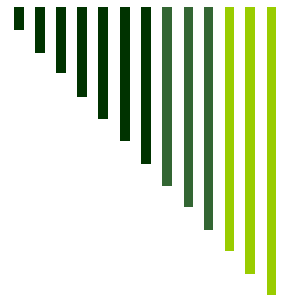


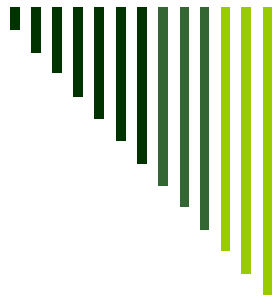
Fluid and Electrolyte Survey

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



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

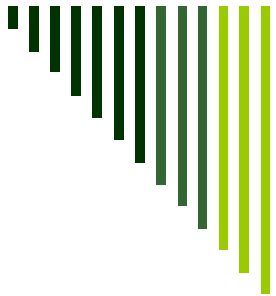
42,000 cc



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 ₃ ⁻	27
Ca ⁺⁺	5	SO ₄ ⁻	3
Mg ⁺⁺	3	PO ₄ ⁻	3
		Organic acids	5
		Protein	16

PLASMA

153 mEq/L cations
153 mEq/L anions

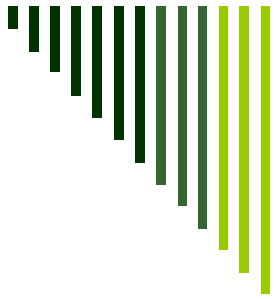
Na+	144	Cl-	114
K+	4	HCO ₃ ⁻	30
Ca ⁺⁺	3	SO ₄ ⁻	3
Mg ⁺⁺	2	PO ₄ ⁻	3
		Organic acids	5
		Protein	1

INTERSTITIAL FLUID

200 mEq/L cations
200 mEq/L anions

K+	150	HPO ₄ ⁻⁻⁻	150
Mg ⁺⁺	40	SO ₄ [—]	150
Na+	10	HCO ₃ ⁻	10
		Protein	40

INTRACELLULAR FLUID



Volume Deficit

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

Measurable Causes

Blood loss
sequestration

Gastrointestinal loss

Non-measurable Causes

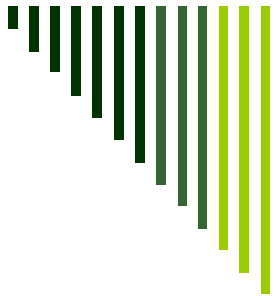
Third spacing / fluid

Traumatized tissues

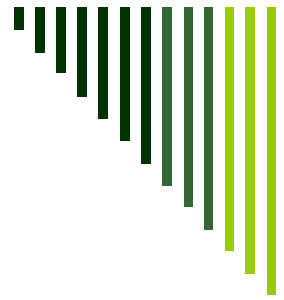
Inflammatory processes

Intestinal obstruction

Burns

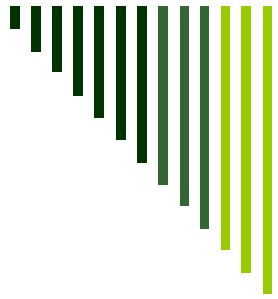


	VOLUME DEFICIT	
SYMPTOMS	MODERATE	SEVERE
Central nervous system	Sleepiness Apathy Slow response Anorexia	Decreased tendon reflexes Stupor Coma
Gastrointestinal	Decrease in food consumption	Nausea Vomiting Silent ileus
Cardiovascular	Tachycardia Collapsed veins Collapsing pulse Orthostatic hypotension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



Oliguria: Definitions

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



Oliguria: Things to Monitor

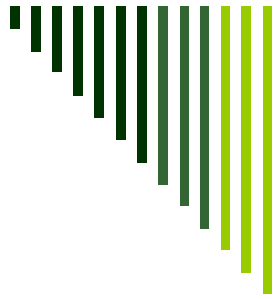
Urine osmolality

Urine sodium

BUN / serum creatinine

Urine and plasma urea

Urine and plasma creatinine



Oliguria: Things to Monitor

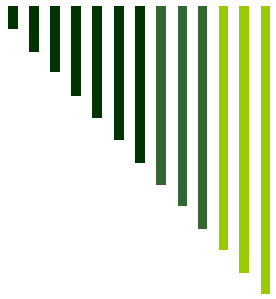
Urine osmolality

Urine sodium

BUN / serum creatinine

Urine and plasma urea

Urine and plasma creatinine



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



Treatment of Volume Deficits

1. Estimate the deficit

Maintenance:

1st 10 kg body weight → 100 cc / kg / day

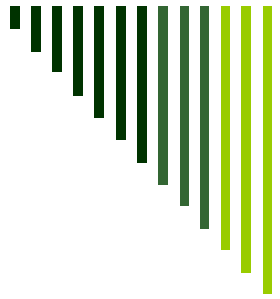
2nd 10 kg body weight → 50 cc / kg / day

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

Measurable losses

Blood loss, GI loss

Insensible losses



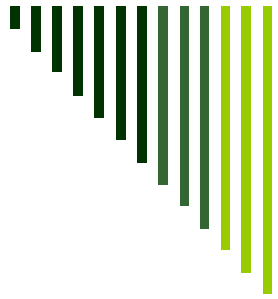
Treatment of Volume Deficits

2. Replace Volume Intravenously

Crystalloid

Colloid

Blood



Treatment of Volume Deficits

3. Assess results

Vital signs

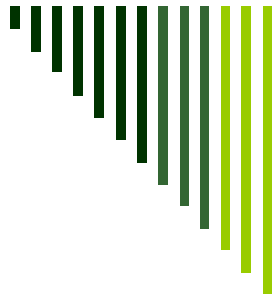
Urine Output

Central venous pressure

Swan-Ganz measurements

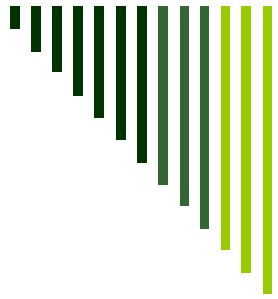
Electrolyte Content of Fluids

SOLUTION	CATIONS					ANIONS		
	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	NH ₄ ⁺	Cl ⁻	HCO ₃ ⁻	HPO ₄ ⁻
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
-



Volume excess

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



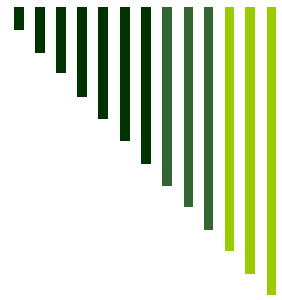
Symptoms of Volume Excess

- Nervous System

- Rarely symptoms

- Gastrointestinal

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



Cardiovascular Symptoms of Volume Excess

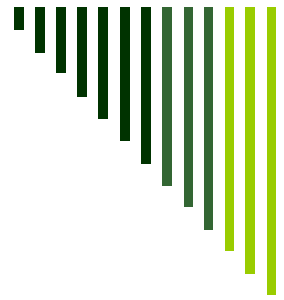
□ Moderate

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

□ Severe

- Pulmonary edema





Tissue Symptoms of Volume Excess

□ Moderate

- Pitting edema
- Basilar rales

□ Severe

- Anasarca
 - Vomiting
 - Diarrhea
 - Rales
-



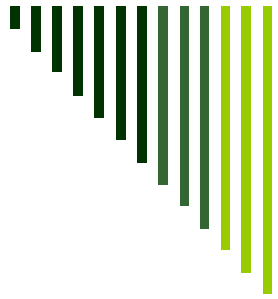
Symptoms of Volume Excess

- Metabolic

- None

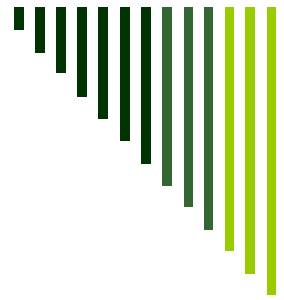
- Renal

- Moderate: None
 - Severe: None
-



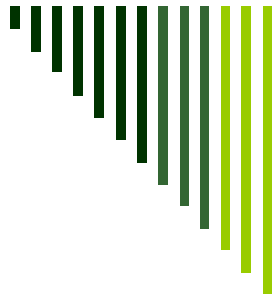
Treatment of Volume Excess

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



Concentration Abnormalities

- Serum Sodium and Osmolality
 - Cell membrane permeability
-



Sodium

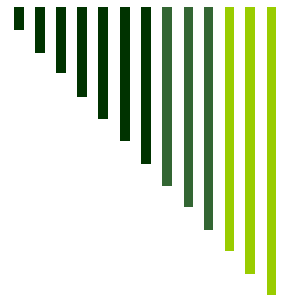
- Plays a major role in water balance and muscle contraction
 - Draws water through permeable membranes in the body thereby distributing fluid throughout the body
-



Hyponatremia

□ Causes

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



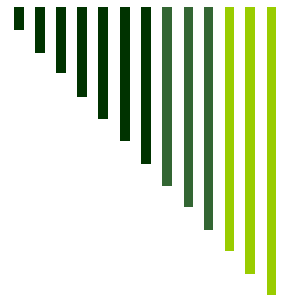
Central Nervous System Signs of Hyponatremia

□ 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
-

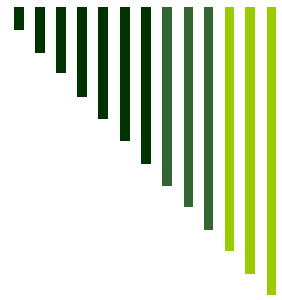


Treatment of Hypernatremia

- 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
-



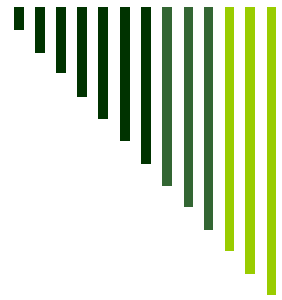
Hyperkalemia: Treatment

- 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⁺
 - 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⁺ in IV solution

- Avoid cardiac toxicities

- ≤ 40 mEq KCl / liter IV fluid

- < 20 mEq KCl / hour replacement



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
-



Management of Hypocalcemia

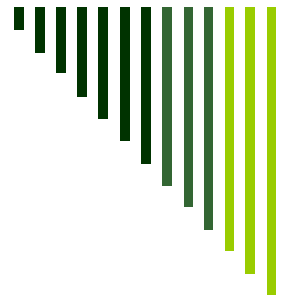
- **MILD SYMPTOMS: paresthesias**
 - Oral Calcium treatment
-



Management of Hypocalcemia

□ **SEEK CAUSE**

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

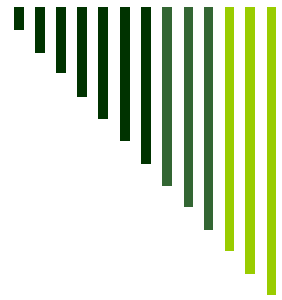


Phosphate and Hypocalcemia

- High serum phosphate
 - Suspect hypoparathyroidism

- Low or normal serum phosphate
 - Suspect bone disease





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
-

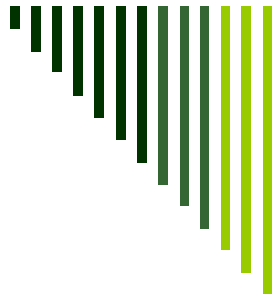


Management of Hypercalcemia

STABLE PATIENT

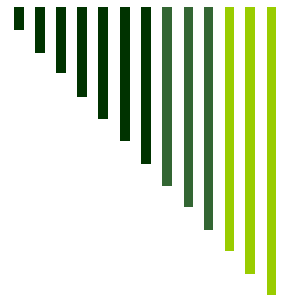
- Low serum phosphate
 - Usually 1° hyperparathyroidism, can give oral phosphate

- 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
-



Magnesium Deficiency: Causes

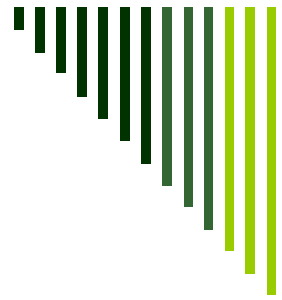
- Starvation
 - Malabsorption
 - GI loss
 - Pancreatitis
 - Alcoholism
 - Diabetic ketoacidosis
 - 1° aldosteronism
-



Magnesium Deficiency: Signs and Symptoms

Similar to hypocalcemia

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



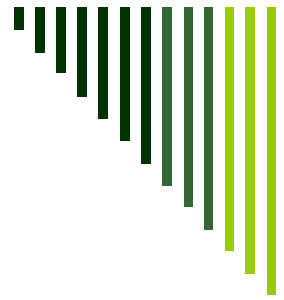
Treatment of Hypomagnesemia

- Correct over-hydration
 - If **severe and symptomatic**:
 - Give 4-8 ml of a 50% MgSO₄ solution in 100-200 ml of D5W IV over 15 minutes
 - Look for causes
 - Oral supplements for stable patients
-



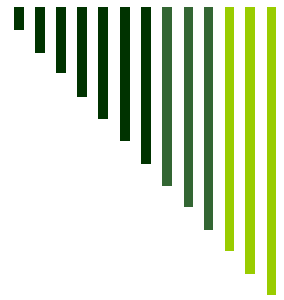
Magnesium Excess

- 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