Disorders of Fluid & Electrolyte Balance

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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, \( \text{PO}_4 \), 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
Fluid Shifts
“Third Spacing”

- 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
Hypovolemic

- 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

■ Patho
  ■ 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+
  - osmosis
  - 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) $\text{ADH} < \text{production of ADH}$
  - 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 → ICF
    - **Acidosis, trauma to cells, and exercise**
      - cause K+ to move from ICF → 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 Pabari (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, overuse of potassium sparing diuretics (spiroaldactone)
Hyperkalemia
K+ > 5.5 mEq/L

- Manifestations:
  - weak skeletal muscles/ paralysis > 8 mEq/L
  - paresthesias
  - irritability
  - abdominal cramping with diarrhea
  - irregular pulse EKG changes 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 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 → < serum K+ level
  - Uncontrolled diabetes mellitus:
    - > Glucose: osmotic diuretic → > potassium via urinary excretion
    - Diabetic Ketoacidosis: → H+ ions in ECF → exchange across cell membranes → 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
Hypokalemia
K+ < 3.5 mEq

- 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
Hypokalemia
K+ < 3.5 mEq

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 prostrate 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 (PO$_4^-$)
3.0 - 4.5mg/dL or 1.8 - 2.6 mEq/L

- Stored with Ca$^+$ in bones & teeth
- PO$_4^-$ & Ca$^+$ are equilibrated
  - $> \text{Ca}^+ = < \text{PO}_4^-$
  - 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 effect other electrolytes

- Hypermagnesemia: > 2.5mEq/L
  - muscle weakness, bradycardia, hypotension, nausea & vomiting

- Hypomagnesemia:< 1.5mEq/L
  - increased neuromuscular irritability
    - Muscle spasms, tetany, seizures
References

