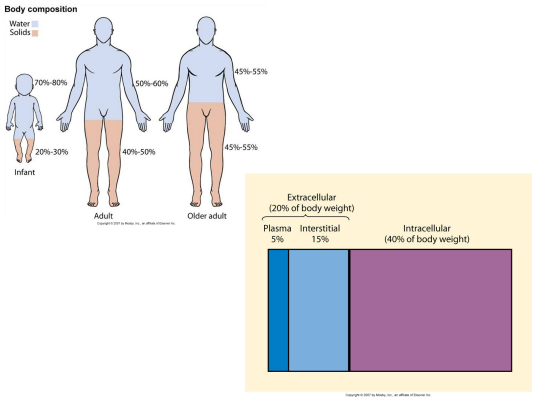
Fluid and Electrolytes & Renal Disorders

Topics for the Day

- Fluids and Electrolytes: review of normal physiology *
- Fluid imbalances *
- Electrolyte Disturbances *
- Beginning acid-base imbalance *
- Renal Disorders
- Fluid Types *



Electrolytes

- Solutes that form ions (electrical charge)
  - Cation (+)
  - Anion (-)
- Major body electrolytes:
  - Na+, K+, Ca++, Mg++
  - Cl-, HCO_3-, HPO_4--, SO_4-

Fluid & Electrolytes

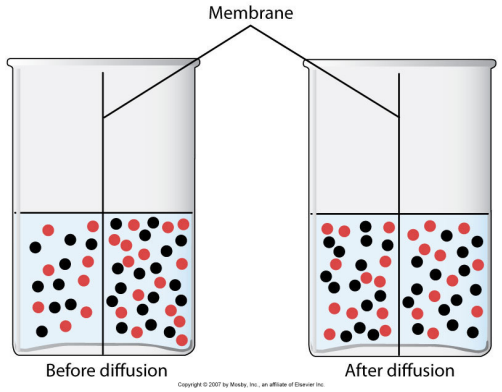
- Fluid: Water
- Electrolytes: ions dissolved in water
  - Sodium, potassium, bicarbonate, etc.
  - Also used medically for non ions (glucose)
- Osmolarity – osmols/kg solvent
- Osmolality – osmols/liter solution
  - In clinical practice are used interchangeably

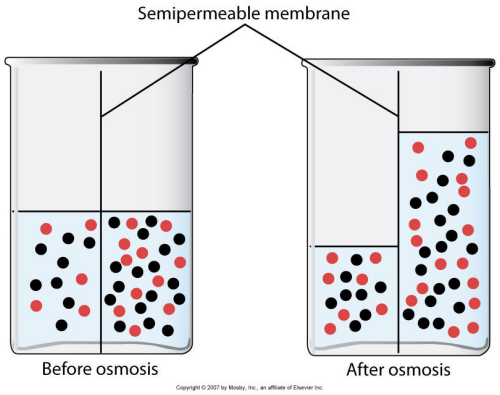
Electrolyte Distribution

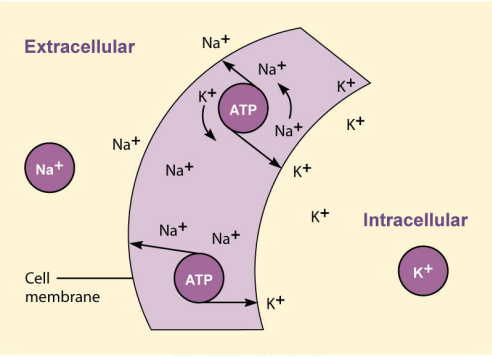
- Major ICF ions
  - K+
  - HPO_4--
- Major ECF ions
  - NA+
  - CL-, HCO_3-
- Intravascular (IVF) vs Interstitial (ISF)
  - Similar electrolytes, but IVF has proteins

Mechanisms Controlling Fluid and Electrolyte Movement

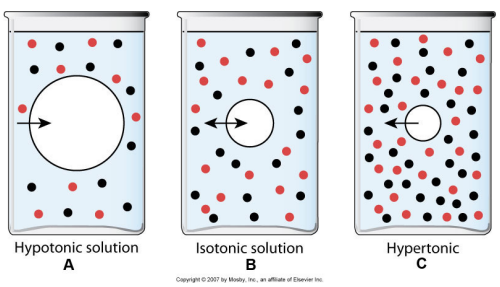
- Diffusion
- Selective Permeability
- Facilitated diffusion
- Active transport
- Osmosis
  - 2*Na + BUN + Glucose/18
- Hydrostatic pressure
- Oncotic pressure







Cells are selectively permeable



Sodium is the largest Determinant of Osmolality

- Na+: 135 – 145 mEq/L
- Ca+: 8.5 – 10.5 mEq/L
- K+: 3.5 – 5 mEq/L
- Osmolality~ 2*(Na+) = 2*(135 - 145 mEq/L)
  - Normal (Isotonic) 280 – 300
  - Low (hypotonic) < 280
  - High (hypertonic) > 300

Fluid Exchange Between Capillary and Tissue: Sum of Pressures

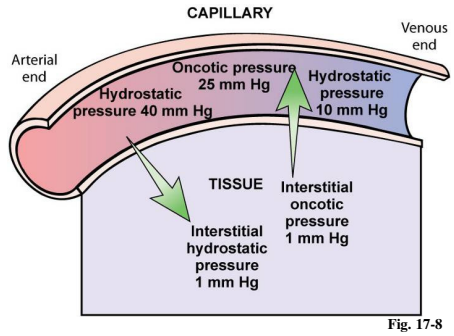


Fig. 17-8

Fluid Shifts

- Plasma to interstitial fluid shift results in edema
  - Elevation of hydrostatic pressure
  - Decrease in plasma oncotic pressure
  - Elevation of interstitial oncotic pressure

Fluid Movement between ECF and ICF

- Water deficit (increased ECF)
  - Associated with symptoms that result from cell shrinkage as water is pulled into vascular system
- Water excess (decreased ECF)
  - Develops from gain or retention of excess water

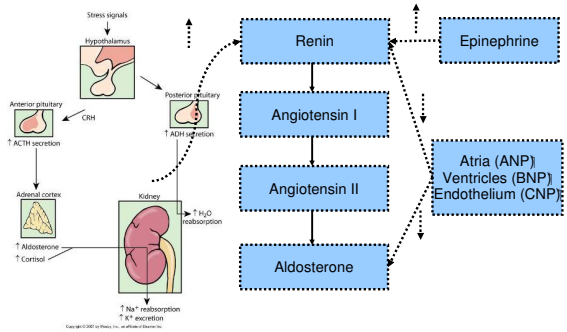
Fluid Spacing

- First spacing: Normal distribution of fluid in ICF and ECF
- Second spacing: Abnormal accumulation of interstitial fluid (edema)
- Third spacing: Fluid accumulation in part of body where it is not easily exchanged with ECF (e.g. ascites)

Regulation of Water Balance

- Hypothalamic regulation
- Pituitary regulation
- Adrenal cortical regulation
- Renal regulation
- Cardiac regulation
- Gastrointestinal regulation
- Insensible water loss

F&E Balance

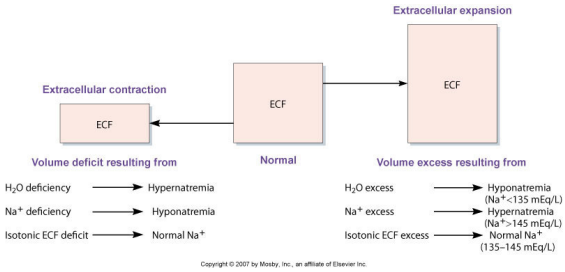


Fluid Status Indicators

- Physical exam
  - Mucous membranes
  - Turgor
- Blood
  - Hematocrit
- Plasma
  - BUN
- Urine
  - Output (volume)
  - Specific Gravity*
    - •< 1.003: less conc
    - •> 1.030: more conc
- Electrolytes

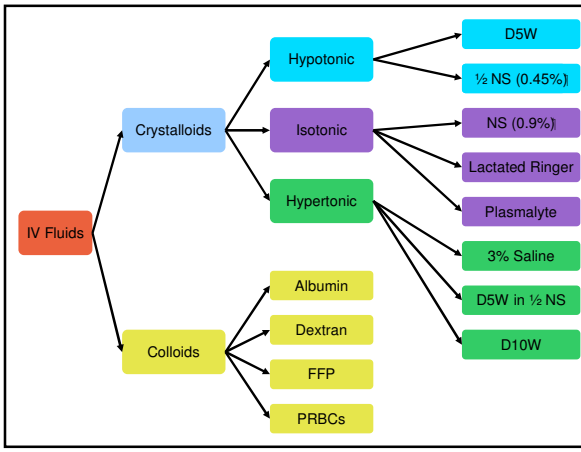
F&E Balance

- Fluids
  - Normal
  - Contracted
  - Expanded
- Electrolytes (Sodium!!!)
  - Isotonic
  - Hypertonic
  - Hypotonic



Extracellular Fluid Deficit

- Causes
  - Inadequate intake, diuresis, excess sweating, burns, diarrhea, vomiting, hemorrhage
- Treatment
  - •Stop underlying disorder
  - •Replace fluids appropriately
  - •Treat complications



Volume Deficit

- Isotonic Deficit
  - Electrolyte drinks
  - Isotonic saline (0.9%) injection
- Hypertonic Deficit
  - Drinking Water
  - Hypotonic saline (0.45%) injection, D5W
- Hypotonic Deficit
  - Isotonic Saline
  - Hypertonic saline (3%)

Extracellular Fluid Excess

- Causes
  - The Three failures: heart, liver, kidney
- Treatment
  - Remove fluid --> ????
  - Treat underlying disorder

Electrolyte Normal Values (memorize!!!!!)

- Sodium 135 – 145
- Potassium 3.5 – 5
- Chloride 106 – 106
- Calcium 9 – 11
- BUN 10 – 20
- Creatinine 0.7 – 1.2
- CO2 (really bicarb) 22 – 26
- Magnesium: 1.5 – 2.5

Electrolyte Disorders: Signs & Symptoms (most common*)

Electrolyte	Excess	Deficit
Sodium (Na)	Hypernatremia Thirst CNS deterioration Increased interstitial fluid	Hyponatremia CNS deterioration
Potassium (K)	Hyperkalemia Ventricular fibrillation ECG changes CNS changes Weakness	Hypokalemia Bradycardia ECG changes CNS changes Fatigue

Electrolyte Disorders Signs and Symptoms

Electrolyte	Excess	Deficit
Calcium (Ca)	Hypercalcemia Thirst CNS deterioration Increased interstitial fluid	Hypocalcemia Tetany Chvostek's, Trousseau's signs Muscle twitching CNS changes ECG changes
Magnesium (Mg)	Hypermagnesemia Loss of deep tendon reflexes (DTRs) Depression of CNS Depression of neuromuscular function	Hypomagnesemia Hyperactive DTRs CNS changes

Hypernatremia

- Manifestations
  - Thirst, lethargy, agitation, seizures, and coma
- Impaired LOC
- Produced by clinical states
  - Central or nephrogenic diabetes insipidus
- Reduce levels gradually to avoid cerebral edema

Hypernatremia Treatment

- Treat underlying cause
- If oral fluids cannot be ingested, IV solution of 5% dextrose in water or hypotonic saline
- Diuretics if necessary

Hyponatremia

- Results from loss of sodium-containing fluids
  - Sweat, diarrhea, emesis, etc.
- Or from water excess
  - Inefficient kidneys
  - Drowning, excessive intake
- Manifestations
  - Confusion, nausea, vomiting, seizures, and coma

Treatment

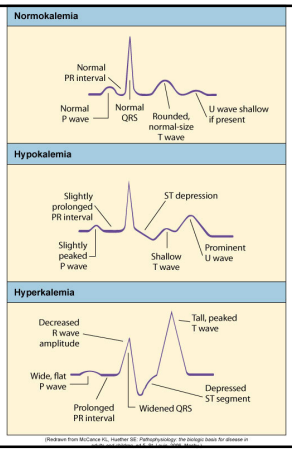
- Oral NaCl
- If caused by water excess
  - Fluid restriction is needed
- If Severe symptoms (seizures)
  - Give small amount of IV hypertonic saline solution (3% NaCl)
- If Abnormal fluid loss
  - Fluid replacement with sodium-containing solution

Hyperkalemia

- High serum potassium caused by
  - Massive intake
  - Impaired renal excretion
  - Shift from ICF to ECF (acidosis)
  - Drugs
- Common in massive cell destruction
  - Burn, crush injury, or tumor lysis
- False High: hemolysis of sample

Hyperkalemia

- Manifestations
  - Weak or paralyzed skeletal muscles
  - Ventricular fibrillation or cardiac standstill
  - Abdominal cramping or diarrhea



Treatment

- Emergency: Calcium Gluconate IV
- Stop K intake
- Force K from ECF to ICF
  - IV insulin
  - Sodium bicarbonate
- Increase elimination of K (diuretics, dialysis, Kayexalate)

Hypokalemia

- Low serum potassium caused by
  - Abnormal losses of K^+ via the kidneys or gastrointestinal tract
  - Magnesium deficiency
  - Metabolic alkalosis

Hypokalemia

- Manifestations
  - Most serious are cardiac
  - Skeletal muscle weakness
  - Weakness of respiratory muscles
  - Decreased gastrointestinal motility

Hypokalemia

- KCl supplements orally or IV
- Should not exceed 10 to 20 mEq/hr
  - To prevent hyperkalemia and cardiac arrest
- No Pee no Kay!!!!!!!!!!!!!!!!!!!!!!!!!!

Calcium

- Obtained from ingested foods
- More than 99% combined with phosphorus and concentrated in skeletal system
- Inverse relationship with phosphorus
  - Otherwise…

Calcium

- Bones are readily available store
- Blocks sodium transport and stabilizes cell membrane
- Ionized form is biologically active
  - Bound to albumin in blood
  - Bound to phosphate in bone/teeth
  - Calcified deposits

Calcium

- Functions
  - Transmission of nerve impulses
  - Myocardial contractions
  - Blood clotting
  - Formation of teeth and bone
  - Muscle contractions

Calcium

- Balance controlled by
  - Parathyroid hormone
  - Calcitonin
  - Vitamin D/Intake
- Bone used as reservoir

Hypercalcemia

- High serum calcium levels caused by
  - Hyperparathyroidism (two thirds of cases)
  - Malignancy (parathyroid tumor)
  - Vitamin D overdose
  - Prolonged immobilization

Hypercalcemia

- Manifestations
  - Decreased memory
  - Confusion
  - Disorientation
  - Fatigue
  - Constipation

Treatment

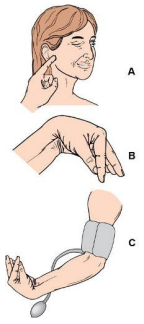
- Excretion of Ca with loop diuretic
- Hydration with isotonic saline infusion
- Synthetic calcitonin
- Mobilization

Hypocalcemia

- Low serum Ca levels caused by
  - Decreased production of PTH
  - Acute pancreatitis
  - Multiple blood transfusions
  - Alkalosis
  - Decreased intake

Hypocalcemia

- Manifestations
  - Weakness/Tetany
  - Positive Trousseau's or Chvostek's sign
  - Laryngeal stridor
  - Dysphagia
  - Tingling around the mouth or in the extremities



Treatment

- Treat cause
- Oral or IV calcium supplements
  - Not IM to avoid local reactions
- Treat pain and anxiety to prevent hyperventilation-induced respiratory alkalosis

Phosphate

- Primary anion in ICF
- Essential to function of muscle, red blood cells, and nervous system
- Deposited with calcium for bone and tooth structure

Phosphate

- Involved in acid–base buffering system, ATP production, and cellular uptake of glucose
- Maintenance requires adequate renal functioning
- Essential to muscle, RBCs, and nervous system function

Hyperphosphatemia

- High serum PO_4^{3-} caused by
  - Acute or chronic renal failure
  - Chemotherapy
  - Excessive ingestion of phosphate or vitamin D
- Manifestations
  - Calcified deposition: joints, arteries, skin, kidneys, and corneas
  - Neuromuscular irritability and tetany

Hyperphosphatemia

- Management
  - Identify and treat underlying cause
  - Restrict foods and fluids containing PO_4^{3-}
  - Adequate hydration and correction of hypocalcemic conditions

Hypophosphatemia

- Low serum PO_4^{3-} caused by
  - Malnourishment/malabsorption
  - Alcohol withdrawal
  - Use of phosphate-binding antacids
  - During parenteral nutrition with inadequate replacement

Hypophosphatemia

- Manifestations
  - CNS depression
  - Confusion
  - Muscle weakness and pain
  - Dysrhythmias
  - Cardiomyopathy

Hypophosphatemia

- Management
  - Oral supplementation
  - Ingestion of foods high in PO_4^{3-}
  - IV administration of sodium or potassium phosphate

Magnesium

- 50% to 60% contained in bone
- Coenzyme in metabolism of protein and carbohydrates
- Factors that regulate calcium balance appear to influence magnesium balance

Magnesium

- Acts directly on myoneural junction
- Important for normal cardiac function

Hypermagnesemia

- High serum Mg caused by
  - Increased intake or ingestion of products containing magnesium when renal insufficiency or failure is present

Hypermagnesemia

- Manifestations
  - Lethargy or drowsiness
  - Nausea/vomiting
  - Impaired reflexes***
  - Respiratory and cardiac arrest

Hypermagnesemia

- Management
  - Prevention
  - Emergency treatment
    - IV CaCl or calcium gluconate
  - Fluids to promote urinary excretion

Hypomagnesemia

- Low serum Mg caused by
  - Prolonged fasting or starvation
  - Chronic alcoholism
  - Fluid loss from gastrointestinal tract
  - Prolonged parenteral nutrition without supplementation
  - Diuretics

Hypomagnesemia

- Manifestations
  - Confusion
  - Hyperactive deep tendon reflexes
  - Tremors
  - Seizures
  - Cardiac dysrhythmias

Hypomagnesemia

- Management
  - Oral supplements (MgO, $MgSO_4$)
  - Increase dietary intake
  - Parenteral IV or IM magnesium when severe

Elemenary Acid-Base balance

- Buffer systems
  - Carbonic Acid
  - Bicarbonate
- Metabolic: bicarb
  - low → metabolic acidosis
  - high → metabolic alkalosis
- Respiratory: carbon dioxide

Metabolic Panel and acid-base

- "CO2" on a BMP means bicarb!!!!!!
- normal 22 – 26
- <22 = ?
- >26 =?

Metabolic Acidosis Manifestat

- **Acidosis causes HYPERKALEMIA!!!**
- **Neuro: Drowsiness, Confusion, H/A, coma**
- **CV: ↓BP, dysrhythmia (K+), dilation**
- **GI: NVD, abd pain**
- **Resp: increased resp (comp)**

Metabolic Alkalosis Manifestat

- **Alkalosis causes HYPOKALEMIA!!!**
- **Neuro: Dizziness, Irritability, Nervous, Confusion**
- **CV: ↑HR, dysrhythmia (K+)**
- **GI: NV, anorexia**
- **Neuromuscular: Tetany, tremor, paresthesia, seizures**
- **Resp: decreased resp (comp)**

MEMORIZE Arterial pH, PaCO2, HCO_3-!!!!!!!

TABLE 17-15 Normal Arterial and Venous Blood Gas Values

Parameter	Arterial	Venous
pH	7.35-7.45	7.35-7.45
$PaCO_2$	35-45 mm Hg	40-45 mm Hg
Bicarbonate (HCO_3^-)	22-26 mEq/L (mmol/L)	22-26 mEq/L (mmol/L)
PaO_2*	80-100 mm Hg	40-50 mm Hg
Oxygen saturation	96%-100%	60%-85%
Base excess	±2.0 mEq/L	±2.0 mEq/L

*Decreases above sea level and with increasing age.

Interpretation of ABGs

- **Diagnosis in six steps**
  - **Evaluate pH**
  - **Analyze $PaCO_2$**
  - **Analyze HCO_3^-**
  - **Determine if Balanced or Unbalanced**
  - **Determine if CO_2 or HCO_3^- matches the alteration**
  - **Decide if the body is attempting to compensate**

Interpretation of ABG

1. **pH over balance**
2. **PaCO2 = "respiratory" balance**
3. **HC03- = "metabolic" balance**
4. **If all three normal = balanced**
5. **Match direction. e.g., if pH and PaCO2 are both acidotic, then primary respiratory acidosis**
6. **If other is opposite, then partial compensation; if pH normal, then fully compensated.**

Interpretation of ABGs

- **pH 7.36**
- **$PaCO_2$ 67 mm Hg**
- **PaO_2 47 mm Hg**
- **HCO_3 37 mEq/L**
- **What is this?**

Interpretation of ABGs

- pH 7.18
- $PaCO_2$ 38 mm Hg
- PaO_2 70 mm Hg
- HCO_3^- 15 mEq/L
- What is this?

Interpretation of ABGs

- pH 7.60
- $PaCO_2$ 30 mm Hg
- PaO_2 60 mm Hg
- HCO_3^- 22 mEq/L
- What is this?

Interpretation of ABGs

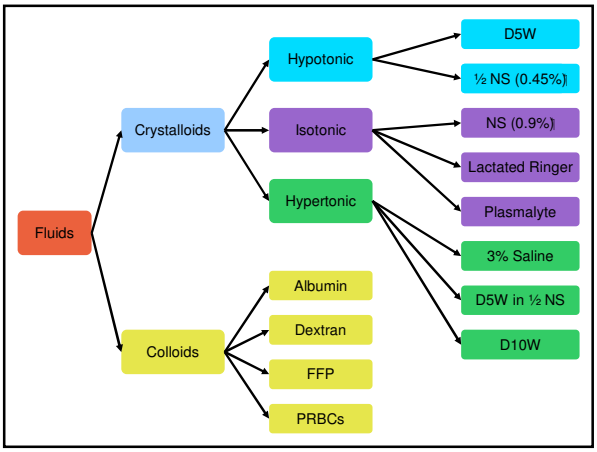
- pH 7.58
- $PaCO_2$ 35 mm Hg
- PaO_2 75 mm Hg
- HCO_3^- 50 mEq/L
- What is this?

Interpretation of ABGs

- pH 7.28
- $PaCO_2$ 28 mm Hg
- PaO_2 70 mm Hg
- HCO_3^- 18 mEq/L
- What is this ?

Putting it all together

- Always pay attention to
  - Patient history
  - Vital signs
  - Symptoms and physical exam findings
  - Lab Values
- Always ask:
  - What is causing this abnormal finding?
  - What can be done to fix it?



IV Fluids

- Purposes
  1. Maintenance
     - When oral intake is not adequate
  2. Replacement
     - When losses have occurred

D5W (Dextrose = Glucose)

- Hypotonic
- Provides 170 cal/L
- Free water
  - Moves into ICF
  - Increases renal solute excretion
- Used to replace water losses and treat hyponatremia
- Does not provide electrolytes

Normal Saline (NS)

- Isotonic
- No calories
- More NaCl than ECF
- 30% stays in IVF
  - 70% moves out of IV space

Normal Saline (NS)

- Expands IV volume
  - Preferred fluid for immediate response
  - Risk for fluid overload higher
- Does not change ICF volume
- Blood products
- Compatible with most medications

Lactated Ringer's

- Isotonic
- More similar to plasma than NS
  - Has less NaCl
  - Has K, Ca, PO_4^{3-}, lactate (metabolized to HCO_3^-)
    - CONTRAINDICATED in lactic acidosis
- Expands ECF

D5 ½ NS

- Hypertonic
- Common maintenance fluid
- KCl added for maintenance or replacement

D10W

- Hypertonic
- Max concentration of dextrose that can be administered in peripheral IV
- Provides 340 kcal/L
- Free water
- Limit of dextrose concentration may be infused peripherally

Plasma Expanders

- Stay in vascular space and increase osmotic pressure
- Colloids (protein solutions)
  - Packed RBCs
  - Albumin
  - Plasma
  - Dextran