Disorders of fluid and electrolyte balance

Homeostasis:

the various physiologic arrangements which serve to restore the normal state

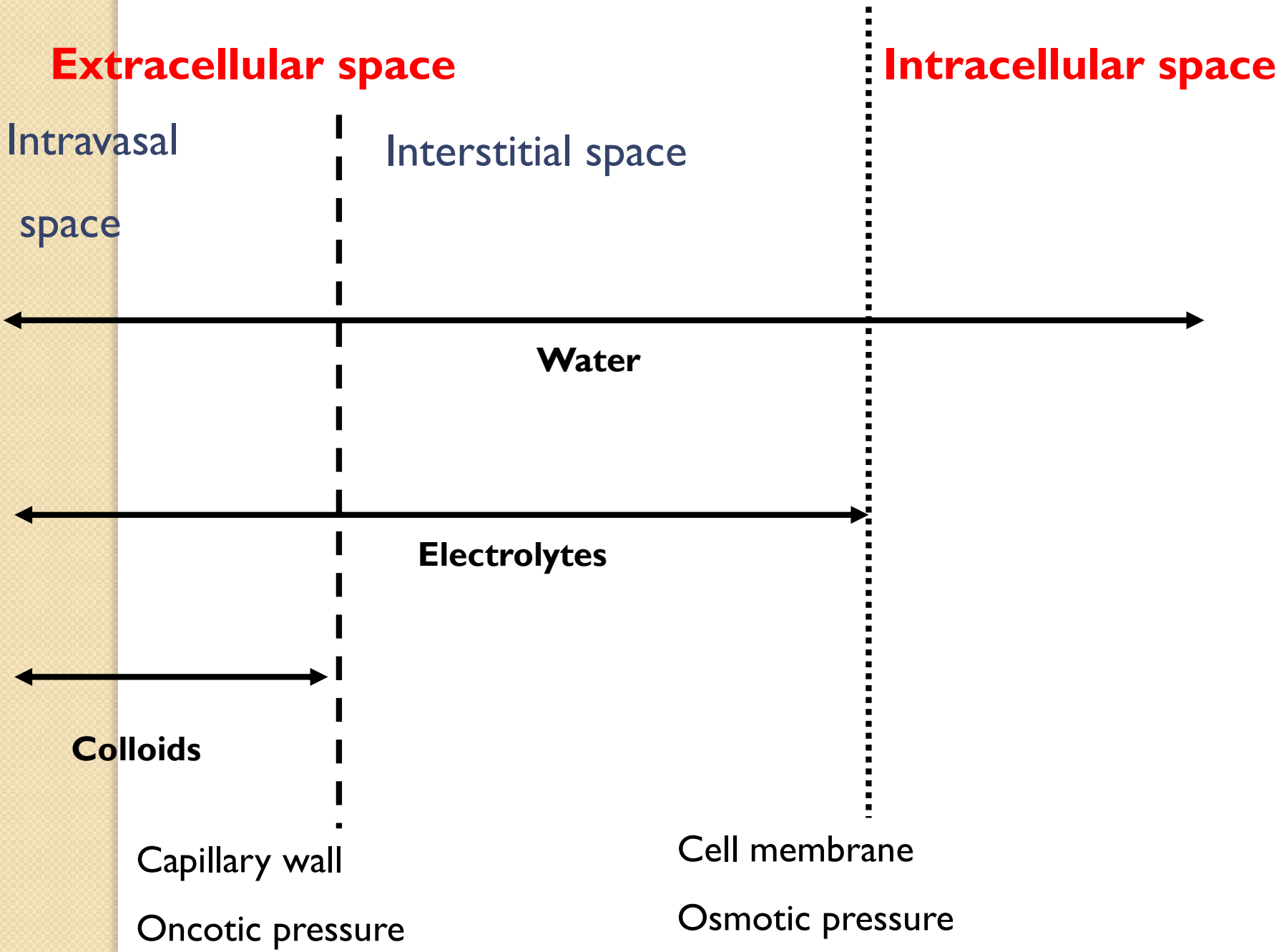
- Fluid balance
- Electrolyte balance
- Osmotic balance
- Acid-base balance

Body fluids distribution

total body water = 0,6/0,5/x(kg body weight)

distributed in compartments:

- **intracellular**
- **extracellular** (interstitial water - 75%, intravascular water – 25%)
- **transcellular** (third-space, water distributed in the digestive tract, spinal fluid, biliary system and lymphatic system)


Extracellular space
Intracellular space
Intravasal space
Interstitial space
Water
Electrolytes
Colloids
Capillary wall
Oncotic pressure
Cell membrane
Osmotic pressure

Daily Water Balance (liters)

INPUT		OUTPUT	
FLUID INTAKE	1.5	INSENSIBLE	0.8
FOOD	0,8	SWEAT	0,1
METABOLIC	0.3	FECES	0.2
Total	2,6	URINE	1.5
		Total	2.6

Electrolytes

- Chemicals dissolved in the body fluid
- Adjusted by intake, output, acid-base balance, hormones, cell integrity

Ionic balance

Provide:

- Resting membrane potential (i/cellular and e/cellular concentration ratio)
- Neuromuscular excitability

Ionic fluid area content

Ions, meq/L	Plasma	Extracellular	Intracellular
Na+	141	143	15
K+	4	4	140
Ca+	2,5	1,3	0,0001
Mg+	1	0,7	15
Cl-	103	115	8
HCO3-	25	28	15
SO4-	0,5	0,5	10

Lab normals – magic 4

Electrolyte	Range	Magic 4
Potassium	3,5-5,5	4
Sodium	135-145	140
Chloride	98-106	104
pH	7,35-7,45	7,4
pCO2	35-45	40
HCO3	22-26	24

Control mechanisms

- **Filtration** – seaparation of solid matter and fluid from a mixture, through the membrane which only the fluid can pass
- **Diffusion** – movement of the molecules from high concentration to low
- **Osmosis** – diffusion of water through the cell mambrane
- **Active transport** (against to gradient, require energy, Na/K/ATP pump)

Control mechanisms

Kidneys (JG cells)	Kidneys (adrenal cortex)	Hypothalamus	Heart
• Sense low Na, low volume • Release renin • Convert Angiotensinogen to Angiotensin I wich converts in Angiotensin II • Stimulate release of Aldosterone	• Sense low serum osmo or low Na • Release Aldosterone • Na reabsortion • K excretion • Increase serum osmo	• Senses high serum osmo or high Na • Stimulates thirst • Release of vasopressin • Keeps water i/vascular • Concentrates urine • Decreases serum osmo	• Senses high volume through stretch receptors in Right atrium • Secrets ANP, BNP • Increases Na excretion • Dilates blood vessels • Decreases serum osmo

Osmolarity=water balance

- Serum osmo=285-295 mOsm/kg
- Urine osmo=50 mOsm/kg
- Urine osmo/serum osmo=1/3

Plasma osmolarity =

2Na + urea (mg/dl)/2.8+glycemia (mg/dl)/18

Fluid disorders:

- Volume and Osmolarity disorders
- refered to the extracellular space

- Water lack or excess
- Sodium lack or excess

!!! Intracellular space is determined by the volume and osmolarity of extracellular space.

Fluid disorders

- ingestion disorders
- eliminate disorders
- disorders of control mechanisms

Primary disorders

- Water deficiency
- Water excess
- Sodium excess
- Sodium deficiency

Disorders of fluid homeostasis

Diagnosis:

- Physical signs: skin turgor, oedema, mucous membranes, neck veins, puls, level of consciousness, capillary refill, fontanel (children)

- Clinical sings: blood pressure; heart rate; (respiratory rate); body temperature; CVP; urine output; serum and urine Na, osmolarity; Htk; serum total protein

Fluid deficit (no water, no salt, or both)

- Lack of water – **hypertonic**

profuse sweating, fever, diarrhea, renal failure, DI

- Lack of salt – **hypotonic**

Water intoxication, chronic illness, renal failure

- Both – **isotonic**

poor intake, bleeding

Dehydration

	Isotonic	Hypertonic	Hypotonic
Se Na	n	+	-
Se osmolarity	n	+	-
Hb	+	+	+
Htk	+	+	+
Blood volume	-	-	-
Thirst	mod. increase	increased	no

Fluid volume deficit

- Low BP, tachycardia
- Dry moth, thirst
- Rapid weight loss
- Low urine output
- Confusion, lethargy
- Elevated Htk, decreased CVP

What are the symptoms?

What can you do?

- Fluids
- Possible antidiarrheals, antiemetics, antipyretics
- Water deficit (L): 0,6 x kg x ((Na measured/Na normal)-1)

Fluid volume excess

- **Hypervolemia – isotonic**

Too much IV fluid, renal failure

- **Water intoxication – hypotonic**

IV fluids, psych problems, wound irrigation

- **Too much sodium intake – hypertonic**

3% saline IV, $NaHCO_3$

Hyperhydration

	Isotonic	Hypertonic	Hypotonic
SeNa	n	+	-
Se osmolarity	n	+	-
Hb	-	-	-
Htk	-	--	(-)
Blood volume	+	+	+

Fluid volume excess

- Rapid weight gain
- Oedema
- High BP
- Increased urine output
- Neck vein distension, dyspnea
- Low Htk, high Na, low osmo

What are the symptoms?

What can you do?

- Diuretics
- Fluid restriction
- Sodium restriction

Sodium – major cation of ECF

- Controled by kidney, aldosterone
- GI tract absorbs from food
- Imbalances are associated with fluid volume
- Foods high in Na: processed meats, condiments, dairy

Hypernatremia

- Water loss or excess sodium
- Decreased Na excretion – renal failure, corticosteroids
- Increased Na intake – eating too much salt, too much sodium in IV fluids
- Increased water loss – fever, infection, sweating, diarrhea
- Over nasogastric feeding, hyperosmolar coma, dehydration secondary to fever or ambient temperature increase
- Diabetes insipidus
- Excessive administration of hypertonic solution and Sodium bicarbonate

"You are fried"

F Fever (low grade, flushed skin)

R Restless (irritable)

I Increased fluid retention and BP

E Edema (peripheral)

D Decreased urine output, dry mouth

Hypernatremia

What can you do?

- Treat the underlying cause
- Diuretics
- Sodium restriction
- Seizure precautions

Hyponatremia

- Water excess or loss of sodium
- Dilution – polydipsia, freshwater drowning, SIADH
- Increased excretion – sweating, diuretics, GI wound drainage, renal disease
- Decreased intake – NPO, law salt diet, severe vomiting/diarrhea
- Symptoms:

-confusion, headaches

-seizures (can progress to coma)

-abd. cramps

Hyponatremia

What can you do?

- 3% normal saline
- If caused by fluid excess, will need fluid restriction
- Usually can not be fixed by adding sodium to the diet

Sodium deficiency-hyponatremia

- Hyponatremia with euvolaemia

Syndrome of inappropriate antidiuretic hormone secretion (SIADH)

unsuppressed release of antidiuretic hormone (ADH) from the pituitary gland or nonpituitary sources or it's continued action on vasopressin receptors

Potassium

- Key role in the resting membrane potential and action potential of neurons and muscle fibers
- The inter-compartment gradient is maintained by the activity of Na/K/ATP-ase, that pumps Sodium out of cells while pumping Potassium into cells, both against their concentration gradients
- Primary route of loss – kidney

Hyperkalemia

- Causes
  - Impaired excretion
    - Renal failure
    - Use of salt or potassium supplements
    - Receiving old blood
    - Hypoxia
    - Exercise (catabolic state)
    - Drugs (potassium sparing diuretics)
  - Shifts of K out of cells
    - Tissue breakdown (Cell destruction)
    - Acidosis, insulin deficiency

Hyperkalemia

"MURDER"

M muscle weakness

U urine, oliguria, anuria

R respiratory distress

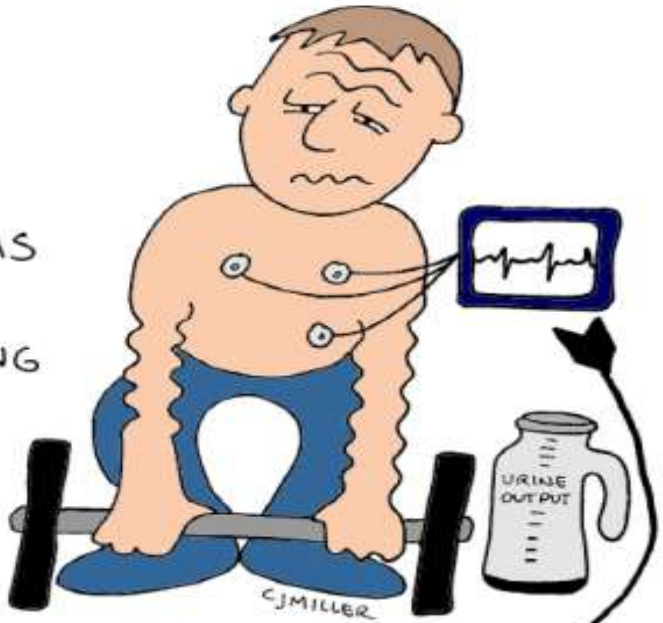
D decreased cardiac contractility

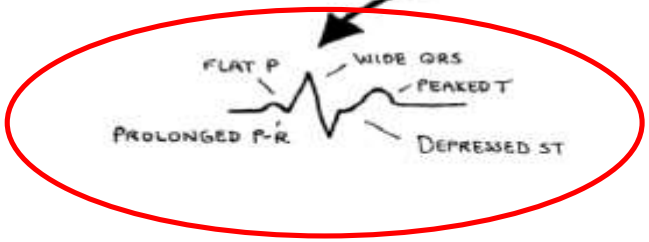
E ECG changes

R reflexes, hyperreflexia, or areflexia

K^+ HYPERKALEMIA ↑

* MUSCLE CRAMPS → WEAKNESS → PARALYSIS
* DROWSINESS
* ↓ BP
* EKG CHANGES
* DYSRHYTHMIAS
* ABDOMINAL CRAMPING
* DIARRHEA
* OLIGURIA



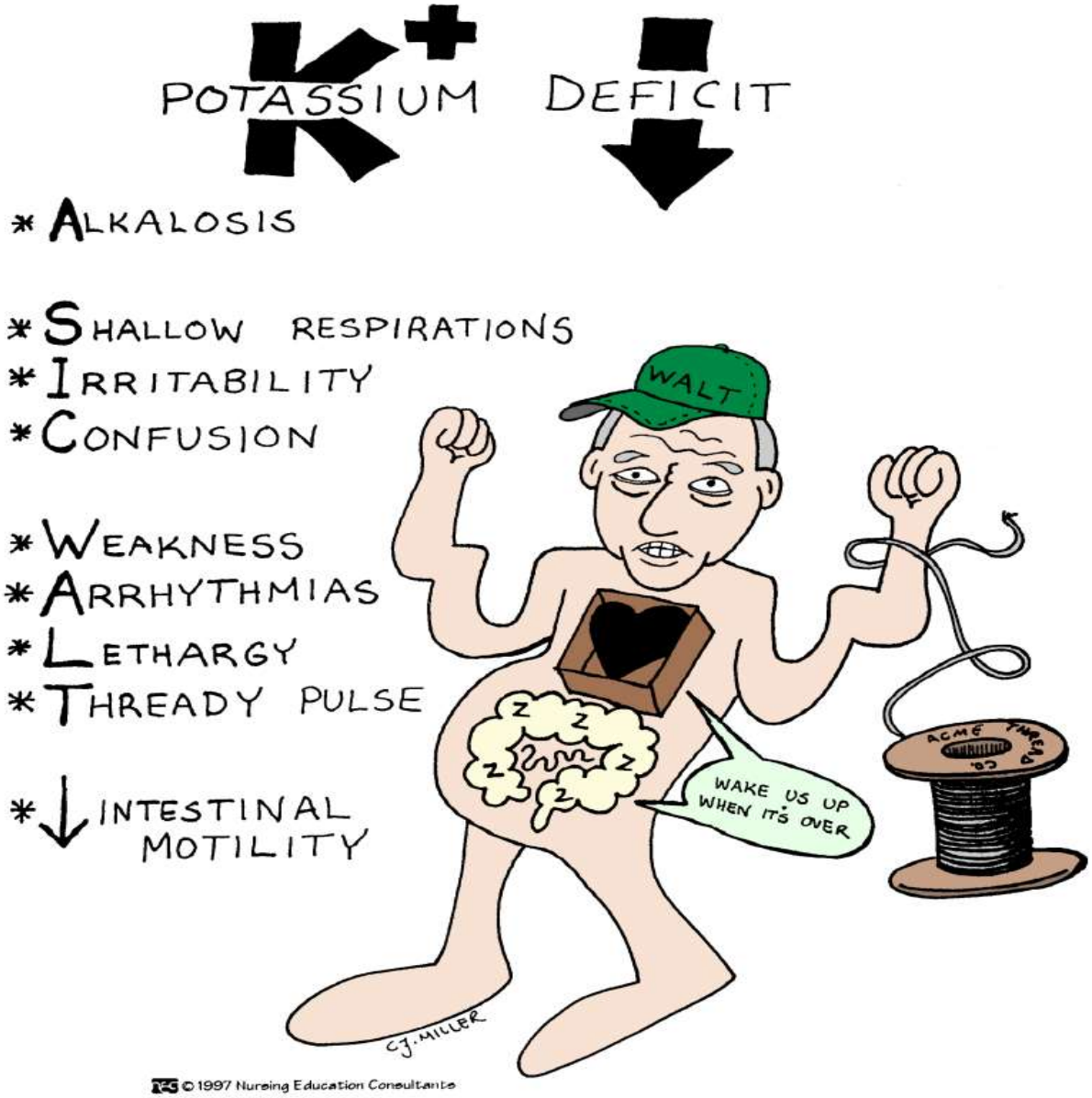


Hyperkalemia therapy

- Direct antagonism of hyperkalemic effect on cell membrane polarization
  - **Calcium gluconate**
- Movement of extracellular K into intracellular compartment
  - **Insulin (+glucose)**
  - **Sodium bicarbonate**
  - β_2-adrenergic agonists
- Removal K from the body
  - **Loop diuretics**
  - Sodium polystyrene sulfonate
  - **Dialysis**

Hypokalemia

- Causes:
  - Decreased K intake
  - Increased excretion: vomiting, diarrhea, renal losses, diuretics
  - Shifts of K into cells: drugs (Insulin, β_2-adrenergic agonists, Theophylline, Caffeine), alkalosis



- ✓flat T waves
- ✓Increased P wave
- ✓ST depression
- ✓U wave
- ✓QT interval prolongation
- ✓arrhytmias

Hypokalemia

What can you do?

Potassium administration

- Must have urine output
- Must be on cardiac monitor
- Assess IV site (prefer CVC)
- Always dilute and give no more than 20 mEq, no faster than 1 hr
- Max concentration in IV fluids is 40 mEq/l
- Never give IV push

Jacobus H. van't Hoff

- the osmotic pressure exerted by any substance in dilute solution is the same that it would exert if present as gas in the same volume as that of the solution; **or, at constant temperature, the osmotic pressure of dilute solutions is proportional to the concentration (number of molecules) of the dissolved substance;** that is, the osmotic pressure, Π, in dilute solutions is $\Pi = RT\Sigma ci$,

where R is the universal gas constant, T is the absolute temperature, and ci is the molar concentration of solute;

- the rate of chemical reactions increases between two- and threefold for each 10°C rise in temperature.

- Starling Forces govern the passive exchange of water between the capillary microcirculation and the interstitial fluid.

- These forces not only determine the directionality of net water movement between two different compartments but also determines the rate at which water exchange occurs.

Formal Relationship

$$J_v = K_f [(P_c - P_i) - (\Pi_c - \Pi_i)]$$

- J_v = Net fluid movement (ml/min). A positive value indicates movement out of the circulation.
- K_f = Vascular Permeability Coefficient
- P_c = Capillary hydrostatic pressure
- P_i = Interstitial hydrostatic pressure
- Π_c = Capillary oncotic pressure
- Π_i = Interstitial oncotic pressure

The Nernst Potential

at what point the two forces (chemical and electrical gradients) balance each other

$$E = z(61.5) \times \frac{[X]\ \text{extracellular}}{[X]\ \text{intracellular}}$$