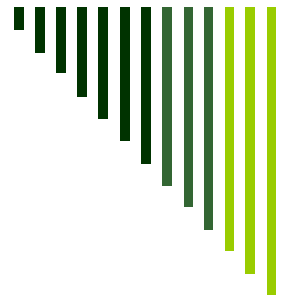


# Fluid and Electrolyte Survey

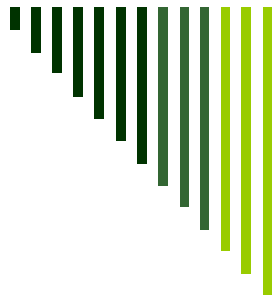
**Dr. Thomas VanderLaan  
Dr. Melanie Walker  
Huntington Memorial Hospital  
Pasadena, California**

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# Anatomy of Body Fluid Compartments

- Total body water
    - 50 to 70% of total body weight
    - Varies with age, sex and fat content
-



# Functional Compartments of Body Fluids

70 kg male

% Body weight

3,500 cc

Plasma

10,500 cc

Interstitial  
Fluid

28,000 cc

Intracellular  
volume

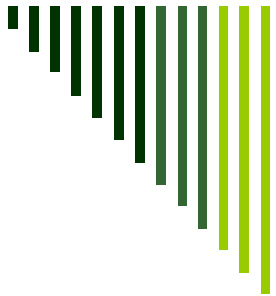
**42,000 cc**



Total extracellular  
volume 20%  
...plasma 5%  
...interstitial 15%

Total intracellular  
volume 40%

**Total body water 60%**



# Chemical Composition of Body Fluid Compartments

154 mEq/L cations  
154 mEq/L anions

Na+	142	Cl-	103
K+	4	HCO <sub>3</sub> <sup>-</sup>	27
Ca <sup>++</sup>	5	SO <sub>4</sub> <sup>-</sup>	3
Mg <sup>++</sup>	3	PO <sub>4</sub> <sup>-</sup>	3
		Organic acids	5
		Protein	16

**PLASMA**

153 mEq/L cations  
153 mEq/L anions

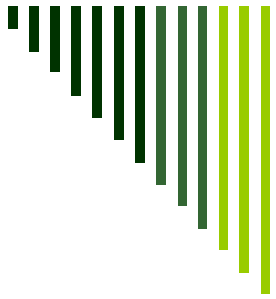
Na+	144	Cl-	114
K+	4	HCO <sub>3</sub> <sup>-</sup>	30
Ca <sup>++</sup>	3	SO <sub>4</sub> <sup>-</sup>	3
Mg <sup>++</sup>	2	PO <sub>4</sub> <sup>-</sup>	3
		Organic acids	5
		Protein	1

**INTERSTITIAL FLUID**

200 mEq/L cations  
200 mEq/L anions

K+	150	HPO <sub>4</sub> <sup>---</sup>	150
Mg <sup>++</sup>	40	SO <sub>4</sub> <sup>—</sup>	150
Na+	10	HCO <sub>3</sub> <sup>-</sup>	10
		Protein	40

**INTRACELLULAR FLUID**



---

# Volume Deficit

**\*\* Most common volume disorder in surgical patients**

## Measurable Causes

Blood loss  
sequestration

Gastrointestinal loss

## Non-measurable Causes

Third spacing / fluid

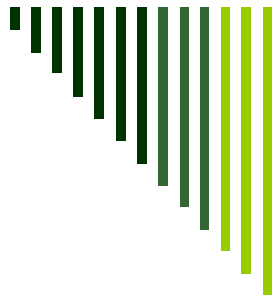
Traumatized tissues

Inflammatory processes

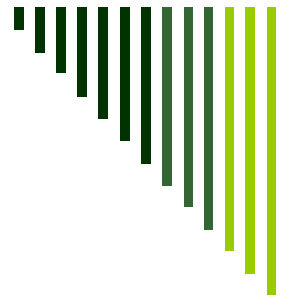
Intestinal obstruction

Burns

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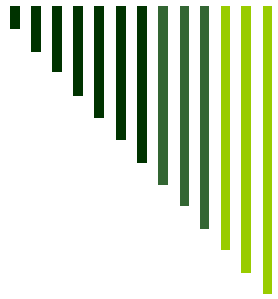


	<b>VOLUME DEFICIT</b>	
<b>SYMPTOMS</b>	<b>MODERATE</b>	<b>SEVERE</b>
<b>Central nervous system</b>	Sleepiness Apathy Slow response Anorexia	Decreased tendon reflexes Stupor Coma
<b>Gastrointestinal</b>	Decrease in food consumption	Nausea Vomiting Silent ileus
<b>Cardiovascular</b>	Tachycardia Collapsed veins Collapsing pulse Orthostatic hypotension	Hypotension Distant heart sounds Cold extremities Absent pulses
<b>Tissue signs</b>	Soft small tongue Decreased turgor	Atonic muscles Sunken eyes
<b>Metabolism</b>	Temperature decrease, mild	Marked temp. decrease
<b>Renal</b>	Oliguria	Anuria



# Oliguria: Definitions

- Prerenal and how to tell
  - Renal and how to tell
  - Oliguria vs. Anuria
-



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## Oliguria: Things to Monitor

Urine osmolality

Urine sodium

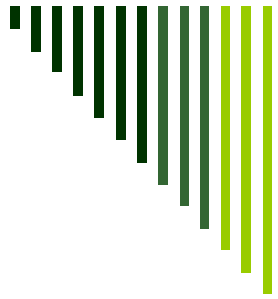
BUN / serum creatinine

Urine and plasma urea

Urine and plasma creatinine

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## Oliguria: Things to Monitor

Urine osmolality

Urine sodium

BUN / serum creatinine

Urine and plasma urea

Urine and plasma creatinine

---



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# Fractional excretion of sodium

Can tell you if the kidney is functioning properly...

---

$FE_{Na} = \text{Urine} / \text{Plasma Na}$

X 100

Urine / Plasma Creatinine

---



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# Treatment of Volume Deficits

1. Estimate the deficit

## Maintenance:

1<sup>st</sup> 10 kg body weight → 100 cc / kg / day

2<sup>nd</sup> 10 kg body weight → 50 cc / kg / day

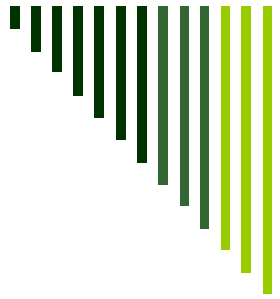
> 20 kg body weight → 20 cc / kg / day

## Measurable losses

Blood loss, GI loss

## Insensible losses

---



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# Treatment of Volume Deficits

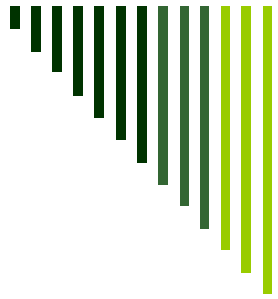
## 2. Replace Volume Intravenously

Crystalloid

Colloid

Blood

---



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# Treatment of Volume Deficits

## 3. Assess results

Vital signs

Urine Output

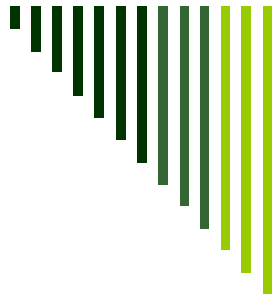
Central venous pressure

Swan-Ganz measurements

---

# Electrolyte Content of Fluids

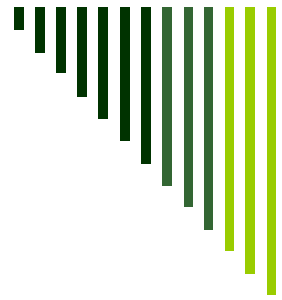
SOLUTION	CATIONS					ANIONS		
	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	NH <sub>4</sub> <sup>+</sup>	Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	HPO <sub>4</sub> <sup>-</sup>
Extracellular fluid	142	4	5	3	0.3	103	27	3
Lactated Ringer's	130	4	2.7		109	28*		
0.9% NaCl	154					154		
M/6 Sodium lactate	167					167*		
M Sodium lactate	1,000					1,000		
3% NaCl	513					513		
5% NaCl	855					855		
0.9% Ammonium Cl					168			



---

## Using different fluids

- Advantages and Disadvantages of:
    - Lactated Ringer's
    - NS
    - Hypertonic Solution
    - Hypotonic solution
-



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## Volume excess

- Most common in the elderly and patients with heart disease
  - Often iatrogenic from over-resuscitation
  - Acute renal failure can be a cause
-



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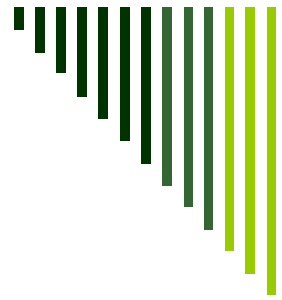
# Symptoms of Volume Excess

- Nervous System

- Rarely symptoms

- Gastrointestinal

- At operation, edema of stomach, colon, omentum and small bowel mesentery
-



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# Cardiovascular Symptoms of Volume Excess

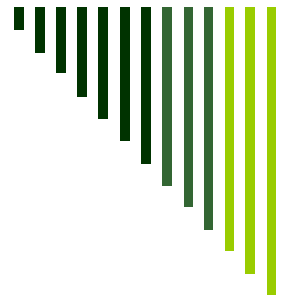
## □ Moderate

- ↑venous pressure
- Distension of veins
- ↑cardiac output
- Murmurs
- ↑pulse pressure

## □ Severe

- Pulmonary edema





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# Tissue Symptoms of Volume Excess

## □ Moderate

- Pitting edema
- Basilar rales

## □ Severe

- Anasarca
  - Vomiting
  - Diarrhea
  - Rales
-

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# Symptoms of Volume Excess

- Metabolic

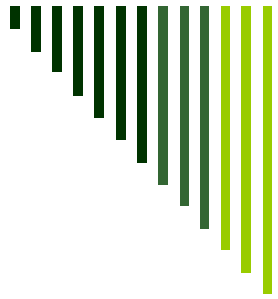
- None

- Renal

- Moderate: None

- Severe: None

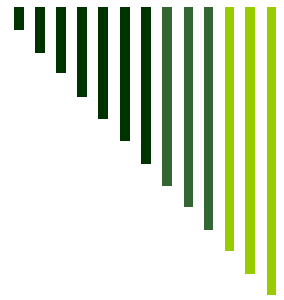
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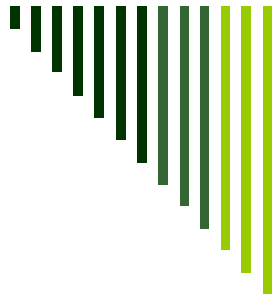
# Treatment of Volume Excess

- Decrease fluid intake
  - Diuretics
  - Inotropic agents
  - Vasodilators
  - Hemodialysis
-



# Concentration Abnormalities

- Serum Sodium and Osmolality
  - Cell membrane permeability
-



# Sodium

- Plays a major role in water balance and muscle contraction
  - Draws water through permeable membranes in the body thereby distributing fluid throughout the body
-

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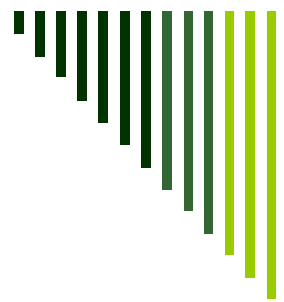


# Hyponatremia

## □ Causes

- Almost always due to ↑ free water
  - Often iatrogenic (fluid replacement)
  - Oliguria
  - Endogenous water release (cell catabolism)
  - Intracellular shifts (sepsis)
  - SIADH
-





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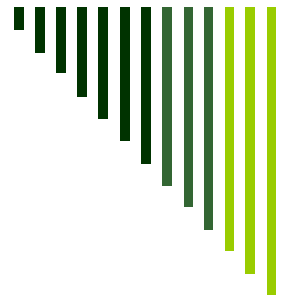
# Central Nervous System Signs of Hyponatremia

## □ Moderate

- Muscle twitching
- ↑ tendon reflexes
- ↑ intracranial pressure

## □ Severe

- Convulsions
  - Loss of reflexes
  - ↑ intracranial pressure
-



---

# Signs and Symptoms of Hyponatremia

- Cardiovascular
    - Changes in blood pressure and pulse related to ↑ ICP
  - Tissues
    - Increased salivation
    - Diarrhea
  - Renal
    - Oliguria progressing to anuria
-

---



# Treatment of Hyponatremia

- Calculate sodium deficit
    - Total body weight X (140 mEq – Serum Na)
  - Replace slowly
    - < 12 mEq / L / 24 hours
    - Dangers of central pontine myelinosis
  - Isotonic vs. Hypertonic solutions
-

---



# Causes of Hypernatremia

- Excessive extrarenal water loss
    - Fever
    - Tracheostomy
    - Burns
-

---



# Causes of Hypernatremia

- ↑ Renal water loss
    - High output renal failure
    - Diabetes insipidus
-

---



# Causes of Hypernatremia

- Solute loading
    - ↑ protein intake
    - Osmotic diuretics
-

---



# CNS Signs of Hypernatremia

## Moderate

- Restlessness
- weakness

## Severe

- Delirium
  - Maniacal behavior
-

---



# Signs of Hypernatremia

## □ Cardiovascular

- Tachycardia
- Hypotension

## □ Renal

- Oliguria
- Fever

## □ Tissue

- Decreased saliva and tears
  - Dry mucous membranes
  - Swollen tongue
  - Flushed skin
-



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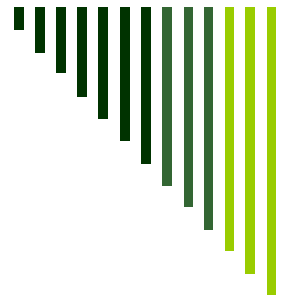


# Treatment of Hypernatremia

- Calculate free water deficit

$$0.6 \times \text{Total body weight} - \frac{140 \times (0.6 \times \text{TBW})}{\text{Na}}$$

- Replace free water
    - Balanced salt solution to prevent CNS symptoms
-



# Potassium

- Normal dietary intake = 50 -100 mEq / day
  - Most is excreted in urine
  - Important for cardiac and neuromuscular function
-

---



# Hyperkalemia

## □ Causes:

- Usually acute renal failure
- Stress
- Catabolism
- Acidosis

## □ Symptoms

- GI:
    - Nausea / vomiting
    - Diarrhea
  - CV:
    - Rhythm abnormalities
    - Heart block
    - Cardiac arrest
-

---



# Hyperkalemia: Treatment

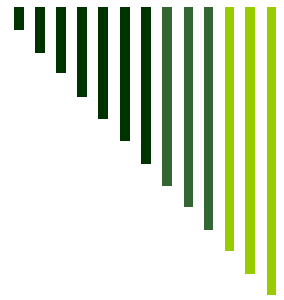
- Withhold exogenous potassium
  - Calcium gluconate
    - Can suppress myocardial effects
  - Sodium bicarbonate, insulin and D10W
    - Helps transfer K intracellular
  - Dialysis
  - Cation exchange resins
-

---



# Hypokalemia: Causes

- More common in surgical patients
    - Prolonged use of IV solutions with K<sup>+</sup>
  - Alkalosis
  - Sodium loading
-



# Hypokalemia: Symptoms and Signs

- Failure of muscle contractility
    - Cardiac, skeletal and smooth muscle
  - Weakness
  - ↓ tendon reflexes
  - Ileus
  - EKG changes
-

---



# Hypokalemia: Treatment

- Prevention

- Replace renal and GI losses of K<sup>+</sup> in IV solution

- Avoid cardiac toxicities

- ≤ 40 mEq KCl / liter IV fluid

- < 20 mEq KCl / hour replacement

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# Calcium

- Critical for:
    - normal cell function
    - neural transmission, cell membrane stability
    - bone structure
    - blood coagulation
  - Daily losses in feces, urine and through skin
  - Daily exchange in bones, GI tract, kidneys
-



---



# Hypocalcemia: Causes

- Chronic renal failure
  - Multiple transfusions
  - Pancreatitis
  - Nutritional deficiency (esp. Vitamin D)
  - Magnesium depletion
  - Drugs
  - Thyroidectomy / Parathyroidectomy
-

---



# Management of Hypocalcemia

*Calcium < 8.0-8.5 mg/dl*  
**SYMPTOMATIC**

- **SEVERE SYMPTOMS: tetany**
    - 20 ml IV 10% Calcium gluconate over 20 minutes  
then 15 mg/kg Calcium gluconate every six hours
    - reassure patient to minimize respiratory alkalosis  
from hyperventilation
-

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# Management of Hypocalcemia

- **MILD SYMPTOMS: paresthesias**
    - Oral Calcium treatment
-

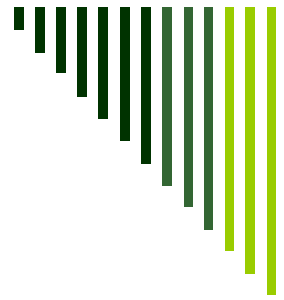
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# Management of Hypocalcemia

## □ **SEEK CAUSE**

- consider magnesium deficiency
  - exclude hypoalbuminemia
  - measure serum phosphate (see next slide)
  - could be excess hydration
-

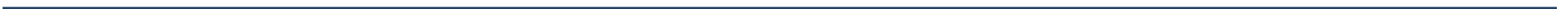


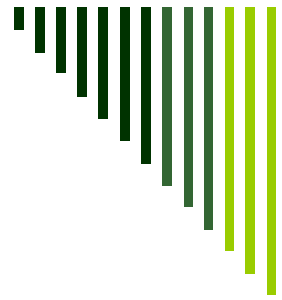
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# Phosphate and Hypocalcemia

- High serum phosphate
  - Suspect hypoparathyroidism

- Low or normal serum phosphate
  - Suspect bone disease

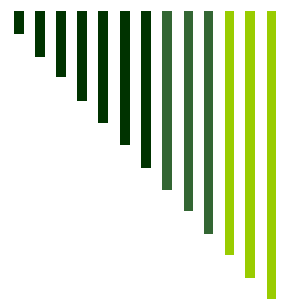




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# Hypercalcemia: Symptoms

- bone defects
  - cardiac changes
  - shock
  - renal hypertension and failure
-



# Hypercalcemia: Causes

- 1° hyperparathyroidism
- Malignancy
  - With or without bone metastasis
- Drugs
  - Some diuretics
  - Vitamins A or D
  - Calcium carbonate
- Metabolic disorders
  - Osteoporosis
  - Thyrotoxicosis
  - Renal tubular acidosis
- Pheochromocytoma (rare)



---

# Management of Hypercalcemia

## *UNSTABLE PATIENT*

*> 14 mg/dl*

- Rehydrate with normal saline
  - Check serum phosphate
  - Give furosemide 40 mg initially then 40-80 mg q. 2 hr
    - Monitor serum electrolytes
  - If patient remains unstable
    - Calcitonin 4 IU/kg subcutaneous or IM q 12°
    - Dialysis might be necessary
-



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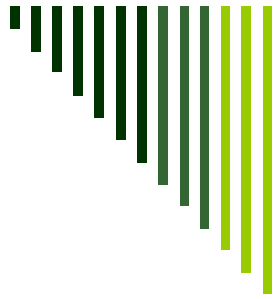


# Management of Hypercalcemia

## *STABLE PATIENT*

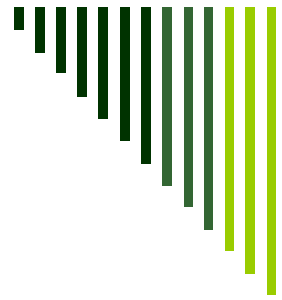
- Low serum phosphate
  - Usually 1° hyperparathyroidism, can give oral phosphate

- Normal or high serum phosphate
    - Suspect malignancy
-



# Magnesium

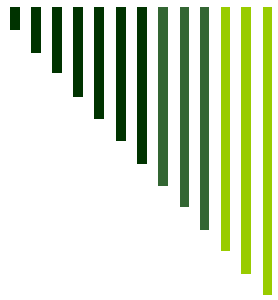
- Essential for function of most enzyme systems
  - Half of total magnesium is stored in bone
  - Kidneys can conserve and excrete
-



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# Magnesium Deficiency: Causes

- Starvation
  - Malabsorption
  - GI loss
  - Pancreatitis
  - Alcoholism
  - Diabetic ketoacidosis
  - 1° aldosteronism
-

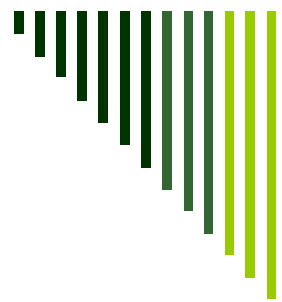


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# Magnesium Deficiency: Signs and Symptoms

*Similar to hypocalcemia*

- Weakness
  - Vertigo
  - Dysphagia
  - Seizures
  - Tetany
  - Delerium
  - ↑ deep tendon reflexes
-



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# Treatment of Hypomagnesemia

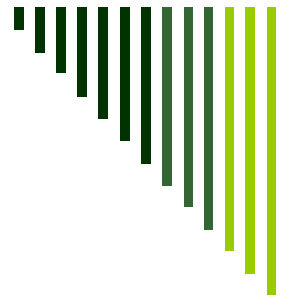
- Correct over-hydration
  - If **severe and symptomatic**:
    - Give 4-8 ml of a 50% MgSO<sub>4</sub> solution in 100-200 ml of D5W IV over 15 minutes
  - Look for causes
  - Oral supplements for stable patients
-

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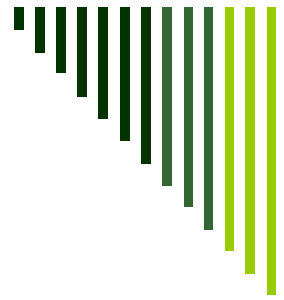
# Magnesium Excess

- Rare
  - Associated with:
    - Acute renal failure
    - Antacids
    - Massive trauma
    - Burns
-



## Magnesium Excess: Signs and Symptoms

- Lethargy
  - Weakness
  - ↓ deep tendon reflexes
  - EKG abnormalities
-



---

# Treatment of Hypermagnesemia

- Withhold exogenous magnesium
- Correct acidosis
- Dialysis may be necessary
- For the symptomatic patient
  - Calcium Gluconate 10% 1-10 ml IV