Fluid & Electrolytes

- Function of fluid
  - Transport of nutrients to & wastes from cells
  - Helps maintain normal body temp.
  - Lubricates & cushions
  - Facilitates digestion & elimination
  - Maintains vascular volume
  - Solvent for electrolytes

- Function of electrolytes
  - Body water regulation & osmolality
  - Acid-base balance
  - Enzyme activity
  - Neuromuscular activity
### Fluid & Electrolytes

- **Body fluid distribution**
  - Water & electrolytes
  - 60% of weight (adult & children > 2 yrs.)
    - ICF – intracellular fluid = 40%
    - ECF – extracellular fluids = 20%
      - Intravascular 5%
      - Interstitial 15%

### Electrolytes

- **Plasma Cations** = 154
  - Sodium (Na) 142
  - Potassium (K) 5
  - Calcium (Ca²⁺) 5
  - Magnesium (Mg²⁺) 2

- **Plasma Anions** = 154
  - Chloride (Cl) 104
  - Bicarbonate (HCO₃⁻) 26
  - Phosphate (HPO₄²⁻) 2
  - Sulfate (SO₄²⁻) 1
  - Organic acids & proteinate 22

- **ICF Cations** = 200
  - Potassium 150
  - Magnesium 40
  - Sodium 10

- **ICF Anions** = 200
  - Phosphate
  - Sulfates (150)
  - Bicarbonate 10
  - Proteinate 40

### Acid-Base Balance

- **pH** – H⁺ ion concentration in blood
- **Hydrogen** is a product of metabolism
- **Normal pH** 7.35 – 7.45
- **Chemical buffer systems**
  - Remove or release Hydrogen ions
  - ECF buffers – phosphates & plasma proteins
  - ICF buffers – phosphates, proteins, & Hemoglobin
  - Bicarbonate – Carbonic acid buffer system
  - Acid – donates H⁺ ions
  - Base – accepts H⁺ ions
**Acid-Base**

- **Acidosis**: pH 6.80
- **Alkalosis**: pH 7.80

Death

1 part acid

20 parts base

Lung

1.2mEq/L

HCO₃⁻

24mEq/L

H₂O + CO₂ ⇌ H₂CO₃ ⇌ H + HCO₃

**Body Fluid Balance**

**Routes of Gains & Losses**

- **Gains**
  - Food: 800-1000ml
  - Fluid intake: 1100-1400ml
  - Oxidative metabolism: 300ml

- **Losses**
  - Lungs: 400ml
  - Skin: 500-600ml
  - G.I tract: 100-200
    - Small intestine absorbs fluid
  - Kidneys: 1200-1500

**Fluid Regulation**

- **Osmolality (Tonicity) = concentration**
  - iso-osmolar, hypo-osmolar, hyperosmolar
  - Normal serum osmolality = 280-295mOsm/kg of H₂O

- Semi permeable membrane

- Isotonic
  - Iso-osmolar

- Isotonic
  - Iso-osmolar
Fluid Regulation - Osmosis

- Osmosis
  - Osmotic pull by particles /unit of water (Osmolality)
  - Movement of fluid from area of < concentration to area of > concentration

Semi permeable membrane

Hypotonic Hypertonic
Hypo-osmolar Hyperosmolar

Fluid Regulation - Osmosis

- Osmosis
  - Osmotic pull by particles /unit of water (Osmolality)
  - Movement of fluid from area of < concentration to area of > concentration

Semi permeable membrane

Fluid Regulation - Filtration

Arterial side Capillary bed Venous side

Interstitial space Cell Lymphatic system

HP = 32 COP = 22 FP = 10
Fluid Regulation - Filtration

Arterial side
Capillary bed
Venous side

HP = 32
COP = 22
FP = +10

HP = 12
FP = -10

Interstitial space
Cell

Lymphatic system

Fluid Regulation

- Thirst mechanism
  - ↑ Plasma Osmolality
  - ↓ Plasma Volume
  - Angiotensin II
  - Thirst Center
  - Dec. Potassium or Inc. Sodium
  - Dry oropharyngeal Mucous membranes
  - Psychological factors

Fluid Regulation – Kidneys
Retention & Excretion

- Regulation of ECF volume & osmolality by selective retention & excretion
- Hydrostatic pressure
- Filtration = excretion of urine/waste products
- GFR = 125ml/minute
- Normal urine output – 20-30ml/hr
Renin-Angiotensin-Aldosterone System

BP\downarrow or Na\downarrow

Glomerulus

Renin secretion

Liver

Angiotensin converted to Angiotensin I

Lungs

Angiotensin I converted to Angiotensin II

Adrenals produce aldosterone

Aldosterone

Angiotensin II – adrenals* secrete aldosterone

Na & H\_2O retention = fluid volume & Na levels

Kidneys retain Na & H\_2O

Antidiuretic Hormone (ADH)

Hypothalmus Osmoreceptors

Brain

ADH

H\_2O retention

↓Urine volume

↑Urine concentration

Plasma Osmolality
**Electrolyte Balancing Act**

- Active transport
  - ATP – solutes move from area of < concentration to areas of > concentration
- The body expands energy to maintain the extracellular Na and the intracellular K by means of cell membrane Sodium – Potassium pump.

**Sodium Balance**

- Normal serum sodium (Na+) – 135 – 145 mEq/L (Cl 95 - 108)
- 95% in ECF
- Primary role – Control H₂O distribution & volume
- Normal intake 50-90mEq as NaCl
- Kidney conserves or excretes Na prn

**Potassium (K⁺)**

- Function
  - Regulation of ICF osmolality
  - Promotes transmission/conduction of nerve impulses
  - Promotes contraction of skeletal, cardiac, & smooth muscle
  - Maintenance of acid-base balance
### Potassium (K⁺)

- Major intracellular cation – 150 mEq/L
- Normal serum levels – 3.5–5 mEq/L
- Poor storage – daily requirement needs
- Kidneys excrete 80-90% of K⁺

### Dietary Sources of K

- Meats
- Vegetables
- Fruits
- Dried fruits, nuts, seeds
- Chocolate

### Calcium

- Se Ca²⁺
  - Total 8.5 – 10.5 mg/dL (100 ml)
    - Bound with protein & ionized
  - Ionized – 4 – 5 mEq/L
  - 99% in bones & teeth
## Calcium - Function

- Transmission & conduction of nerve impulses
- Stimulates skeletal, smooth, & cardiac muscle contraction
- Promotes coagulation
- Bone & teeth formation
- Hormone secretion

## Calcium – Regulation

- Vitamin D
- Phosphates
  - $\text{PO}_3^-$
  - Inverse relationship with Calcium
- PTH
- Calcitonin

## Magnesium

- Distribution
  - 2/3 found in bones
  - 1/3 found in ICF
  - 1% in ECF
- Absorbed in small bowel
- Excreted by kidneys
- Function
  - Intracellular metabolism
  - Neuromuscular - similar to calcium
Bicarbonate
• HCO³⁻
• Major chemical buffer in ECF & ICF
• Regulated by kidneys
• Arterial measurement
  – 20-26 mEq/L
• Venous measurement
  – CO₂ content 24-30 mEq/L

ABG Values
• pH 7.35 – 7.45
  – <7.35
  – >7.45
• PaCO₂ 35-45 mmHg
  – <35 (hypocapnia)
  – >45 (hypercapnia)
• HCO₃⁻ 20-26 mEq/L
  – <20 (acidosis)
  – >26 (alkalosis)

Acid-Base

\[
\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \\
\text{K}\text{I}\text{D}\text{N}\text{E}\text{Y}\text{S}
\]
Acid-Base - Acidosis

Gain of acid

H₂CO₃

H₂O + CO₂ → H₂CO₃ → H⁺ + HCO₃⁻

HCO₃⁻

Death

Acidosis

7.35 7.45

Alkalosis

7.80

Metabolic Acidosis – Mechanism

• Accumulation of fixed acids
  – Lactic acidosis
  – Renal failure
  – Ketoacidosis
  – Ingestion
    • ASA
    • Antifreeze

• Loss of base
  – Renal tubular acidosis
  – Carbonic anhydrase inhibitors
    • Diamox
    – Diarrhea
**Metabolic Acidosis - Symptoms**

- pH ↓
- HCO3 ↓
- Hyperventilation (PaCO2 ↓) compensatory
- Lethargy/weakness
- Hyperkalemia
- Hypotension & myocardial depression

**Respiratory Acidosis**

- **Causes**
  - Inadequate excretion of CO2
  - Acute or chronic respiratory alterations
- **Risk factors favoring hypoventilation**
  - Obesity
  - Tight binders/dressings
  - Postoperative pain
  - Abdominal distention

**Respiratory Acidosis – Symptoms**

- ABG’s
  - pH ↓
  - PaCO2 ↑
  - HCO3 (↑ compensatory)
- Headache
- Hypertension
- Hyperkalemia
- Hypoxemia
Acid-Base

Alkalosis

Gain of base

Death

H₂O + CO₂ → H₂CO₃ ↔ H + HCO₃

Acidosis

Loss of acid

H₂CO₃

HCO₃

H₂O + CO₂ → H₂CO₃ ↔ H + HCO₃

1 part acid

20 parts base

6.80

7.80

7.35

7.45

Acid-Base - Alkalosis

Acidosis

Death

H₂CO₃

HCO₃

H₂O + CO₂ → H₂CO₃ ↔ H + HCO₃

Alkalosis

Death

K I D N E Y S

L U N G S

1.2mEq/L

24mEq/L

Acid-Base - Alkalosis

Death

Gain of base

H₂CO₃

HCO₃

H₂O + CO₂ → H₂CO₃ ↔ H + HCO₃

Acidosis

Death

K I D N E Y S

L U N G S
Metabolic Alkalosis - Causes

• Fixed acid loss
  – Vomiting/G.I suction
  – Hypokalemia
• Excess bicarbonate intake
  – Alkali ingestion
  – I.V. NaHCO₃
• Excess bicarbonate reabsorption

Metabolic Alkalosis – Symptoms

• ABG’s
  – pH ↑
  – HCO₃↑
  – PaCO₂ (↑ compensatory)
• Hypoventilation
• Decreased LOC
• Hypokalemia
• Hypochloremia
• Tetany/paresthesia

Respiratory Alkalosis

• Causes relate to hyperventilation
  – Anxiety
  – High fever
  – Thyrotoxicosis
  – Hypoxemia
  – Salicylate intoxication (early)
Respiratory Alkalosis - Symptoms

- ABG’s
  - pH ↑
  - PaCO2 ↓
  - HCO3 ~ (↓ compensated)
- Lightheadedness/confusion
- Inability to concentrate
- Paresthesia
- Palpitations
- Dry mouth

Influencing Factors in Total Body Water

- Body fat
  - Fat cells contain less water
- Sex
  - Women less body fluid than men
- Age
  - Infants
    - 70-80% body weight (Adult 60%)
    - 50% extracellular (Adult 20%)
  - Older adult
    - ↓ % of body weight

Influencing Factors

- Elderly
  - Diminished thirst response
  - Altered ADH response
  - Decreased ability to concentrate urine
  - Chronicity
  - Debilitation
  - Changes in cognition
- Infant - child
Risk Factors

- Compromised regulatory mechanisms
  - Congestive heart failure
  - Renal failure
  - Cirrhosis
  - Steroid excess
- ADH stimulation
- Excess sodium containing fluids/foods
- IV solutions

Alterations in fluid intake & output

- Medications
- G.I.
  - Dysphagia
  - Nausea/vomiting
  - Diarrhea
  - Insufficient intake
  - G.I. suction
- Restraints
- Skin
  - Diaphoresis
  - Wounds/burns
- Fever
  - Increase in metabolism
  - Tachypnea
- Blood loss

History and Interview

- Age
- Acute illness
- Respiratory/Cardiovascular disorders
- Chronic illness
- Renal / G.I. disorders
- Environment
- Diet/ lifestyle
- Medications
Normal Findings

- General
- VS
- Weight
- Intake & Output
- Urine
- Skin turgor
- Mucous membranes
- Thirst
- Edema
- Neck Veins
- Neuromuscular signs

Diagnostic Tests

- Serum electrolytes
  - Sodium
  - Potassium
  - Chloride
  - CO₂
- Serum osmolality
- ABG's
- Hematocrit
- BUN
- Creatinine
- BUN:creatinine ratio
- Specific gravity
- Urine osmolality

Isotonic Imbalance - Fluid Volume Deficit (FVD)

- Decrease in intravascular & interstitial fluids = hypovolemia
- Isotonic FVD
  - Equal water & lyte loss
  - Hemorrhage
  - Diaphoresis
  - Diuretics
Fluid Volume Deficit - Isotonic

- S&S
  - BP
  - Heart rate
  - Mucous membranes
  - Skin turgor
  - Weight
  - Venous filling
  - Urine output
  - LOC

FVD - Diagnostic Tests

- Serum Na$^+$ \(\Rightarrow\) or \(\uparrow 145\)
- BUN \(\uparrow >25\)
- Hematocrit \(\uparrow >50\%\)
- Specific gravity \(\uparrow > 1.025\)

Extracellular Fluid Volume Excess (FVE)

- Abnormal fluid retention in intravascular & interstitial spaces
- Secondary to \(\uparrow\) serum Na
- Sodium & Water retained in proportion

\[\text{NA 140mEq/L} \quad \text{ISOTONIC} \quad \text{FLUID}\]

\[\text{NORMAL VOLUME} \quad \text{EXCESS VOLUME}\]
Isotonic Fluid Volume Excess

• Causes
  – Congestive heart failure
  – Renal failure
  – Excessive sodium intake
  – Increased serum aldosterone levels
  – Steroids

Isotonic Fluid Volume Excess

• S&S
  – Weight
  – Edema
  – BP
  – Urine output
  – Venous filling
  – Breath sounds

FVE – Manifestations

• Cardiovascular
  – B.P.
  – Pulse quality
  – Pitting edema
    • Sacral
    • Peripheral
  – Weight gain
  – Distended veins
  – S₃ heart sound

• Respiratory
  – Constant, irritating cough
  – Crackles (Rales)
  – Dyspnea
  – Cyanosis
  – Pleural effusion

• Neurological
  – LOC
FVE – Diagnostic Tests

- Serum sodium
- Hematocrit (% RBC’s in plasma)
- Urine specific gravity
- BUN

Osmolar Imbalances

Dehydration

- Hyperosmolar FVD
  - Water loss > lyte loss
  - Na 140
  - Na 150

Water Excess

- Hypo-osmolar FVE
  - Water gain > lyte gain
  - Na 140
  - Na <135

Hypoosmolar Imbalance – H₂O excess

- Causes
  - Excessive amounts of hypotonic (hyposmolar)solutions
    - D₅W
    - 0.45% saline
  - Excessive intake of free water
  - SIADH
Intracellular Fluid Volume Excess (ICFVE)

- Fluid shift from extracellular spaces to intracellular
- Due to serum hypo-osmolality
- Cellular edema

Effect of Na Imbalance on Cell

Hypernatremia:
Na > 145mEq/L

Cell shrinks as water is pulled out into ECF
**Effect of Na Imbalance on Cell**

**Hyponatremia:**

Na < 135mEq/L

Due to excess water gain or Na loss

Cell swells as water is pulled in from ECF

---

**Effect of Na Imbalance on Cell**

**Hyponatremia:**

Na < 135mEq/L

Cell swells as water is pulled in from ECF

---

**Hypernatremia – Symptoms**

- S&S of FVE or FVD
- Thirst?
- Temperature?
- Mucous membranes?
- Restlessness, weakness with mild to moderate ↑Na
- Disorientation, delusions, hallucinations with severe ↑Na
- Lethargy, stupor, coma
- Muscle irritability and convulsions
## Hyponatremia – Symptoms

- **Relate to Na level**
  - 120-125 mEq/L
    - Nausea
    - Malaise
  - 115-120 mEq/L
    - Headache
    - Lethargy
    - Obtundation
  - <110-115 mEq/L
    - Seizures
    - Coma

- **Volume status**
  - ECF depletion
  - Weakness
  - Fatigue
  - Muscle cramps
  - Postural dizziness

- **Lab data**
  - Se Na?
  - Ua Na?
  - Se osmolality?

## HYPOKALEMIA

- **Serum K⁺ < 3.5 mEq/L**

- **Causes**
  - Inadequate nutrient intake
  - G.I. Losses
  - Renal losses
  - Stress – increased cortisol levels
  - Steroids
  - Alkalosis

## Hypokalemia – Symptoms

- **Musculoskeletal**
  - Weakness
  - Paralysis
  - Leg cramps

- **G.I.**
  - Ileus
  - Anorexia
  - Vomiting

- **Respiratory**
  - Respirations?
  - SOB
  - Apnea

- **Renal**
  - Polyuria

- **Cardiovascular**
Hyperkalemia \( Se \ K^+ > 5.0 \text{ mEq/L} \)

- **Causes**
  - Decreased potassium excretion
    - Oliguric renal failure
    - Potassium sparing diuretics
  - High potassium intake
    - Excess oral potassium supplements
    - Excessive or rapid IV \( K^+ \) replacement
  - Shift of \( K^+ \) out of cells
    - Acidosis, tissue trauma, malignant cell lysis (chemotherapy)

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Hyperkalemia – Symptoms

- **Cardiovascular**
  - EKG changes
  - Dysrhythmias
  - Weakened contractility
  - Tachycardia then bradycardia
  - Cardiac arrest

- **GI**
  - Nausea
  - Intestinal colic
  - Hyperactive bowel sounds

---

Hyperkalemia - Symptoms

- **Neuromuscular**
  - Vague muscle weakness
  - Flaccid muscle paralysis
  - Paresthesia

- **Renal**
  - Oliguria
  - Anuria
Hypercalcemia — Causes

• Metastatic Cancer
• Immobilization
• Hyperparathyroidism
• Intake
  – Thiazide diuretics, Lithium
  – Excess intake of Ca<sup>2+</sup> antacids
  – Excess intake of Vitamins A or D

Hypercalcemia — Symptoms

• Neuromuscular weakness
• Renal
  – Polyuria (DI)
  – Hypercalcuria
• GI
  – N & V
  – ↓ peristalsis
  – Constipation
• Cardiovascular
• Impaired cerebral functioning

Hypocalcemia — Symptoms

• Neuromuscular
  – Tetany
  – ↓ threshold potential – less stimulus required for action potential
  – Hyperexcitability of motor & sensory nerves
  – Paresthesia
  – Trousseau’s sign
  – Chvostek’s sign
Hypermagnesemia – Symptoms
- Diminished neuromuscular transmission
- Decreased muscle function
- Hypotension
- Respiratory depression
- Cardiac arrest

Hypomagnesemia <1.8mg/dL Causes
- Losses from G.I tract
- Alcoholism
- Rapid administration of citrated blood
- Medications
  - Loop diuretics
  - Cisplatin

Nursing Diagnosis
- Fluid volume excess
- Fluid volume deficit
- Ineffective breathing pattern
- Impaired mobility
- Impaired skin integrity
- Altered oral mucous membranes
Nursing Interventions

• Assess fluid volume status
• Obtain daily weights
  – 1 liter = 1 kg (2.2 lb.)
• Measure & calculate I & O
• Monitor lab values
• Provide frequent mouth care
• Administer tube feedings &/or IV fluids
• Protect skin integrity
• Safety – implement measures to prevent falls
• Pulmonary toilet
• Offer fluids as appropriate
• Medications

Fluid Types

• Oral rehydration.
• Intravenous solutions
  – Isotonic electrolyte solutions to treat hypotensive patient – expands plasma volume.
    • Lactated Ringer’s.
    • 0.9% Normal Saline.
  – Hypotonic solutions – provides free water & lytes – allows kidneys to select & retain needed amounts. Decreases intravascular osmolality.
    • 0.45%N.S.
    • D₅%/0.2%N.S.

Parenteral Fluids

• Purposes of Fluid Therapy
  – Maintenance Needs
    • Fluids
    • Electrolytes
  – Replacement
  – Correction of electrolyte disturbances
**Parenteral Fluids**

- Assessment
  - I & O
  - Daily body weights
  - Vital signs
  - Skin turgor
  - Urinary specific gravity
  - Laboratory values
  - I.V. site

**Crystalloids**

- **Dextrose Solutions**
  - D5W
    - Isotonic \( \rightarrow \) Hypotonic
    - Free water to aid renal excretion of solutes
    - Calories 50Gm Dextrose
    - Avoid excess

- **Sodium Chloride solutions**
  - Isotonic Saline (0.9% NaCl)
  - Expands extracellular fluid
  - Does not enter the ICF
  - Use
    - ECF deficits
    - Hyponatremia
    - Hypochloremia
    - Metabolic alkalosis
Crystalloids

- 0.45% NaCl
  - Hypotonic
  - Provides Na, Cl, free water
  - Basic fluid for maintenance
- Uses
  - Maintenance
  - Hypovolemia with hypernatremia

Crystalloids

- Balanced electrolyte solutions
  - Lactated Ringers (Na, Cl, K, Ca, lactate)
    - Lactate → Bicarbonate
    - Metabolic acidosis
    - Third spacing
    - Fluid resuscitation
  - Normosol
  - Isolyte
  - Plasma-Lyte

Colloids

- Protein or starch molecules in fluid
- Increase osmotic pressure – volume expansion
- Albumin
  - 5% – equivalent to plasma
  - 25% - hyperoncotic
  - Plasma expander
- Dextran
  - Low molecular weight (dextran 40)
  - High molecular weight (dextran 70)
- Hetastarch
- Supplemental fat emulsions (Lipids)
Adverse effects of IV therapy

- Fluid Volume Excess/Deficit
- Activity intolerance
- Impaired skin integrity
- Impaired tissue perfusion
- Risk for dysrhythmias
- Risk for injury
- CP: electrolyte imbalances (specify)
- Altered nutrition
- Ineffective breathing patterns