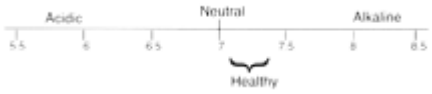
Acid-Base Balance

- Acid-Base balance is a function of the chemical and physiological components of the body.
- This control is attained through the production and elimination of H+ ions
- pH is the measure of alkalinity and or acidity of a solution.

pH Scale



Free H+ Ions

- Body fluid pH is the measure of the body fluid's free H+ level.
- The lower the pH value of a fluid, the higher the level of free hydrogen in that fluid.
- A change of (1) pH unit represents a 10-fold change in free H+
- A pH change of one tenth (7.4 -- 7.3)represents a large increase in H+ concentration.

Blood

The normal arterial pH of blood is 7.35---7.45
The normal venous pH of blood is 7.31---7.41

Cause and Effect of pH

- Changes in normal blood pH interfere with many physiologic functions by:
- Changing the shape of hormones and enzymes so they may no longer perform their normal functions
- Changing the distribution of other electrolytes causing fluid and electrolyte imbalances

Cont. Cause &Effect

- Altering the excitable membrane so the heart, nerve, skeletal muscles, and GI tract are either more or less active than normal
- Decreasing the uptake, activity, and effectiveness of many hormones and drugs.

Acid-Base Balance

- The body keeps blood pH between 7.35 and 7.45 -----Slightly Alkaline
- Normal body fluid remains at near neutral value when the acids and the bases are nearly balanced limiting the total number of free or unbalanced H+

Acid–Base Balance

- Acid-Base balance occurs by matching the rate of H+ production with activities for H+ removal or uptake

Acid

- Substances that release H+ when dissolved in water
- The strength of an acid is measured by how easily it releases a H+ in solution

  (HCL + H2O = H+ + CL- + H2O
- A weak acid does not completely separate in water

  CH3COOH =acetic acid

Base

- A base binds free H+ in solution (reducing the amount of free H+ in solution)

  NaOH= Sodium Hydroxide
- Strong bases bind H+ easily while weak bases bind H+ less readily

  HCO3

Buffers

- Can either bind a H+ into a fluid or release a H+ from a fluid
- How a buffer reacts when dissolved in water depends on the existing acid-base balance of that fluid.
- Always acts to bring the fluid as close as possible to normal body fluid pH (if the fluid is basic the buffer releases H+, if acidic acts as base binding H+)

Fluids

- Liquids with a pH of 7.0 are neutral; free H+ level in which the number and strength of the acids and bases are equal
- Liquids with a pH ranging from 1.0-6.99 have more or stronger (or both) acids compared to the amount or strength of the bases Acidic

Fluids

- Fluids with a pH of 7.01-14.0 have more or stronger (or both) bases compared with the amount and strength (or both) of acids basic

Bicarbonate Ions

- Body fluids contain many types of acids but only a few types of bases.
- Bicarbonate (HCO3-) most common base
- Carbonic acid (H2CO3) most common acid
- In ECF a constant ratio of 1 molecule of carbonic acid to 20 free bicarbonate ions
- Both of these substances and their constant ratio are related to production and elimination of carbon dioxide and hydrogen ions.

Carbonic Anhydrase Equation

- Carbon dioxide content of a fluid is directly related to the amount of H+ in the fluid
- Whenever conditions cause CO2 to increase, more free H+ are created
- Likewise whenever whenever free hydrogen production increases , more CO2 is produced

Body Control of pH

pH= kidneys (bicarbonate)

_____

lungs (carbon dioxide)

Sources of Acids in the Body

- Acids are formed as normal waste products of carbohydrate, protein, and fat metabolism
- Carbohydrate metabolism forms carbon dioxide ---------- converted to free hydrogen ions.
- Fat and protein metabolism directly create acids.

Waste Products

- Carbon dioxide is a waste product of glucose breakdown and other metabolic reactions: the complete breakdown of one molecule of glucose forms
  - 36 molecules of ATP
  - 6 molecules of water
  - 6 molecules of carbon dioxide

Physiological Processes

- Carbon dioxide is exhaled by the lungs during breathing
- This exchange helps determine blood pH by how much carbon dioxide is produced in the body by cells during metabolism versus how rapidly that carbon dioxide is removed by by breathing

Cont. Physiological Processes

- The break down of foods for energy results in the formation of fixed acids
- Protein breakdown forms sulfuric acid
- Fat breakdown form fatty acids
- Lactic acid formation results in the metabolism of glucose under anaerobic conditions
- Anaerobic conditions occur with hypoxia, sepsis, and shock.

Cont.

- Incomplete breakdown of fatty acids, occur when large amounts of fatty acids are being metabolized form ketoacids.
- When cells are damaged or destroyed, cell membranes are broken and cell contents are released. Some acids are released into the ECF

Sources of Bicarbonate

- Bicarbonate comes from the break down of carbonic acid
- Bicarbonate absorption from foods
- Pancreatic production of bicarbonate
- Movement of cellular bicarbonate into the ECF
- Kidney reabsorption of filtered bicarbonate

Normal

- Normal Arterial Blood Gas Values
- pH7.35-7.45
- $PaCO_2$35-45 mm Hg
- PaO2 80-95 mm Hg
- HCO3 22-26 mEq/L
- O2 Saturation95-99%
- BE +/- 1

Acid-Base Regulatory Mechanisms

- Chemical
- Respiratory
- Renal

Regulatory Mechanisms

- Buffers are the first line of defense against change in the amount of free H+
- Always present act fast to reduce or raise the amount of free H+ to normal

Chemical Buffers

- Chemical buffers are paired mixtures, usually a weak base and an acid salt.

Two most common chemical buffers are:

- Bicarbonate buffers ---- active in both ECF and ICF
- Phosphate buffers ---- active in ICF only

Protein Buffers

- Proteins are the largest source of buffers.
- Proteins in the body can either bind or release free H+ as needed
- Both ECF and ICF proteins serve as buffers
- Major cell protein buffer is hemoglobin
- Extracellular protein buffers are albumin and globulins

Respiratory-Acid/Base Mechanisms

- Second line of defense, when chemical buffers alone fail
- Breathing controls amount of free H+ by controlling the amount of carbon dioxide in arterial blood
- Breathing rids the body of excess carbon dioxide created by metabolism

Cont.

- CO_2 higher in capillary blood than in the air in the alveoli, CO_2 diffuses freely from the blood into the alveolar air.
- This air exhaled during breathing exits the body
- Even with impaired respiration CO_2 usually continues to be exhaled

Hyperventilation

- Respiratory regulation of acid-base balance is under the control of the central nervous system
- Special receptors in the respiratory area of the brain are sensitive to changes in the amount of CO_2 in brain tissue

Cont. Hyperventilation

- As CO_2 in brain, blood and tissues rise above normal, central receptors trigger the neurons to increase the rate and depth of breathing
- When the amount of CO_2 returns to normal, the rate and depth of breathing return to normal

Hypoventilation

- If the amount of free H^+ is too low, then the amount of CO_2 is also too low
- Central receptors sense these low levels and stop or slow the neuron activity in the respiratory centers, decreasing the rate and depth of respiration
- The respiratory system's response in regulating acid-base balance is rapid.

Renal Regulation of Acid-Base

- The kidney is the third line of defense against wide changes in body fluid pH
- Mechanism stronger but take longer to initiate (24-48 hours)
- When blood changes are persistent, renal mechanism either increase or decrease excretion and reabsorption

Cont. Renal Mechanisms

- Kidney movement of bicarbonate (tubules)
- Formation of acids (inside phosphate-buffering system cells of kidney tubules)
- Formation of ammonium (trapping of H+ in ammonia to form ammonium– loss of H+)

Compensation

- Correction of blood pH
- A pH below 6.9 or above 7.8 is usually fatal
- Respiratory compensation mechanism are limited and can be overwhelmed easily
- More powerful, result in rapid changes in ECF, but are not fully triggered unless imbalance continues several hours to days

Cont. Compensation

- The lungs can usually compensate for acid-base imbalances of metabolic origin (prolonged running causes build-up of lactic acid, H+ levels in ECF increase and pH drops---breathing is triggered, rate and depth increase

Cont. Renal

- A healthy kidney can compensate or correct for changes in blood pH when the respiratory system is either overwhelmed or is not healthy (Pt. with COPD, CO_2 retainer, kidney excretes more H^+ and increase the reabsorption of HCO_3 back into the blood
- When these back up compensation mechanism are completely effective problems are fully compensated, even though O_2 &bicarb are abnormal

Cont Compensation

- Sometimes the respiratory problem causing the acid-base disturbance is so severe the kidney can only partially compensate, and the pH is not quite normal

Age Related Changes

- Older people are at greater risk for pH problems
- Lungs and kidneys are less able to respond to minor changes in H^+ production or elimination
- Some drugs alter normal pH compensating mechanisms

Cont. Age Related

- Gas exchange is reduced as a person ages
- less alveolar membrane,
- thicken vessels impair gas exchange
- All of these conditions causes CO2 retention, increasing the H+ concentration

Cont. Age Related Cause

- Kidney function decreases with age
- Can handle normal metabolism
- Can not compensate when health problems, such as pneumonia, fever, or infection interfere with acid-base balance
- Diuretics and Digoxin cause increase excretion of H+ causing increased pH

Assessment of Acid-Base

- Acid-base involves all cell of the body
- Exam functioning of systems responsible for acid-base balance
- Patterns that affect acid-base balance are
  - Activity-Exercise
  - Elimination
  - Cognitive-Perceptual Patterns

Physical Assessment

- Hydration status:
- Mucus membranes
- Skin turgor
- Urine specific gravity
  1.010-1.030

Stable weight

Accurate I&O

Cont

- Muscle tone
- Strength
- Movement
- Coordination
- Cardiac assess rate and rhythm
- GI assess motility

Diagnostics

- ABG's
- Serum electrolytes
- BUN/Creatinine
- Glucose
- Osmolarity

- ABG's
- Serum electrolytes
- BUN/Creatinine
- Glucose
- Osmolarity
- Urine tests
- GFR
- Urine glucose
- Acetone
- Protein
- blood

Acidosis

- Acid-base balance of the blood and other ECF is disturbed by an excess of H+
- This problem is reflected as an arterial blood gas below 7.35
- Acidosis is not a disease but a condition caused by a disorder or pathologic process

Acidosis

- Individuals at the greatest risk for acidosis are those with problems that impair breathing
- Older adults with chronic health problems are at a greater risk for developing acidosis
- Acidosis can result from an actual or relative increase in the amount or strength of acids.

Cont. Acidosis

- Actual acid excess either by overproduction or under-elimination of H+
  (diabetic ketoacidosis and seizures)
- Relative acidosis the amount or strength or both of bases decrease, making the fluid more acidotic
  (pancreatitis and dehydration)

Acidosis

- Acidosis causes an increase in cations. Excess cations creates an imbalance of other electrolytes, especially potassium. These electrolytes imbalances disrupt the function of nerve, cardiac muscle and skeletal muscle.
- Even slight increases in the blood H+ levels reduce the activity of many hormones and enzymes.
- Many drugs are less affective during acidosis

Metabolic Acidosis

- Four processes can result in metabolic acidosis: overproduction of H+
  underelimination of H+
  underproduction of HCO_3^-
  overelimination of HCO_3^-

Overproduction of H+

- Excessive breakdown of fatty acids- occurs with DKA or starvation (when glucose is not available for fuel, the body breaks down fats.

Cont. Overproduction

- Anaerobic lactic acidosis- occurs when cells are forced to use glucose without adequate oxygen(anaerobic metabolism) glucose is incompletely metabolized and forms lactic acid. Lactic acidosis occurs whenever the body has too little oxygen. (heavy exercise,seizure activity,fever, and tissue hypoxia)

Underelimination of H+

- Occurs when H+ are produced at the normal rate but are not eliminated at the same rate of production. Kidney failure causes acidosis. Too many H+ retained. Lungs are left to eliminate H+ alone.

Underproduction of Bicarbonate

- Base-deficit state exists when the blood levels of HCO3 are too low. Base-deficit acidosis happens when H+ production and elimination are normal but too few HCO3 are present. HCO3 is made in the kidneys and pancreas---so renal failure and reduced hepatic &pancreatic function=base-deficit acidosis

Overelimination of HCO3

- Base-deficit acidosis when H+ production and removal are normal, but too many HCO3 are lost. (diarrhea)

Respiratory Acidosis

- Occurs when any area of respiratory function is impaired, reducing the exchange of O2 and CO2. Leads to CO2 retention---any increase in CO2 causes an increase in H+. CO2 retention leads to respiratory acidosis.
- Respiratory acidosis results from only one mechanism=increased production of H+

Respiratory Acidosis

- Four types of problems can cause respiratory acidosis: Respiratory depression
  Inadequate chest expansion
  Airway obstruction
  Reduced alveolar capillary diffusion

Combined Metabolic & Respiratory Acidosis

- Both can occur at the same time
- Uncorrected respiratory acidosis always leads to metabolic acidosis
- Cardiac Arrest

Collaborative Management

How do we approach these problems?

- Vital signs
- Complaint
- History including Risk Factors (acid-base imbalance, cardiac, renal, pulmonary, current meds.
- Medical Conditions (Dm, ARF, Pancreatitis)
- Nutrition and status
- Symptoms (may need to ask family)

Cont. Collab. Mgt

- Key clinical manifestations are similar for both: changes in the excitability membrane activity of neurons of skeletal, and gastric smooth muscle

Collab. Mgt.

- Psychological: behavioral changes may be the first clinical manifestation of acidosis
- Labs: ABG pH used to confirm diagnosis this test alone does not confirm the diagnosis manifestation of metabolic and respiratory acidosis are similar but treatment is different

Metabolic Acidosis

- ABG's and electrolytes:

ABG's low pH < 7.35

low bicarbonate<21

normal partial pressure of carbon dioxide(PaCO2)

Electrolytes:

Elevated serum potassium

Normal Chloride levels

Respiratory Acidosis

- ABG's :

Low pH < 7.35
Elevated Paco2
Low partial pressure Pao2
Electrolytes:
Elevated K+
Variable Bicarbonate levels
CO_2 is 20 times more diffusible than oxygen, so decreased PaO_2 usually occurs first

Interventions

- Focus on correction of the underlying problem (pneumonia, COPD)
- Correction requires identification of specific type of acidosis

Metabolic Acidosis

- Interventions include hydration and drugs (rehydration and antidiarrheal drugs for acidosis from prolonged diarrhea—bicarbonate only if serum bicarbonate is low)

Respiratory Acidosis

- Interventions—maintain a patent airway and enhance gas exchange
  drug therapy (bronchodilators, mucomyst)
  oxygen therapy (caution in co2 retainers)
  pulmonary hygiene(positioning , fluids0
  ventilatory support(as needed)
  prevention of complications

Alkalosis

- Acid-base balance of the blood is disturbed with an excess of base, especially bicarbonate.
- Alkalosis is a decrease in the free H+ level of the blood. ---pH > 7.45
- Alkalosis can be caused by metabolic problems, respiratory problems, or both.

Cont. Alkalosis

- Alkalosis can result from an actual or relative increase in the amount or strength or both
- Actual base excess alkalosis=Base (usually Bicarbonate) is either overproduced or undereliminated
- Relative alkalosis the actual amount or strength of the bases does not increase, acids decrease= acid deficit over-elimination or underproduction of acid

Metabolic Alkalosis

- Either increase in bases or decrease in acids
- Base Excess caused by an excessive intake of bicarbonates, carbonates,acetates,citrates, and lactates. Excessive use of oral antiacids can also cause metabolic alkalosis.
- Increased citrate in massive blood transfusions, acetate and lactate in hyperalimentation etc…

Acid deficit

- Decreases in acids can be caused by disease processes or medical treatment (vomiting, excess cortisol, hyperaldestronism. Medical treatment prolonged Nasogastric suctioning, thiazide diuretics)

Respiratory Alkalosis

- Excessive loss of carbon dioxide through hyperventilation (response to fear, fever, metabolic acidosis, central nervous system leison and drugs =salicylates, catecholamines.)

Clinical Manifestations

- Same for metabolic and respiratory alkalosis.
- Many symptoms are the result of hypocalcemia and hypokalemia. Changes in the function of the CNS, Neuromuscular, cardiovascular, and respiratory systems.

Labs

- ABG's: Metabolic Alkalosis
- High pH . 7.45
- Elevated bicarbonate > 28mEq/L
- Rising Partial pressure (Paco2)
- Normal Pao2
- Decreased Calcium
- Decreased Potassium

* Increased bicarbonate with with raising Paco2

Respiratory Alkalosis

- ABG's :
- High pH
- Low bicarbonate level
- Low Paco2
- Low serum K+
- Low serum Calcium

Interventions

- Prevent further loss of hydrogen, K+, Ca++, and Cl-, restore fluid balance, to monitor changes

Blood Gas Evaluation

- Step 1---Determine if the pH represents acidosis or alkalosis or normal
- Normal pH 7.35-7.45 (slightly alkalotic)

Examples:
pH=7.0 ---------acidic
pH=7.9----------alkalotic
pH=7.4----------normal
pH=7.5----------alkalotic
pH=7.3----------acidic
** pH alone is not sufficient to tell the cause of a

Cont. ABG Eval

- Step 2 Evaluate the pCO2

pCO2 35-45 mmHg (Respiratory Component)
<35 respiratory alkalosis
>45 respiratory acidosis

Practice: pCO2 (22)--------Resp. Alkalosis
pCO2 (32)-------Resp. Alkalosis
pCO2 (35)------- Normal
pCO2 (40)-------Normal
pCO2 (50)-------Resp. Acidosis
pCO2 (60)-------Resp. Acidosis

ABG's

- Step 3 HCO3----Bicarbonate (metabolic Component Normal 22-26mmHg
  - HCO3 (22)--------- Normal
  - HCO3 (16)---------Metabolic acidosis
  - HCO3 (30)--------Metabolic alkalosis
  - HCO3 (25) --------Normal

Compensation: Buffer system (lungs and kidney)

Goal 20:1 ratio base to acid= normal pH

ABG's

- Step 4 Is there compensation? To what extent?
- Compensation = 2 imbalances. Which is the primary problem? Which imbalance is due to compensation? pH is the clue
- If the pH is leaning toward acidosis or alkalosis the value matching this imbalance is the primary problem.