Class 6 Objectives

Upon completion of this lesson, the student will be able to:
- describe the outcomes associated with hypo and hypervolemia.
- distinguish between the different etiologies of major electrolyte imbalances.
- list the manifestations of electrolyte imbalances.
- identify normal distribution of ICF and ECF.
- state the normal serum values for Na, K, Cl, Mg, PO₄, Ca.

Starling’s Law of the Capillary

- Fluids leave (filtration) or enter (re-absorption) the capillaries depending on how the pressure in the capillary and interstitial spaces relate to one another.
- Volume re-absorbed is similar to volume filtered: “A net equilibrium”
- Regulates relative volumes of blood & interstitial fluid
Capillary Exchange
- The 5% of blood in the systemic capillaries = the bulk of blood that exchanges materials with systemic tissue cells
- Substances that pass through thin capillary walls into interstitial fluid and then into cells are: nutrients & oxygen
- Substances that are secreted by tissue cells and removed from them are: wastes & CO2

Fluids
- Distribution of total body water (TBW)
  - 60% of adult body weight is fluid
    - Gender, body mass & age considerations
  - Intracellular (ICF, within cells = 40% of body weight)
  - Extracellular (ECF, plasma, interstitial & lymph =20% of body weight)
- 1 Litre water = 2.2lb or 1 kg

Developmental Differences
- Infants & young children
  - Four areas of immature functioning
    - Increased fluid intake and output relative to size
    - Total body fluid is 20% more than adults
    - Greater surface area relative to size: > water loss through skin
    - Increased metabolic rate up to 2 years
    - Immature kidney function
      - requires more fluid to excrete wastes
Fluid Shifts
“Third Spacing”

- Excess fluid in interstitial spaces and connective tissues between cells [edema]
  - OR
  - Excess fluid in potential spaces [effusion]
    - peritoneal cavity
    - pericardial sac
    - synovial cavities of joints
    - alveoli or intra-pleural spaces

Etiology
- Caused by an increase in filtration and/or decrease in reabsorption due to altered capillary forces

Pathophysiology
- Lymph edema
- Angioedema

Mechanisms causing third spacing & edema
- Massive inflammation
- Venous obstruction
- Increased blood volume
- Low serum albumin

Hypovolemia

- A decrease in the ECF volume
- Intravascular and interstitial volume
- Isotonic volume deficit may be due to
  - Decreased intake of isotonic fluids
  - Or excessive
    - Vomiting or diarrhea
    - Hemorrhage
    - Urine output
Hypovolemia

- Hematocrit (Hct) is sensitive to fluid shifts
  - volume (%) of erythrocytes in whole blood
  - 40-54 mL/dL males
  - 37-47 mL/dL females
  - 11.2-16.5 mL/dL children
- BUN will be elevated d/t < volume
  - 11-23 mg/dL

Hypovolemia: manifestations

- Decreased tissue perfusion
  - Check capillary refill time
- Decreased blood volume
  - Hypotension, tachycardia, oliguria
- Tissue dehydration
  - Loss of skin turgor
  - Possible temperature elevation

Hypovolemia

- Nursing Responsibilities:
  - calculate I & O frequently
    - minimal urinary output = 30cc/hr
    - check urine specific gravity
  - check O2 saturations
  - draw & analyze blood gases
  - auscultate lungs (side to side)
  - check temperature distal from heart
  - give isotonic solutions (oral or IV)
    - Normal saline, dextrose, Ringer’s lactate
  - give a fluid bolus as ordered
Hypervolemia

- Excess of isotonic fluid in the intravascular and interstitial spaces
  - Isotonic fluid retention
    - Oliguric state r/t renal failure
  - Secondary Hyperaldosteronism
    - Inappropriate renal reabsorption of water and sodium, and increased renal secretion of potassium
  - Iatrogenic hypervolemia

Hypervolemia

- Path
  - An excess in blood volume results in elevated CHP and third spacing
  - Clinical manifestations
    - Edema
    - Hypertension
    - Bounding pulse
    - Increased urinary output

Major Electrolytes

- Electrolytes
  - Na+, K+, Ca++, Mg+ = cations
  - HCO-3, Cl-, PO-4 = anions
- ICF = K+
- ECF = Na+
  - osmolality
  - osmolarity
  - capillary dynamics
Hyponatremia
(Na+ < 135 mEq/L)

- Low sodium determined by blood chemistry
  - The most common electrolyte imbalance:
    - 2.5% of hospitalized patients
  - Sodium supports neuron transmission
- Mechanism and examples
  - Free water gain
  - Deficient sodium intake
  - Renal sodium loss in excess of water
  - Water in excess of sodium gain

Hyponatremia
(Na+ < 135 mEq/L)

- Manifestations
  - Water excess → rapid weight gain
  - Na+ loss → neurological symptoms
    - irritability, seizures, < LOC
  - Muscle cramps
  - Anorexia/ Nausea/Vomiting (subtle signs)
- Treat water excess
  - Fluid restriction (I&O)
- Treat sodium loss
  - Oral or IV sodium

Hypernatremia
(Na+ > 145 mEq/L)

- Etiology
  - Water loss or sodium gains
    - Elderly / or comatose patients
    - Na+ intake > water intake
    - Diabetes insipidus (excessive fluid loss) < production of ADH
    - Damage to hypothalamic thirst center?
      - Tumor or CVA?
- Manifestations
  - Thirst, dry tongue
  - Restlessness; < LOC; Coma; Intracranial bleeds
  - Weight changes
Hypernatremia
(Na+ >145 mEq/L)

Treatment (Rx)
- Dilute Na+ and promote secretion
- Fluids (5% D/W) and diuretics
- Always check LOC
  - loose alertness & orientation
  - sepsis, head injury, intracranial bleed
- Sodium pulls fluid to cause blood vessels to burst

Potassium (K+)
3.5-5.0 mEq/L

- Primarily an intracellular ion; small amount in plasma is essential for normal neuromuscular and cardiac function
- Maintained by the cellular sodium-potassium pump
- K+ changes in altered excitability of muscles
- Eliminated by kidneys
  - renal problems causes hyperkalemia
  - Insulin: causes K+ to move from ECF to ICF
  - Acidosis, trauma to cells, and exercise
- cause K+ to move from ICF to ECF:

Hyperkalemia
(K+ > 5.5 mEq/L)

- Major Causes
  - Increased potassium intake
    - excess or rapid delivery of K+
    - penicillin containing K+
    - Massive blood transfusion with irradiated packed red cells
      Buntain and Pabaal (1999)
  - Shift of K+ from the ICF to ECF
    - Acidosis, uncontrolled DM
    - increased cell lysis (e.g. cytotoxic drugs)
  - Decreased renal excretion
    - Digitalis toxicity, renal failure, oversecretion of potassium sparing diuretics (spiroaldactone)
Hyperkalemia
$K^+ > 5.5 \text{ mEq/L}$

- Mainfestations:
  - Weak skeletal muscles/paralysis $> 8 \text{ mEq/L}$
  - Paresthesias
  - Irritability
  - Abdominal cramping with diarrhea
  - Irregular pulse $\rightarrow$ EKG changes $\rightarrow$ Cardiac standstill
  - EKG changes
    - Peaked T-waves and a shortened QT interval occur
    - Depressed ST segment and widened QRS interval

Hyperkalemia
$K^+ > 5.5 \text{ mEq/L}$

- Management
  - Eliminate K+
  - Diuretics (Lasix)
  - Dialysis
  - Kayexalate
  - Increased fluids
  - IV insulin
  - Cardiac monitor

Hypokalemia
$K^+ < 3.5 \text{ mEq}$

- Major causes
  - $<$ intake of potassium or $>$ cellular uptake of potassium
    - Insulin: promotes K+ uptake by muscle & liver cells
    - When insulin is given: K+ goes into ICF $\rightarrow$ < serum K+ level
  - Uncontrolled diabetes mellitus:
    - Glucose: osmotic diuretic $\rightarrow$ potassium via urinary excretion
    - Diabetic Ketoacidosis: H+ ions in ECF $\rightarrow$ exchange across cell membranes $\rightarrow$ K+ is first elevated and then K+ stores are excreted via urine
Hypokalemia
K+ < 3.5 mEq

Epinephrine: promotes uptake into cells
- stress, acute illness, hypoglycemia
Excessive GI loss: diarrhea & ng suction
- metabolic alkalosis
Diuretics: Lasix (watch K+ levels)
Excessive renal excretion
- elevated aldosterone
- diuresis

Signs & Symptoms
- Muscle weakness: hypotonia
- Cardiac dysrhythmias (T-wave inversion or PVCs)
- Atony of smooth muscle
  - intestinal distention
  - constipation
  - paralytic ileus
  - urinary retention
- Confusion or disorientation

Management
- Administer KCL slowly and accurately
  - dilute properly with other IV fluids
    - 10 mEqs/1 hour
  - can cause pain and necrosis of veins
    - use central IV line for large rapid amounts
- Bring pt out of immediate danger & restore gradually
- Consider discontinuing diuretic therapy
- Consider chloride for metabolic alkalosis
Calcium
8.8 - 10 mg/dL

- Major functions:
  - Transmission of nerve impulses
  - Cardiac muscle contractions
  - Blood clotting factor
  - Formation of teeth & bone
  - Muscle contraction

- Requires:
  - Vitamin D
  - Parathyroid hormone (PTH)
  - Calcitonin from thyroid gland

http://lpi.oregonstate.edu/infocenter/minerals/calcium/capth.html

Hypocalcemia
Ca+ < 8.5 mg/dL

- Nutritional deficiency of calcium or Vitamin D
- Parathyroid deficiency d/t surgical removal
- Children & elderly d/t dietary deficiency
- Bone cancer: excess bone formation
  - "Hungry Tumor" syndrome
  - Treatment of prostate cancer with estrogen depletes ECF calcium levels
- Blood transfusions
  - preserve blood with citrate & this binds with calcium
Hypocalcemia
Ca⁺ < 8.5 mg/dL

- Manifestations:
  - Chvostek’s sign
  - Trousseau’s sign
  - Dysrhythmias: < threshold for depolarization in cardiac cells
  - Paresthesias: “pins & needles”
  - Abdominal cramping & diarrhea
  - Tetany, Seizures (severe hypocalcemia)

Hypercalcemia
Ca⁺ > 10.5 mg/dL

- Malignancies or hyperparathyroidism
  - PTH secreting tumor (adenoma)
  - Skeletal calcium secreted into bloodstream
  - Metastatic breast cancer & multiple myeloma
  - Prolonged immobility: loose Ca⁺ from bone into blood
  - Osteoporosis: Ca⁺ is liberated into bloodstream
  - Manifestations:
    - lethargy/ weakness/ fatigue/ constipation
    - pathogenic fractures → calcium loss from bone

Phosphate (PO₄⁻)
3.0 - 4.5 mg/dL or 1.8 - 2.6 mEq/L

- Stored with Ca⁺ in bones & teeth
  - PO₄⁻ & Ca⁺ are equilibrated
    - > Ca⁺ = < PO₄⁻ excreted by kidneys
- Hypophosphatemia: < 2.7 mg/dL
  - clinical manifestations
    - confusion, weakness, seizures, numbness, coma
- Hyperphosphatemia: > 4.5 mg/dL
  - common in renal failure
## Magnesium (Mg+): 1.5 - 2.5 mEq/L

- Second most abundant ICF cation
- Essential for neuromuscular function
- Changes in serum Mg+ levels affect other electrolytes
- **Hypermagnesemia:** > 2.5mEq/L
  - Muscle weakness, bradycardia, hypotension, nausea & vomiting
- **Hypomagnesemia:** < 1.5mEq/L
  - Increased neuromuscular irritability
    - Muscle spasms, tetany, seizures

## References