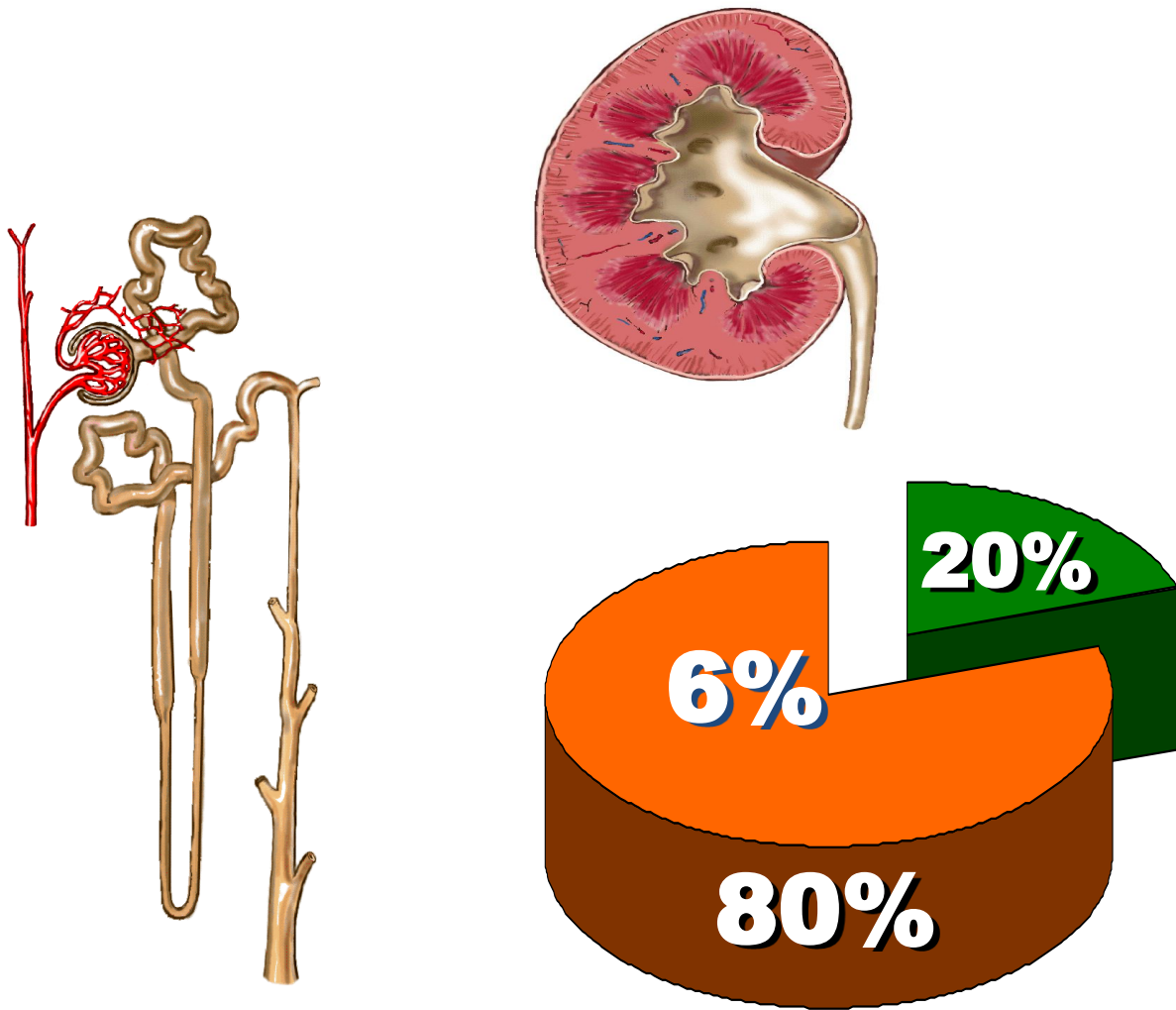
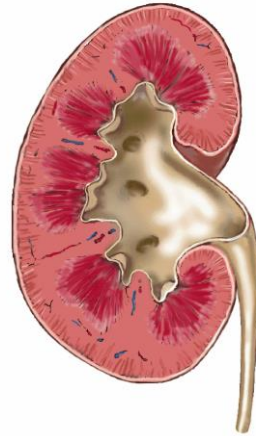


# Renal & Electrolyte Disturbances



# RENAL



## I. INTRODUCTION

**AACN-CCRN/CCRN-E 6%**

- ◆ Chronic Renal Failure
- ◆ Acute Renal Failure
- ◆ Life Threatening Electrolyte Disturbances

## II. RENAL PHYSIOLOGY

### Major Functions of the Kidney

1. Excretion of Metabolic Wastes
2. Urine Formation
3. Acid-Base Balance Regulation
4. Electrolyte Regulation
5. Fluid Regulation
6. Blood Pressure Regulation
7. Erythropoietin Secretion/Anemia Regulation

### Renal Assessment

1. Blood Work
  - ✓ Blood Urea Nitrogen
  - ✓ Creatinine
  - ✓ Serum Electrolytes
  - ✓ Hgb & Hct
  - ✓ Serum Albumin
  - ✓ Serum Osmolality

### **Blood Urea Nitrogen: BUN: 5.0 – 25 mg/dL**

Urea is formed in the liver along with CO<sub>2</sub> as a waste by product of protein metabolism. It is carried by the blood and excreted by the renal system. **Elevated BUN** levels are significant for either increased protein catabolism or decreased renal excretion of urea. Situations, which would increase protein catabolism, include high protein diets, GI bleeding (protein from blood is broken down), DKA, burns and cancer. Any pre-renal (shock state, poor renal perfusion) or intra-renal failure (nephrotoxic medications or kidney diseases) will decrease the GFR and therefore urea excretion. The elevation of the metabolic waste products can cause fatigue, muscle weakness, and seizures. Volume status of the patient can also affect the BUN. **Treatment** is related to the cause of the elevation, which would include hydration, stopping protein catabolism, and/or dialysis.

**Creatinine: 0.6 – 1.5 mg/dL slightly lower in females, children and elderly**

Creatinine is a waste product of creatinine phosphate breakdown. Creatinine phosphate is a high-energy compound found in skeletal muscle tissue and is released during muscle breakdown. There is no biological use for creatinine so the kidneys excrete it all. Creatinine level is a reflection of glomerular filtration and a very good indicator of renal function. It will be elevated in renal disease and muscle wasting disorders (MG, MD, acromegaly), CHF, shock, and rhabdomyolysis. High levels of ascorbic acid and cephalosporin antibiotics may cause a false positive elevation. Treatment is to restore kidney function or dialysis.

**BUN:Creatinine Ratio: 10:1 – 20:1**

Helpful to identify if azotemia is from a renal or nonrenal cause. Elevated creatinine is indicative of renal failure whereas elevated BUN could be caused from a variety of conditions including dehydration.

**Creatinine Clearance Test:**

**Male: 95 – 135 ml/min**

**Female: 85 – 125ml/min**

Indicative of glomerular filtration rate. Compares the amount of creatinine in the urine to the amount in the blood over the same time period.

$$\frac{\text{Urine Creatinine X Urine Volume}}{\text{Serum Creatinine}} = \text{Creatinine clearance rate}$$

1. Urine Assessment

- ✓ Volume & Concentration
- ✓ Urinalysis (see table)
- ✓ Renal Clearance Studies

3. Other Tests

- ✓ KUB X-ray
- ✓ Renal Arteriography
- ✓ IVP
- ✓ CT
- ✓ Ultrasound
- ✓ Biopsy

**III. CHRONIC RENAL FAILURE or Chronic Kidney Disease**

Acute renal failure affects many body systems.

Chronic renal failure affects EVERY body system.

Chronic renal failure (CRF) is a permanent, irreversible condition in which the kidneys cease to remove metabolic wastes and excessive water from the blood. (ESRF, ESRD, CRD, CKD)

- ◆ Etiology - more than 100 different diseases can cause RF
  - ✓ Glomerular Disease
  - ✓ Tubular Diseases
  - ✓ Vascular Kidney Diseases
  - ✓ Urinary Tract Disease
  - ✓ Infection (kidney)
  - ✓ Systemic Vascular Diseases
  - ✓ Metabolic Diseases
  - ✓ Connective Tissue Diseases

#### **A. Terms**

1. Azotemia – Nitrogenous Waste Products in the Bloodstream
2. Uremic Syndrome – Systemic and Laboratory Manifestations of ESRD
3. Renal Replacement Therapy – Treatment Options

#### **B. Stages of Renal Failure**

1. Diminished Renal Reserve
2. Renal Insufficiency
3. End Stage Renal Disease (ESRD) – Affects every system in the body

##### ◆ **Renal Alterations**

- Disruptions in GRF
- Abnormal urine production and water excretion
- Electrolyte Imbalances
- Metabolic Abnormalities

##### ◆ **Metabolic Alterations**

- Urea & Creatinine
- Sodium
- Potassium
- Acid-Base Balance
- Calcium & Phosphate

##### ◆ **Cardiac Alterations** (CV disease is the leading cause of death for ESRD pts)

- Hypertension
- Congestive Heart Failure
- Uremic Pericarditis

##### ◆ **Hematologic Alterations**

- Anemia
- Decreased Erythropoietin

- Decreased RBC Survival
- Iron and Folic Acid Def
- Bleeding

#### ◆ **Gastrointestinal Alterations**

- Mouth Inflammation (ulcers)
- Anorexia
- Nausea
- Vomiting
- Hiccups
- Uremic Colitis
- Diarrhea or Constipation

#### ◆ **Neurologic Alterations**

- Lethargy and Daytime Drowsiness
- Decreased Attention Span
- Insomnia
- Weakness in Extremities
- Parestheses
- Seizures and Coma

#### ◆ **Pulmonary Alterations**

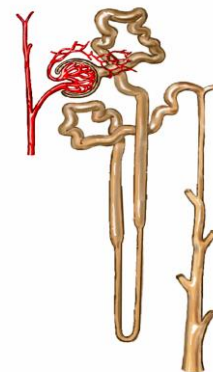
- Respiratory Effort Changes – Kussmaul’s Breathing
- Breath Smells Like Urine – Uremic Halitosis
- Deep Sighing
- Yawning
- Shortness of Breath

#### ◆ **Integumentary Manifestations**

- ◆ Skin Oils and Turgor Decreased
- ◆ Pruritus (itching)
- ◆ Ecchymoses (bruises)
- ◆ Purpura (purple patches)
- ◆ Uremic Frost

### C. **Treatment:** Renal Replacement Therapies

- ◆ Medications
- ◆ Hemodialysis
- ◆ Peritoneal Dialysis
- ◆ Renal Transplant



#### IV. ACUTE RENAL FAILURE: Acute Kidney Disease

**A. Pathophysiology:** a sudden deterioration in renal function usually associated with the loss of the kidney's ability to concentrated urine, as well as the retention and accumulation of nitrogen wastes.

- ◆ Decreased Glomerular Filtration Rate
- ◆ Interstitial Inflammatory Changes
- ◆ Tubular Lumen Obstruction
- ◆ Oliguric, < 400 mL/day
- ◆ Non-Oliguric, Large Amt of Dilute Urine

**B. Common Etiologies**

- ◆ Severe Hypotension (all forms of shock)
- ◆ Heart Failure
- ◆ Dehydration
- ◆ Nephrotoxic Agents
- ◆ Complication of Infection
- ◆ Severe Hypertension

Category	Cause/Conditions
<b>Pre Renal</b>	Volume: Dehydration
The problem is not actually with the kidneys but with perfusion (blood flow) to the kidneys	Ischemia: hypovolemic shock, cardiogenic shock, septic shock, hypoxemia, low cardiac output, heart failure, severe hypertension
	Hemodynamic instability, multisystem organ failure, trauma
<b>Post Renal</b>	Urethral: Stricture, Prostatic Hypertrophy
The problem is not actually with the kidneys but after the kidneys.	Urethral: fibrosis, calculi, blood clots
	Bladder: neurogenic problems, neoplasms/cancer, obstruction
	Trauma
<b>Renal</b> The problem is in the kidney itself effecting function. Kidney diseases	Glomerulus: acute glomerulonephritis, acute cortical necrosis, hepatorenal syndrome
	Tubule: acute tubular necrosis, acute pyelonephritis

	Nephrotoxins: heavy metals, antibiotics, radiographic contrast media, anesthetics
	Pigments: hemoglobin, myoglobin
	Trauma, intravenous hemolysis, rhabdomyolysis

### C. Differentiating Pre-Renal From Renal Diagnosis for ATN

Assessment	Pre-Renal (Hypoperfusion)	Renal (Tissue Damage)
Urinary Sodium	< 20mEq/L	> 20 mEq/L
BUN:Creatinine Ratio	> 20:1	10-20:1 (normal)
Responds (increase in UO) to volume or diuretics	Positive Response	No Response

### D. Phases of ARF

#### ◆ Onset Phase

- BUN & Creatinine Rising
- Urine Output Dropping
- Diuretics Still Working
- Acidosis Beginning

#### ◆ Oliguric Phase

- Alteration in Electrolyte Balance
- Potential for Infection
- Alteration in A-B Balance
- Alteration in Nutrition Status
- Uremic Syndrome
- Alteration in Pulmonary Status
- Alteration in GI Function

#### ◆ Diuretic Phase

- Fluid Loss
- Goal is to maintain adequate fluid balance and regulate electrolytes
- Alteration in Electrolytes

#### ◆ Recovery Phase

- Goal is Supportive Care
- Prevent Further Insults
- Assessment of Renal Function

- Keep patient well hydrated and free from infection
- Prevent Further Insults

**E. Systemic Response to Acute Failure**

- ◆ Hypertension
- ◆ Tachycardia
- ◆ Decreased UO
- ◆ Lethargy
- ◆ Pulmonary Edema
- ◆ Depends on Type
- ◆ Very Similar to Chronic Failure

**F. Nursing Care Needs**

- ◆ Ensure Hydration
- ◆ Fluid Challenges
- ◆ Diuretics
- ◆ Monitor Fluid Status
- ◆ Weigh Daily & I & O
- ◆ Monitor Electrolyte Imbalance
- ◆ Support Renal Function

**G. Treatment Options/Alternatives**

- ◆ Drug Therapy
- ◆ Diet Therapy
- ◆ Renal Replacement Therapies (CVVH, Hemodialysis, Peritoneal Dialysis)
- ◆ Renal Transplant

**H. Support Therapy for ATN**

<b>Pt Problem</b>	<b>Treatment</b>
Extracellular Volume Overload	Restrict NaCl and H <sub>2</sub> O Diuretics Dialysis
Hyponatremia	Restrict Oral H <sub>2</sub> O Restrict Hypotonic IV Solutions
Hyperkalemia	Restrict K intake                      Dialysis K Binding Resins                      Glucose/Insulin Eliminate K Supplements      NaBicarb      Ca Gluconate
Metabolic Acidosis	Na Bicarb                                      Dialysis



Hyperphosphatemia	Restrict $\text{PHO}_4$ Phosphate Binding Agents	Dialysis
Hypocalcemia	Calcium Carbonate Phosphate Binding Agents	Calcium Gluconate Dialysis
Hypermagnesemia	D/C Mg Containing Antacids Dialysis	
Nutrition	High Protein Enteral or Parental Nutrition	
Drug Dosage	Adjust Doses Around GFR Avoid NSAIDS, ACE I, Dye, Nephrotoxic Abx	

## V. Renal Replacement Therapies

**Goal** – to remove body waste and fluids in the presence of acute or chronic renal failure

### A. Terms –

- **Diffusion:** movement of particles from an area of greater to an area of lesser concentration. During dialysis diffusion results in the movement of urea, creatinine, and uric acid from the patient's blood in the dialysate
- **Osmosis:** the movement of water across a semi-permeable membrane from an area of lesser to an area of greater concentration (osmolality) of particles. During dialysis osmosis results in extra fluid from the patient being removed.
- **Ultrafiltration:** the movement of fluid across a semi-permeable membrane as a result of an artificially created pressure gradient. More efficient than osmosis for the removal of water.
- **Dialysis:** involves the movement of fluid and particles across a semipermeable membrane. It is a treatment that can help restore fluid and electrolyte balance, control acid-base balance, and remove waste and toxic material from the body. It can sustain life successfully in both acute and chronic situation where substitution for or augmentation of normal renal function is needed.

**B. Insurance Coverage** – in 1972 the Congress enacted legislation that provides for people with ESRD to receive Medicare regardless of age. This is not true in all countries.

## **HEMODIALYSIS**

**Goal** – involves shunting the patient's blood from the body through a dialyzer in which diffusion and ultrafiltration occur and then back into the patient's circulation. Requires access to the pt's blood, a mechanism to transport the blood to and from the dialyzer (where exchange of fluid, electrolytes, and waste products occur). HD can be used in the treatment of acute and chronic renal failure

**Access** – five different types of access can be used

- ◆ Arteriovenous Fistula
- ◆ Arteriovenous Graft
- ◆ External Arteriovenous Shunt
- ◆ Femoral Vein Catheterization
- ◆ Subclavian Vein Catheterization

**Contraindications** - Causes rapid fluid shifts

- ◆ Labile Cardiovascular States
- ◆ Recent MI
- ◆ Hypotension

**Complications**

- ◆ Hypotension
- ◆ Air Embolism
- ◆ Arrhythmias
- ◆ Infection
- ◆ Disequilibrium Syndrome -Rapid shifts in osmolality between cerebral spinal fluid and blood can lead to cerebral edema
- ◆ Coagulopathies - Heparin used during dialysis to prevent clotting of blood outside of body

**Chronic Care Needs** –

- ◆ Patients are typically hemodialyzed 2-3 times a week for 2-4 hours
- ◆ Require many medication

- ◆ Encounter multiple acute and chronic health risks as a result of the renal failure and dialysis
- ◆ Have dietary and fluid restrictions
- ◆ Safety concerns regarding access sites
- ◆ Assessment requirements for access sites

## **PERITONEAL DIALYSIS**

**Goal** – The goal is the same as above but a machine is not used to perform the “cleaning of the blood.” The dialyzing fluid is instilled into the peritoneal cavity, and the peritoneum becomes the dialyzing membrane. PD is used for acute and chronic renal failure and can be done in the hospital or at home.

**Access** – an abd catheter is inserted into the peritoneal space. In chronic use this catheter remains in place permanently and only changed periodically should problems arise.

**Procedure** – Approximately 2 liters of sterile dialysate is instilled into the peritoneal cavity and allowed to dwell for a period of time. During this time osmosis and diffusion of particles takes place. The catheter is then reopened and the fluid is drained from the patient (entire process is called an exchange). This process is done repeated during a 24 hr period.

### **Contraindications**

- ◆ Peritonitis
- ◆ Abdominal Surgery
- ◆ Abdominal Adhesions
- ◆ Pregnancy

### **Complications**

- ◆ Peritonitis
- ◆ Respiratory Distress

**Chronic Care Needs** – PD can be done independently at home and the individual can lead a fairly normal schedule. Not as many risks as HD. Most common problem is infection of abd catheter.

- ◆ Continuous ambulatory peritoneal dialysis (CAPD) – 4 –5 exchanges are done a day.
- ◆ Continuous cyclic peritoneal dialysis (CCPD) – exchanges are done with the use of a machine to control the infusion, dwell and drain times and patients can set up before going to sleep

and have their PD occur automatically while they sleep. They are completely independent the rest of the day.

## **CONTINUOUS RENAL REPLACEMENT THERAPY**

**Goal** - CRRT provides continuous ultrafiltration of extracellular fluid and clearance of uremic toxins. Only done in the critical care setting.

**Access** – Arterial and venous cannulation sites are required or two venous cannulation.

**Procedure** – the blood leaves the patient and flow through a hemofilter where the ultrafiltration takes place and removal of water and waste (collected into standard urine bag) and then the blood is returned to the patient via the venous access. The flow gradient to move the blood through the filter is the patient's own blood pressure. There are several types of processes that are used in the critical care setting for CRRT. Not necessary to learn this year. It will be covered in your acute care course next fall.

### **Contraindications:**

- ◆ Inability to tolerate extracorporeal circulation
- ◆ Hypercoagulability
- ◆ Inability to tolerate anti-coagulation therapy (heparin)
- ◆ Fluid, electrolyte and acid-base shifts are less severe than with hemodialysis and usually better tolerated

### **Complications**

- ◆ Fluid Imbalance - Hypo/Hypervolemia (Depends on ultrafiltration rate and intravascular volume requirements)
- ◆ Electrolyte Imbalance - Hypokalemia, Hyponatremia, Hypocalcemia, and Hypomagnesaemia
- ◆ Metabolic Acidosis - Bicarbonate readily removed
- ◆ Drug removal - Potential for removing most drugs
- ◆ Hemorrhage - Heparin used as blood leaves body to prevent coagulation
- ◆ Thrombosis/Infection
- ◆ Hypo/Hyperthermia

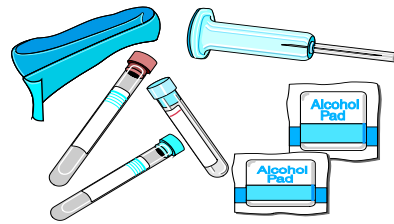
## **VI. RENAL TRANSPLANTATION**

## **VII. SUMMARY**

# Fluids & Electrolytes

## I. INTRODUCTION

Fluid and electrolyte monitoring are an essential component of patient assessment. These factors regulate most physiological functions and the acid base balance.



## II. FLUID BALANCE

### A. Total Body Water – 60% of body weight (approximately 40L)

1. Intracellular – 67% of total body H<sub>2</sub>O
  - a. Primarily made up of intracellular electrolytes
2. Extracellular – 33% of total body H<sub>2</sub>O
  - a. Plasma Water – 8%, Water, proteins and lipids
  - b. Interstitial Fluid & Lymph – 20%, Fluid bathing the cells
  - c. Transcellular Fluid – 7%, Pleural, pericardial, peritoneal, synovial and fluids in secretions (GI, respiratory, salivary)

### B. Osmolarity – the concentration of particles within a solution

1. Plasma osmolarity avg.  $290 \pm 5$  mOsm/kg
  - Na is the primary regulator of extracellular osmolarity
  - K is the primary regulator of intracellular osmolarity

2. Calculated osmolarity = 
$$2(\text{Na}) + \frac{\text{BG}}{18} + \frac{\text{BUN}}{2.8}$$

### C. IV Fluids:

The most common IV solution used in Med/Surg is D5.45NS w 20KCL because it is most “like” normal fluid in the human body. Typically at 125ml/hr – 3L a day

#### 1. Isotonic Fluids

- ✓ Normal Saline & Lactated Ringers
- ✓ 275 -295 mOsm/L
- ✓ Volume Expanders
- ✓ Tend to stay in intravascular space

#### 2. Hypotonic Fluids

- ✓ .45% NS or less
- ✓ Less than 275mOsm/L
- ✓ Severe Dehydration with Dry Tissues
- ✓ Leak out of vascular space into tissues

### 3. Hypertonic Fluids

- ✓ 3% NS and above
- ✓ D5WLR
- ✓ D5 .9%NS
- ✓ Greater than 290 mOsm/L
- ✓ Volume Expanders
- ✓ Stay in intravascular space
- ✓ PULL fluid from interstitial space and tissues

## III. ELECTROLYTE BALANCE

### A. Physiology:

Electrolytes are particles or solutes found throughout the body in fluids. They carry an electrical charge and are essential for fluid and acid base balance within the body. The cations (positively charged ions) are sodium ( $\text{Na}^+$ ), potassium ( $\text{K}^+$ ), magnesium ( $\text{Mg}^{++}$ ), and calcium ( $\text{Ca}^{++}$ ). The anions (negatively charged ions) are chloride ( $\text{Cl}^-$ ), bicarbonate ( $\text{HCO}_3^-$ ), sulfate ( $\text{SO}_4^-$ ), and phosphate ( $\text{PO}_4^-$ ).

The four major functions of electrolytes are:

1. Regulate Acid Base Balance
2. Maintain Fluid Balance and Osmolarity
3. Distribute the Body Fluid and  $\text{H}_2\text{O}$  Between the Compartments
4. Promote Neuromuscular Function/Irritability

### B. Distribution:

Electrolytes are found in the intracellular and extracellular fluid. They are concentrated in one of these two compartments and exert osmotic properties within that compartment. Electrolytes help to maintain total body fluid balance and also help to regulate fluid movement in and out of the cell. For example  $\text{K}^+$  is the major intracellular ion and  $\text{Na}^+$  is the major extracellular ion and they each play a significant role in maintaining homeostasis within each of their compartments. Each electrolyte serves a unique physiologic function and concentrations

above or below the “normal” range can affect homeostasis or specific organ function detrimentally.

<b>ELECTROLYTE or COMPOUND</b>	<b>PRIMARY COMPARTMENT</b>	<b>EXTRACELLULAR CONCENTRATION</b> (plasma or intravascular)	<b>INTRACELLULAR CONCENTRATION</b>
Sodium ( $\text{Na}^+$ )	Extracellular	135 – 146 mEq/L	10 – 15 mEq/L
Potassium ( $\text{K}^+$ )	Intracellular	3.5 – 5.5 mEq/L	140 - 150 mEq/L
Calcium ( $\text{Ca}^{++}$ )	Extracellular	T 8.5 – 10.5 mg/dL I 4.0 – 5.0 mg/dL	0 - 2 mg/dL
Magnesium ( $\text{Mg}^{++}$ )	Intracellular	1.5 – 2.5 mEq/L	30 – 40 mEq/L
Phosphate ( $\text{PHO}_4^-$ )	Intracellular	2.5 – 4.5 mg/dL 1.7 – 2.6 mEq/L	100 mEq/L
Chloride ( $\text{Cl}^-$ )	Extracellular	96 – 109 mEq/L	1 – 4 mEq/L
Bicarbonate ( $\text{HCO}_3^-$ ) or Serum $\text{CO}_2$	Extracellular	22 – 26 mEq/L	4 – 10 mEq/L

# Sodium

## Hyponatremia

Fluid Excess  
Sodium Deficit

## Hypernatremia

Fluid Deficit  
Sodium Excess

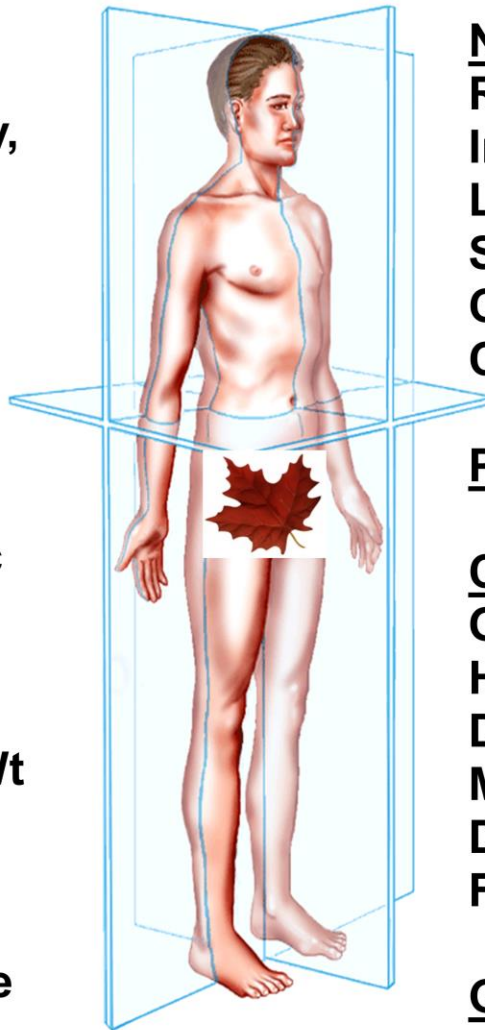
Neuro:  
Headache,  
Fatigue, Apathy,  
Seizures,  
Confusion →  
Coma

Pulm: Resp  
Distress

CV: Orthostatic  
Hypotension,  
Drop CVP

GI: Anorexia, Wt  
Loss, N/V, Abd  
Cramps

Mus/Sk: Muscle  
Weakness



Neuro:  
Restlessness,  
Irritability,  
Lethargy,  
Seizures,  
Confusion →  
Coma

Pulm: Dyspnea,

CV: Tachycardia,  
Orthostatic  
Hypotension,  
Dry Mucous  
Membranes,  
Dehydration,  
Flushed Skin

GU: Low Urine

Mus/Sk: Muscle  
Weakness



# Potassium

## Hypokalemia

Decrease Intake  
Increased Loss  
Shift of K into Cells

## Hyperkalemia

Excess Intake  
Decreased Loss  
Shift K out of Cells

### Neuro:

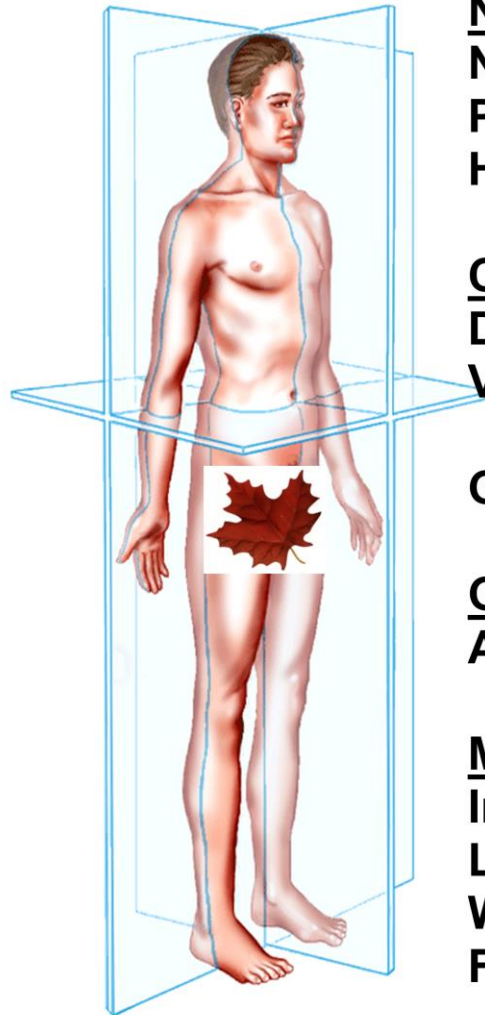
Lethargy,  
Decreased  
Reflexes,  
Confusion,  
Depression

CV: Drop BP,  
Dysrhythmias,  
Cardiac Arrest

GI: Anorexia,  
N/V, Distension  
Ileus

GU: Dilute,  
Urine, Water  
Loss, Thirst

Mus/Sk: Weak,  
Flaccid, Resp  
Arrest



### Neuro:

Numbness,  
Paresthesias,  
Hyporeflexia

CV: Conduction  
Disturbances,  
V-Fib, Asystole

GI: N/V/D

GU: Oliguria,  
Anuria

Mus/Sk: Early →  
Irritability  
Late →  
Weakness  
Flaccid Paralysis

### ECG Changes:

- ✓ Hypokalemia
  - ⇒ Depressed ST segments
  - ⇒ Flat or inverted T wave,
  - ⇒ Presence of U waves
  - ⇒ Dysrhythmias, ventricular
  - ⇒ Cardiac arrest
- ✓ Hyperkalemia
  - ⇒ Tall, peaked, tented T waves
  - ⇒ Flattened or absent P waves
  - ⇒ Widening QRS
  - ⇒ Asystole

### HyperKalemia Treatment: Three-Part Therapy

1. **Cardiac Protect:** 10ml of Calcium Chloride or Calcium Gluconate slow IV push. Renders the myocardium less excitable by decreasing the effects of excess extracellular  $K^+$ .
2. **Shift  $K^+$  into the Cell:**
  - ✓ 1 amp Sodium Bicarbonate
  - ✓ 5-10U Regular Insulin
  - ✓ 50ml Bolus 50% Dextrose
  - ✓ Albuterol 10 – 20mg inhalation or intravenous (beta<sub>2</sub> adrenergic agent – stimulates B<sub>2</sub> receptor in the pancreas to release more insulin).
3. **Removal of  $K^+$ :**
  - ✓ Loop Diuretic
  - ✓ Sodium Polystyrene Sulfonate (Kayexalate) a cation exchange resin given orally or by retention enema. Oral administration is more effective. Each 1gm will lower the  $K^+$  1mEq with orally administration, and 0.5mEq with rectal administration. Sorbitol prevents constipation.
  - ✓ Dialysis can also be utilized to remove  $K^+$  from the body.

# Magnesium

## Hypomagnesemia

Excess Loss  
Decreased Intake  
Impaired Absorption  
Alkalosis

## Hypermagnesemia

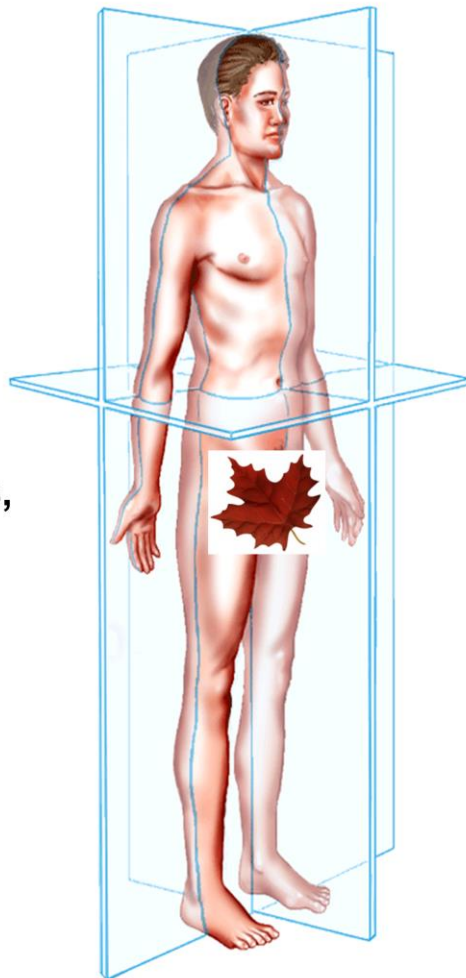
Excess Intake  
Renal Insufficiency/Failure  
Acidosis

Neuro: Agitation,  
Depression,  
Confusion,  
Convulsions,  
Paresthesias,  
Ataxia,  
Hyperreflexia,  
Vertigo, Seizures

CV: Dysrhythmias,  
Tachycardia,  
Hypertension,  
Vasoconstriction

GI: N/V

Mus/Sk: Cramps,  
Spasticity, Tetany



Neuro:  
Hyporeflexia,  
Lethargy → Coma

Pulm: Resp  
Depression,  
Apnea

CV: Dysrhythmias,  
Hypotension,  
Flushed/Warm  
Skin, Vasodilation

Mus/Sk: Muscle  
Fatigue,  
Hypotonia, Bone  
Pain,  
Osteoporosis,  
Fractures

# Calcium

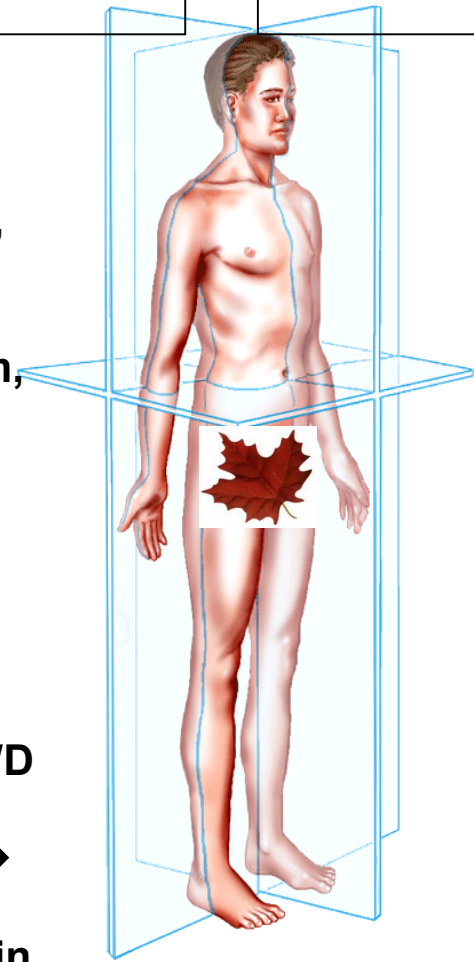
## Hypocalcemia

Excess Loss  
 Inadequate Intake  
 Decreased Ionized  
 GI/Bone Absorption  
 ↓Alkalosis

## Hypercalcemia

Excess Intake  
 Loss from Bones  
 Mobilization from Bones  
 ↑Acidosis

**Neuro:** Tingling  
 → Convulsions,  
 Hyperreflexia  
**Pulm:**  
 Laryngospasm,  
 Bronchospasm  
**CV:**  
 Dysrhythmias,  
 Cardiac Arrest,  
 Bruising,  
 Bleeding  
**GI:** Inc  
 Peristalsis, N/V/D  
**Mus/Sk:**  
 Osteoporosis →  
 Fractures, Abn  
 Deposits of Ca in  
 Body Tissues,  
 Muscle Spasm,  
 Tetany



**Neuro:** Dec  
 Reflexes, Lethargy  
 → Coma, Seizures  
**CV:** Depressed  
 Activity,  
 Dysrhythmias,  
 Cardiac Arrest  
**GI:** Dec GI Tract  
 Motility, N/V,  
 Constipation  
**GU:** Kidney  
 Stones, Flank Pain  
**Mus/Sk:** Muscle  
 Fatigue,  
 Hypotonia, Bone  
 Pain,  
 Osteoporosis,  
 Fractures

### ECG Changes

Hypo: > ST segment, > QT,  
 torsades de pointes, < HR  
 Hyper: Short ST/QT, Heart Blocks