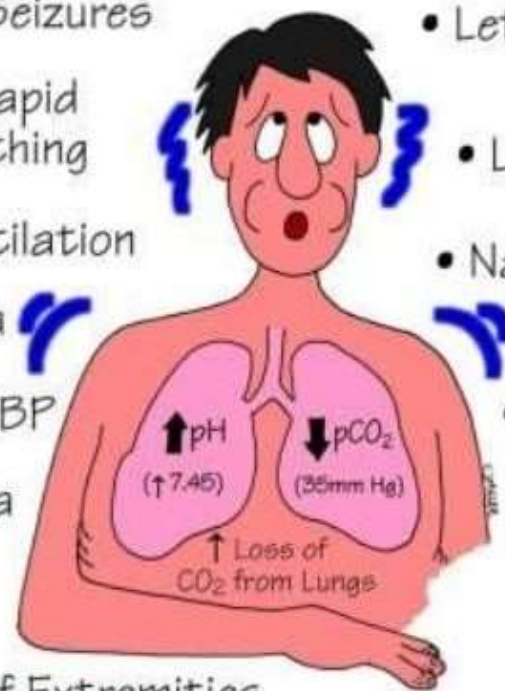


Respiratory alkalosis rapid RR

- CNS hyperactivity (pain, fever)
- CNS trauma, CVA, infection
- Hypoxia: increase demand (anemia, hyperthyroidism)
- Hypoxemia: Pneumonia, PE, pulmonary edema
- Liver insufficiency, pregnancy

RESPIRATORY ALKALOSIS

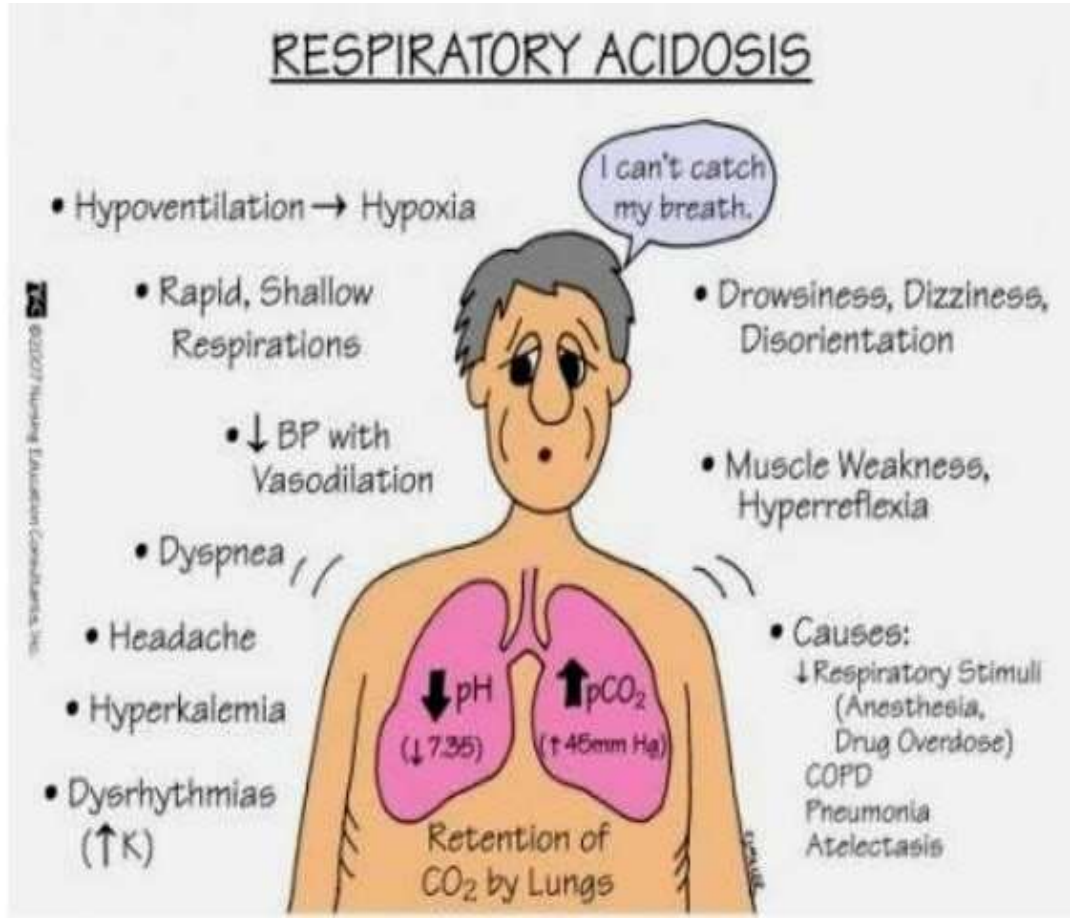
- Seizures
- Deep, Rapid Breathing
- Hyperventilation
- Tachycardia
- ↓or Normal BP
- Hypokalemia
- Numbness & Tingling of Extremities



- Lethargy & Confusion
- Light Headedness
- Nausea, Vomiting
- Causes:
  - Hyperventilation (Anxiety, PE, Fear)
  - Mechanical Ventilation

Respiratory acidosis: low RR

- CNS depression (acute stroke, head trauma, narcotic overdose)
- Increase ICP
- Neurological: GBS
- Neuromuscular disease: MG
- Obstructive lung disease: COPD, OSA, foreign body

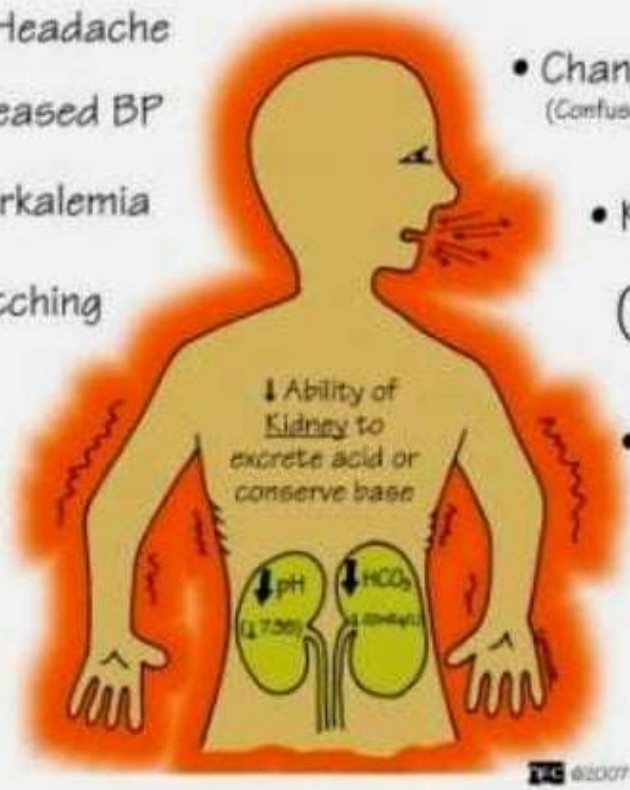

RESPIRATORY ACIDOSIS
I can't catch my breath.
• Hypoventilation → Hypoxia
• Rapid, Shallow Respirations
• ↓ BP with Vasodilation
• Dyspnea
• Headache
• Hyperkalemia
• Dysrhythmias (↑K)
• Drowsiness, Dizziness, Disorientation
• Muscle Weakness, Hyperreflexia
• Causes:
↓ Respiratory Stimuli (Anesthesia, Drug Overdose)
COPD
Pneumonia
Atelectasis
↓pH (↓7.35)
↑pCO2 (↑45mm Hg)
Retention of CO2 by Lungs

Metabolic acidosis

- Again, process add proton (lower pH)
- Is this extra proton because we losing HCO3 adding acid
- This lead to Anion gap

METABOLIC ACIDOSIS

- Headache
- Decreased BP
- Hyperkalemia
- Muscle Twitching
- Warm, Flushed Skin (Vasodilation)
- Nausea, Vomiting Diarrhea



- Changes in LOC (Confusion, ↑drowsiness)
- Kussmaul Respirations (Compensatory Hyperventilation)
- Causes:
  - DKA
  - Severe Diarrhea
  - Renal Failure
  - Shock

Anion gap

- Anion = Cations
- Na + K + unmeasured cations (Mg + Ca + globulin) = Cl + HCO3 + unmeasured anions (PO4 + SO4 + albumin + acid)
- Na – (Cl + HCO3) = unmeasured anion – unmeasured cation

AGMA

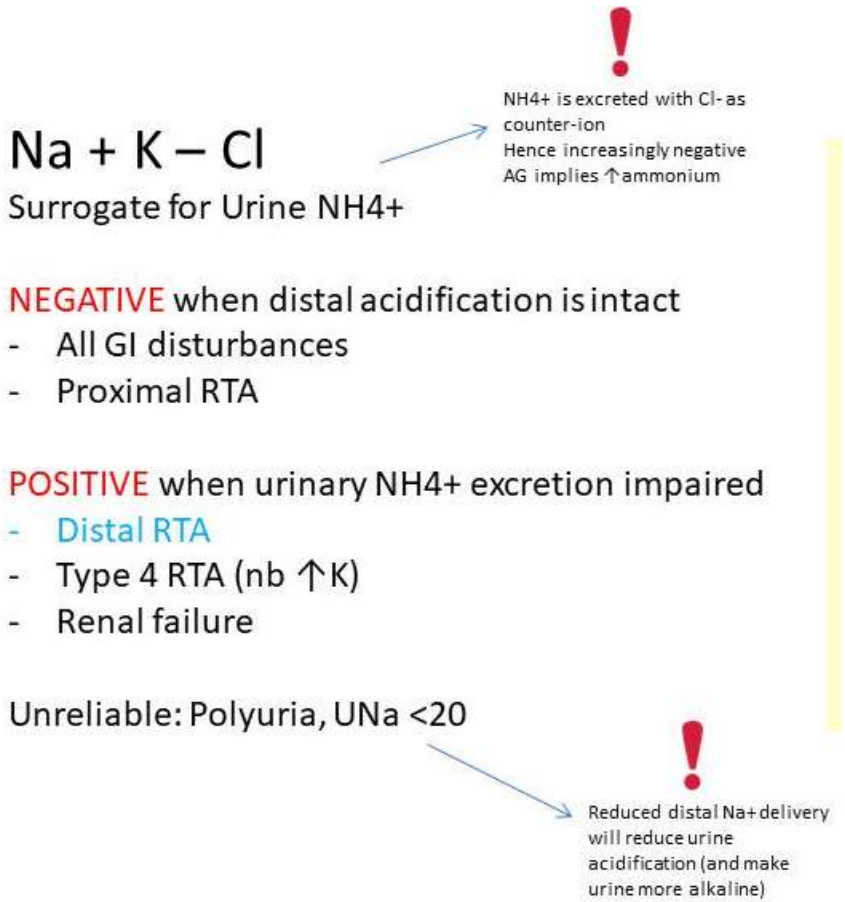
G	Glycols (ethylene and propylene)
O	5-Oxoproline (pyroglutamic acid) chronic paracetamol use, EtOH, poor nutrition, vegetarian diet, renal failure, infection, flucloxacillin/dicloxacillin/netilmicin, Vigabatrin
L	Lactate
D	D-lactic acid Associated with short bowel syndrome
M	Methanol and other toxins (ethanol, Aldehyde)
A	Aspirin, salicylates
R	Renal failure
K	Ketoacidosis

EtOH, ethyl alcohol,.

NGMA

- Gastrointestinal losses of HCO_3
  - Diarrhea
  - Enteric fistula
  - Pancreatic fistula
- Ureteral diversions
  - Uretero-sigmoidostomy
  - Ileal bladder
  - Ileal ureter
- Renal tubular acidosis
  - Proximal
  - Distal
  - Buffer deficiency (phosphate, ammonia)
- Medications
  - Carbonic anhydrase inhibitors (i.e., acetazolamide)
  - Amphotericin B

Urine AG


NH4+ is excreted with Cl- as counter-ion
Hence increasingly negative AG implies ↑ammonium
Na + K – Cl
Surrogate for Urine NH4+
NEGATIVE when distal acidification is intact
- All GI disturbances
- Proximal RTA
POSITIVE when urinary NH4+ excretion impaired
- Distal RTA
- Type 4 RTA (nb ↑K)
- Renal failure
Unreliable: Polyuria, UNa <20
Reduced distal Na+ delivery will reduce urine acidification (and make urine more alkaline)

Metabolic alkalosis

- Associated with hypochloremia and hypokalemia

Phases of metabolic alkalosis

- Generation: loss of acid, gain HCO3
- Maintenance stage: kidney loss ability excrete HCO3 and paradoxically absorb HCO3 (volume contraction, low GFR, CL or K depletion, high CO2, secondary aldosteronism)
- Hypokalemia: enhance reabsorption of HCO3, ammoniagenesis (production of HCO3), stimulate H, K ATPase

Causes

- *Exogenous*: milk alkali syndrome
- *Effective EVF contraction*:

- Extra renal:

➢ **Vomiting** (Cl loss and Na, HCO3 retention, volume contraction)
➢ **Chloride loosing diarrhea** (normal Na/H and loss of Cl/HCO3 exchanger)
➢ **Villous adenoma** (volume contraction and hypokalemia)

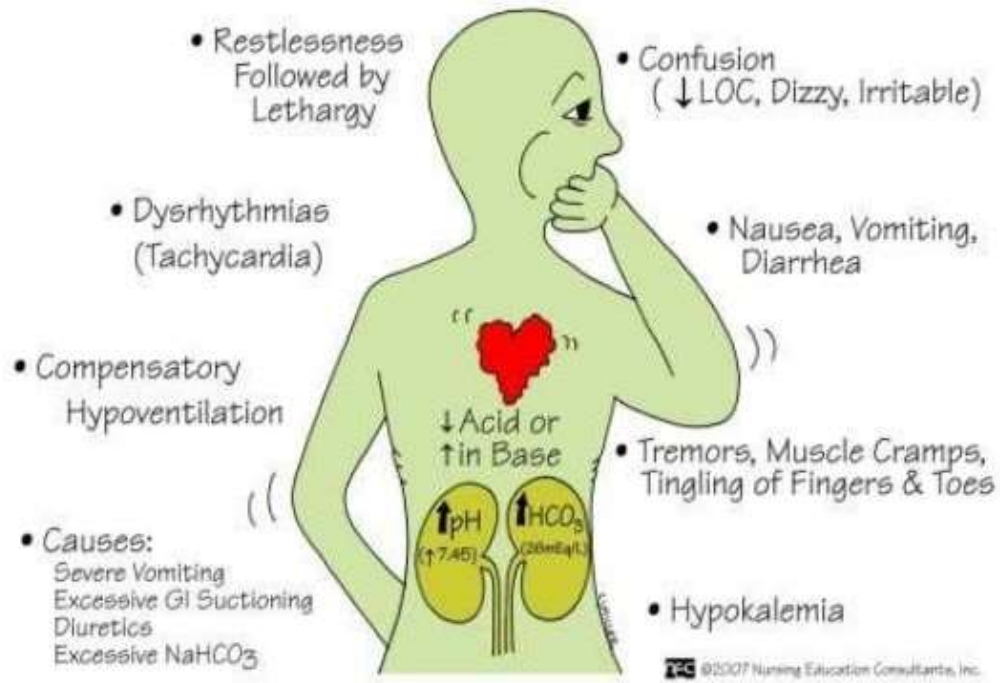
- Renal:

➢ **Diuretics, AR disorders like G and BS** (Hypokalemia and volume contraction)
➢ **Post hypercapnic:** in volume contraction (Chloride loss)
➢ **Non absorbable anions:** distal acidification and K secretion, Mg deficiency

- *ECF excess*: mineralocorticoid excess

- High renin: tumor, RAS
- Low renin: primary hyperaldosteronism, Liddle syndrome

METABOLIC ALKALOSIS



Clinical approach

1- validity

2- acidemia or alkalemia

3- primary disorders

4- compensation

5- AG

6- delta/delta

- pH = 7.52
- PO_2 = 105 mm Hg
- BE = - 3
- Na^+ = 138 m mol / L
- Cl^- = 104 m mol / L

PCO_2 = 26 mm Hg

HCO_3 = 21 m mol / L

SaO_2 = 99%

K^+ = 3.8 m mol / L

Anion Gap = 13

- pH = 7.3
- PO_2 = 60 mm Hg
- BE = + 2
- Na^+ = 140 m mol / L
- Cl^- = 100 m mol / L

PCO_2 = 60 mm Hg

HCO_3 = 26 m mol / L

SaO_2 = 89 %

K^+ = 4 m mol / L

- pH = 7.44
- PO_2 = 100 mm Hg
- BE = - 5
- Na^+ = 137 m mol / L
- Cl^- = 108 m mol / L

PCO_2 = 29 mm Hg

HCO_3 = 19 m mol / L

SaO_2 = 98 %

K^+ = 3.7 m mol / L

- pH = 7.32
- PO_2 = 62 mm Hg
- BE = + 8
- Na^+ = 136 m mol / L
- Cl^- = 96 m mol / L

PCO_2 = 70 mm Hg

HCO_3 = 32 m mol / L

SaO_2 = 90 %

K^+ = 3.5 m mol / L

- pH = 7.30
- PO_2 = 80 mm Hg
- BE = - 14
- Na^+ = 139 m mol / L
- Cl^- = 100 m mol / L

PCO_2 = 30 mm Hg

HCO_3 = 10 mmol / L

SaO_2 = 95 %

K^+ = 4.1 m mol / L

Anion Gap = 29

- pH = 7.50
- PO_2 = 75 mm Hg
- BE = + 16
- Na^+ = 132 m mol / L
- Cl^- = 88 m mol / L

PCO_2 = 50 mm Hg
HCO_3 = 40 mmol / L
SaO_2 = 95 %
K^+ = 3.1 m mol / L
Anion Gap = 4

- pH : 7.36
- PCO_2 : 34 mm Hg
- PO_2 : 100 mm Hg
- HCO_3 : 16mmol/L
- BE : -8
- Sats : 98%
- Na+ : 140mmol/L
- K+ : 3.5mmol/L
- Cl- : 98mmol/L
- Anion Gap : 26

- pH : 7.55
- PCO_2 : 30 mm Hg
- PO_2 : 104 mm Hg
- HCO_3 : 29mmol/L
- BE : +5
- Sats : 99%
- Na+ : 135mmol/L
- K+ : 3.5mmol/L
- Cl- : 95mmol/L
- Anion Gap: 11

- pH : 7.40
- PCO_2 : 28 mm Hg
- PO_2 : 60 mm Hg
- HCO_3 : 15mmol/L
- BE : -9mmol/L
- Sats : 90%
- Na+ : 140mmol/L
- K+ : 3.5mmol/L
- Cl- : 98mmol/L
- Anion Gap : 27