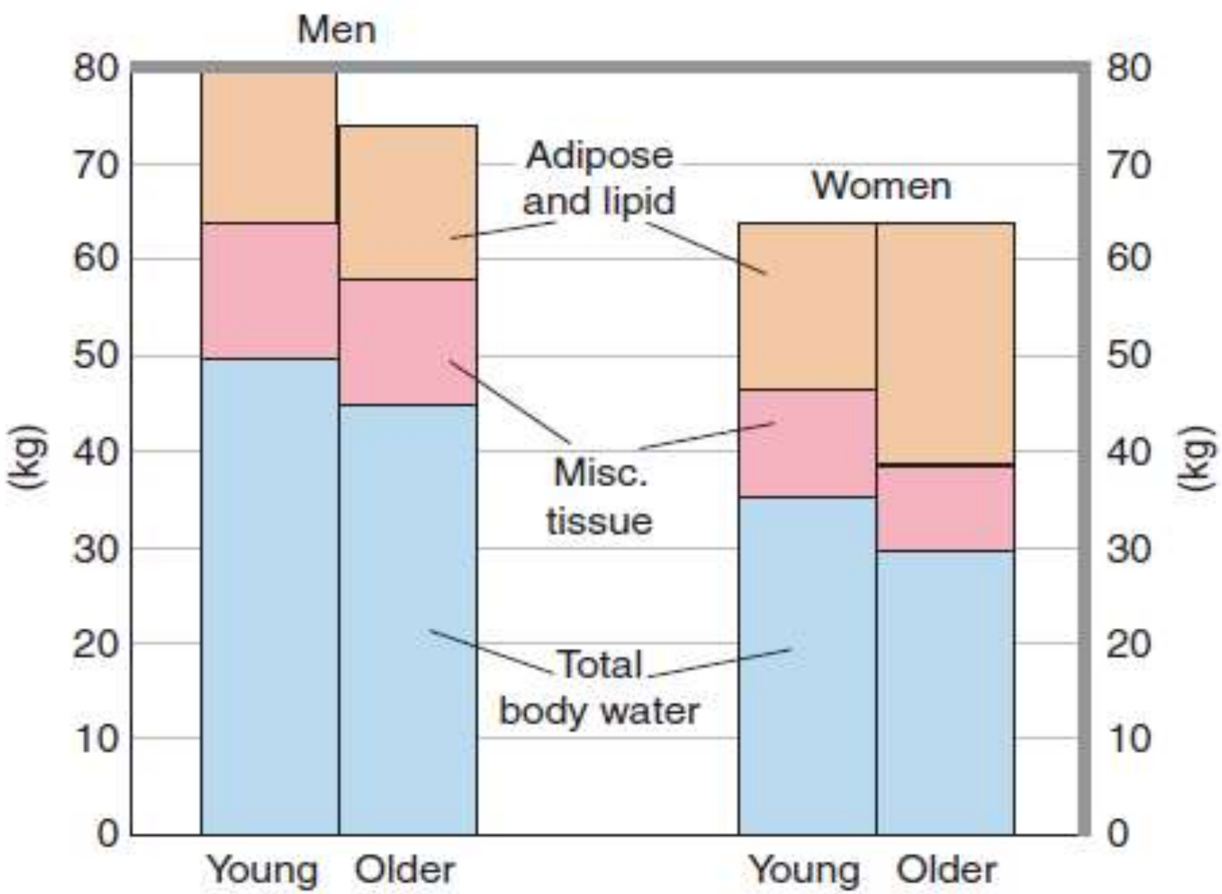
UNIVERSITATEA DE
MEDICINĂ ŞI FARMACIE
TÎRGU MUREŞ

Water & electrolyte disturbances

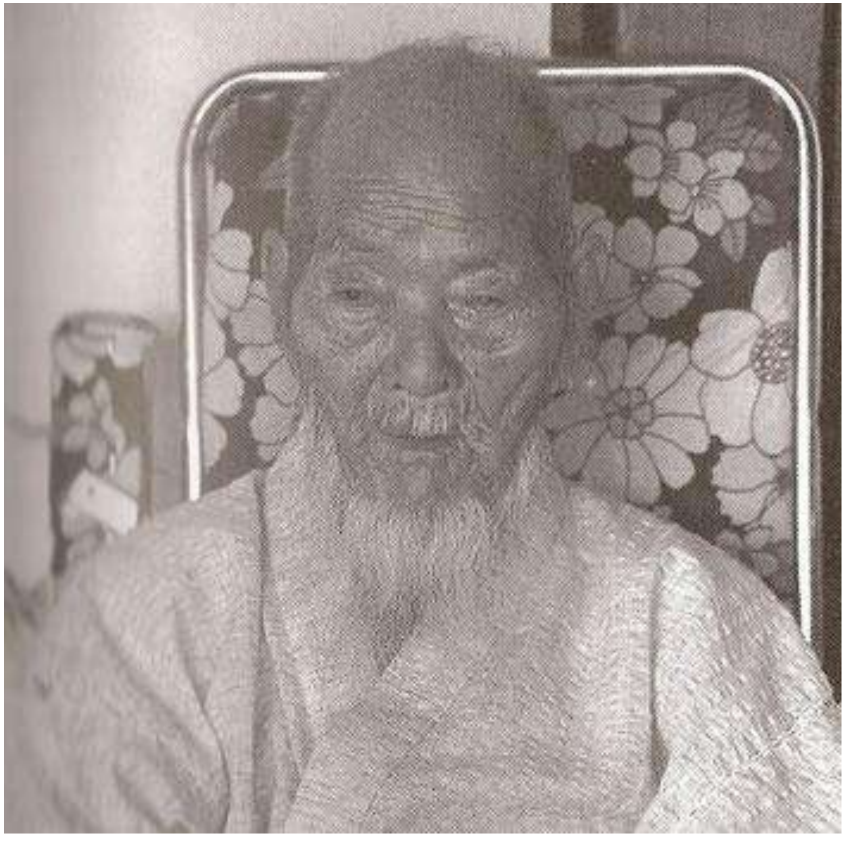
Copotoiu Ruxandra

Total body water TBW

- **60% men, if 70kg TBW = 600ml/l = 42kg**
- **50% women**
- **Age dependent**


Men
Women
Adipose
and lipid
Misc.
tissue
Total
body water
(kg)
80
70
60
50
40
30
20
10
0
Young
Older
Young
Older

Shigechyo Izumi born June 1965, lived 120 years + 237 days



- Worked until 105 yars
- Drank sake
- started to smoke at 70yrs

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

TBW age dependent




UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÂRGU MUREŞ

UNIVERSITATEA DE
MEDICINĂ ŞI FARMACIE
TÎRGU MUREŞ

Growing old

UNIVERSITATEA DE
MEDICINĂ ŞI FARMACIE
TÎRGU MUREŞ

TBW compartments

- Intracellular 2/3 total water = 40% total body weight
- Extracellular 1/3 = 20%total body weight

  - Intravascular 5% total body weight
  - Interstitial fluid 15% total body weight

  Transcellular – part of extracellular 1-10l

  Plasma + red cells = blood volume = 7% total body weight

Osmolarity = tonicity = nr of particles in solution = 280-295mOsm/l

UNIVERSITATEA DE MEDICINĂ ȘI FARMACIE TÎRGU MUREȘ

Osmolality = mOsm/kg

Measured osmometers

- **Depression of the freezing point**
- **Vaporization**

Calculated

$2xNa^{+}$ + BUN/2.8 + glicemia/18 = 280-295

Urine osmolality

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

50 – 1200mOsm/kg

Hel imbalances

- Compartment volume – regulated by aldosteron

- Fluid concentration– regulated by ADH

Tonicity regulation

AVP arginine vasopressin = ADH

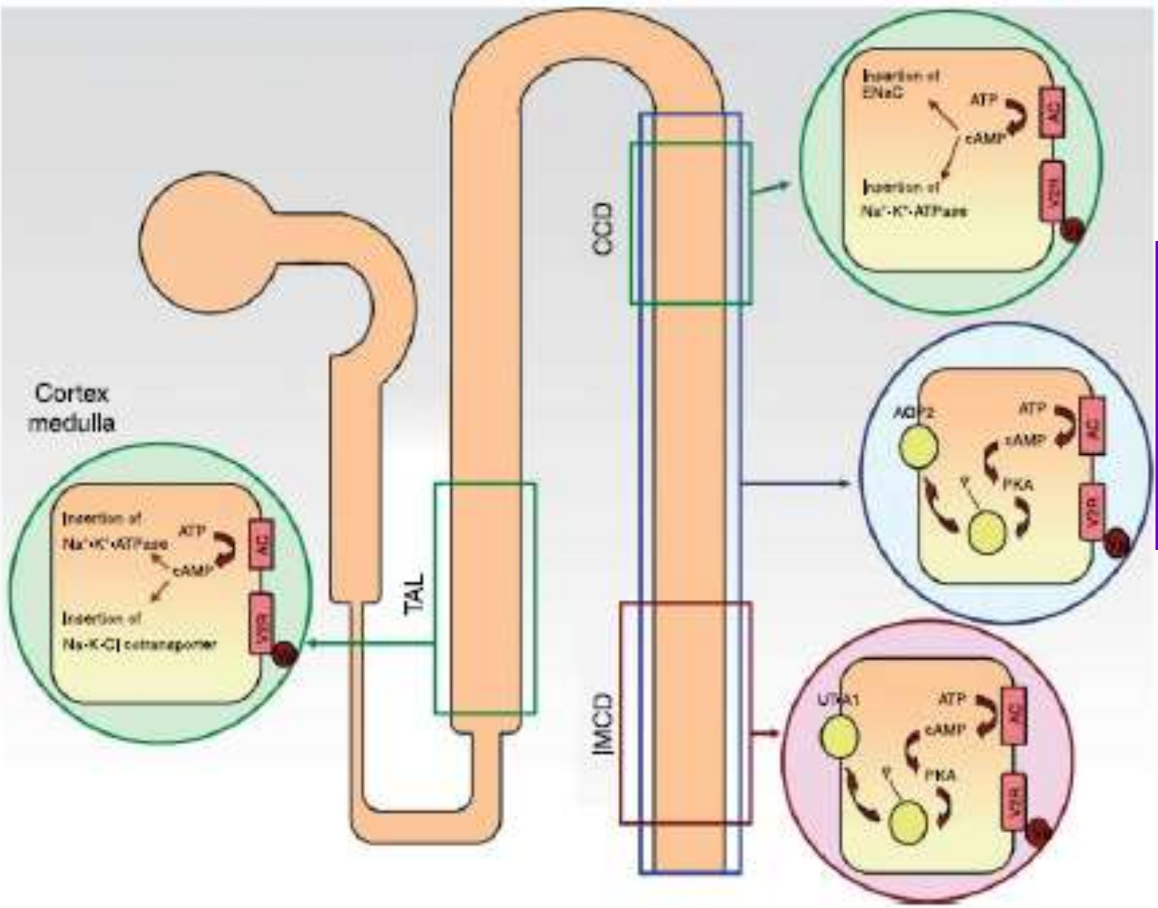
Dependency:

- Water intake
- Hormone output
  - **Small changes of osmolality 1-2% osmorecceptors ant hypothalamus**
  - **Mean BP/blood volume baroreceptors – Ao arch, carotid bodies**

Vasopressin-independent mechanisms in controlling water homeostasis

Carrie Y Y Cheng*, Jessica Y S Chu* and Billy K C Chow
School of Biological Sciences, The University of Hong Kong, Pokfulam, Hong Kong SAR, People's Republic of China

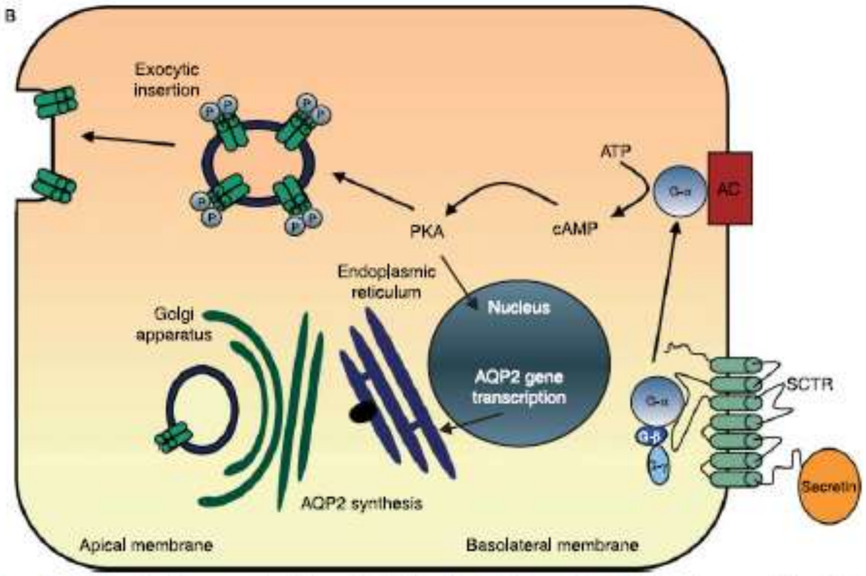
UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

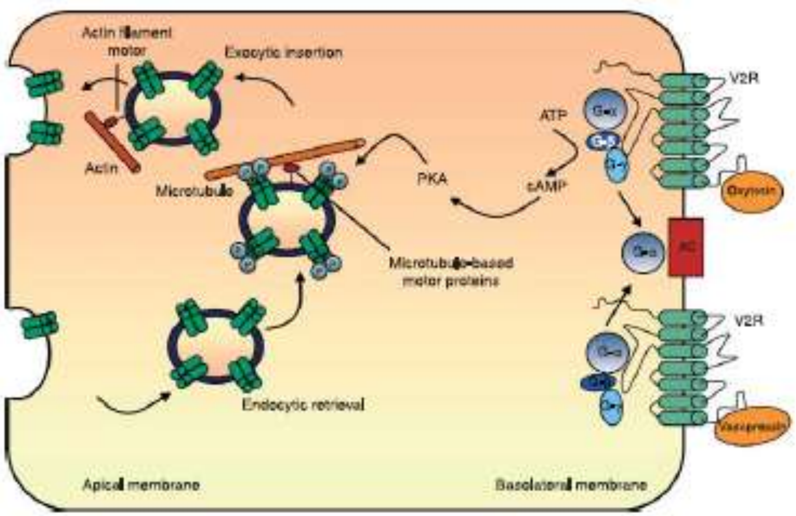


ADH→↑AQP-2channels:

- **Free water reabsorbtion**
- **antidiuresis**

Secretin & oxytocine contribution to water regulation





ICF concentration of solutes # ECF concentration of solutes
70kg adult, masculine, TBW = 42l

Compartment	water	Cations & anions
ICF	28l (40% x 70)	Na+ 10; K 150+; Ma 2+ 40; Fosfates 107; proteins 40; sulfates 43
ECF	Circulating BV = 4.9 (7% x 70kg)	Na+ 142; K+ 4; Ca2+ 5 ; Mg2+ 3; Cl 103; NaHCO3 27
	14l (20% x 70)	Na+

ICF concentration of solutes # ECF concentration of solutes
70kg adult, masculine, TBW = 42l

Compartment	water	Cations & anions
ICF	28l (40% x 70)	Na+ 10; K 150+; Ma 2+ 40;
EC	4.9 (7% x 70kg)	; Mg2+ 3; Cl 103; NaHCO3 27
	14l (20% x 70)	Na+

If the IC stores of solutes are depleted, one needs large amounts of certain electrolytes to replete small serum changes.

ICF concentration of solutes # ECF concentration of solutes
70kg adult, masculine, TBW = 42l

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Compartment	water	Cations & anions
ICF	28l (40% x 70)	Na+ 10; K 150+; Ma 2+ 40;
EC	4.9 (7% x 70kg)	; Mg2+ 3; Cl 103;

If the IC stores of solutes are depleted, one needs large amounts of certain electrolytes to replete small serum changes.

As today, we are unable to assess intracellular electrolytes at the bedside.

Fluid flux between intravascular compartment and interstitium Q

Plasma proteins/interstitial fluid proteins 16/1 = oncotic pressure difference.

$$Q = Kf\ \{(Pc - Pi) - \sigma(\pi c - \pi i)\}$$

Q = net flux

Pc-Pi = hydrostatic pressure capillary/interstitium

πc - πi = oncotic pressure difference

Kf membrane filtration coefficient ml/min/mmHg (capillary surface area x capillary hydraulic conductance)

σ = permeability factor (0 = completely permeable, 1=impermeable)

Fluid flux between intravascular compartment and interstitium Q

Plasma proteins/interstitial fluid proteins 16/1 = oncotic pressure difference.

$$Q = Kf \{(Pc-Pi) - \sigma(\pi c - \pi i)\}$$

Q = net flux

Pc-Pi = hydrostatic pressure capillary/interstitium

πc - πi = oncotic pressure difference

Kf membrane filtration coefficient ml/min/mmHg (capillary surface area x capillary hydraulic conductance)

σ = permeability factor (0 = completely permeable, 1=impermeable)

σ Explains why in capillary leak (shock, ARDS), colloids cannot mainaitn the oncotic pressure difference and leak into the interstitium.

Principles of fluid resuscitation

- **Intravascular hypovolemia should be replaced with isotonic fluids which tend to distribute in the ECF (3:1) intravascular: interstitium.**
- **Hipotonic fluids will distribute evenly between all body compartments.**

- **The endpoint of fluid resuscitation !?**
  - **Surrogate markers: BP, HR, urine output, parameters of perfusion and cardiac function.**

Hyponatremia ser Na^+<135mE/l

Water>>>/Na

Clinical signs: Cerebral edema

Mild: 130-135 - asimptomatic

Moderate: 125-130: fatigue, malaise, nausea, usteadiness

Severe: 115-120 headache, restleness, obtundation, lethargy, seisures, coma, brainstem herniation, respiratory arrest, death

Truisms about Na

- Na is a relative fixed solute 136-140
  - K follows…should be closely monitored and replaced or opposed
- Disturbances in serum Na reflect disorders in water balance

- Administration of water to a patient with impaired water excretion can lead to hyponatremia.

Water intake and excretion/regulation

Hyper Na	Thirst stimulated $\longrightarrow$ ↑water intake ADH release↑ $\longrightarrow$ Concentrated urine	Free water retention
Normo Na		Free water intake = free water excretion
Hypo Na	ADH supressed $\longrightarrow$ Dilute urine	Free water excretion

States of impaired water excretion in the ICU leading to Hyponatremia

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

Volume depleted states

- Volume depletion
- Diuretics

Normal volume states

- SIADH
- Pain
- Postoperative state
- Nausea
- Hypothyroidism

Volume-expanded states

- Congestive heart failure
- Renal failure
- Cirrhosis

Hypo-osmolar hyponatremia

ECV

Hypovolemic

- Simultaneous loss of solute & water →↓ECV→nonosmotoc release of ADH. If water intake →hNa
- Cerebral salt-wasting syndrome

Isovolemic

- SIADH ser Osm<275, Urine>100mOsm/l
- Adrenal insufficiency – nonosmotic ADH release due to cortizol deficiency
- Pregnancy - chorionic GDT ↑

Hypervolemic

- Congestive heart failure
- Cirrhosis
- Chronic kidney disease

Dehidration

- Dehidration – ambiguous term, uable to differentiate between simple water loss and Na loss
- A simple water deficit proportionally reduces ECF and ICF
- A NaCl deficit always reduces ECF

Water deficit (l) = 0,6 x G x Na plasmatic / (140 – 1)

Hyperosmolar Hyponatremia

↑↑osmotically active particles in plasma

Water efflux from ICS→ECS

hNa$^+$ & Hyperosmolality

Hyperosmolar Hyponatremia

↑↑osmotically active particles in plasma

↓

Water efflux from ICS→ECS

↓

hNa$^+$ & Hyperosmolality

Hyperglycemia, mannitol, glycerol, ethanol, sorbitol infusions

Iso-osmolar hNa

- ↑↑ECS by isotonic non-Na containing fluid
- ↑↑ serum proteins & lipids

Hypernatremia >145mmol/l

UNIVERSITATEA DE MEDICINĂ ŞI FARMACIE TÎRGU MUREŞ

- **Brain shrinked, collapsed→vascular damage + intracerebral or SAH**

- **Osmotic myelinosis = late, but following rapid hNa correction:**
  Lethargy, muscle weakness, nausea, hyperreflexia, seizures, coma

HNa

Diabetes insipidus

- **Central diabetes = ADH deficiency: TBI, pituitary surgery, brain death, aneurismal SAH, autoimmmune**

- **Nephrogenic**

  renal resistance to ADH

- **Osmotic diuresis – excess nonresorbable urinary solute**
  - **Hyperglycemia, mannitol, ↑↑serurea, hypertonic medication**

HNa

- Sea water ingestion
- Use of hypertonic saline for cerebral edema
- Use of NaHCO3 iv
- Overdose of tricyclic antidepressants

K^+

- **98% IC = 3 000mEq 140-150mmol/l**
- **EC <2% 60ml ser 3.5-4.5mEq/l**
- **Cellular access ; active Na+, K^+-ATP ase**
- **Cellular exit: passive diffusion**

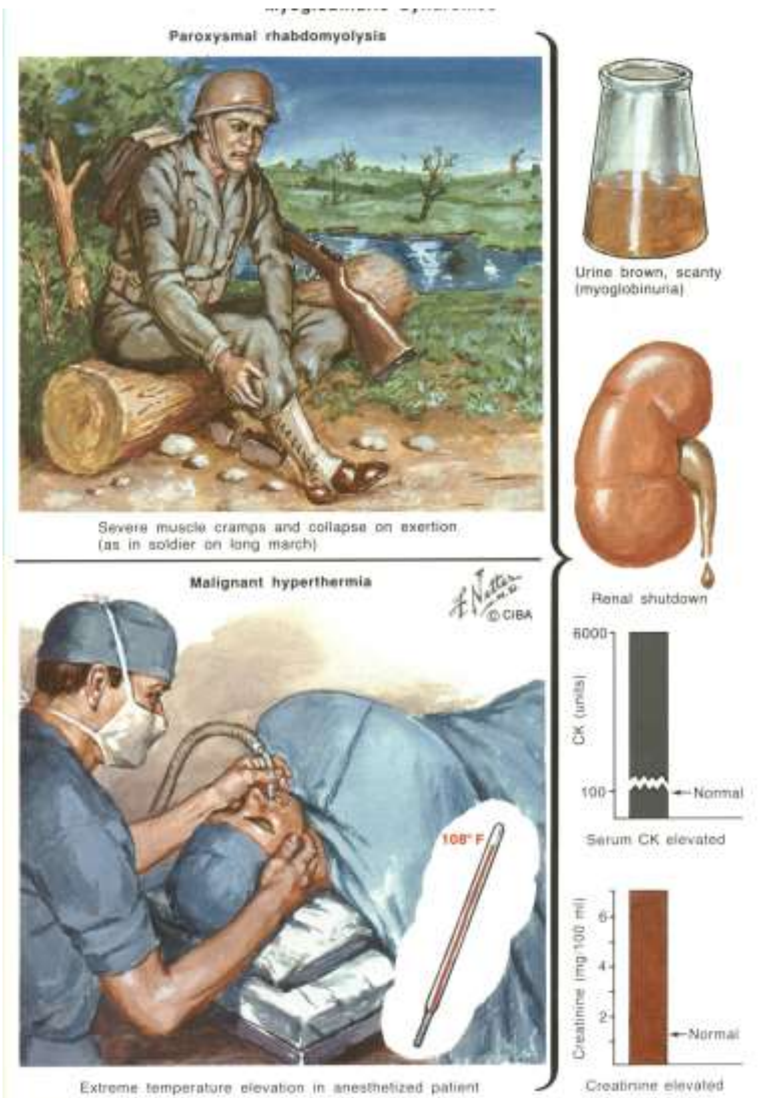
hK <3.5

- ↓ K intake
- ↑renal losses
- Redistribution ECS → ICS

HK+>5.0

- Exogenous
- Endogenous

Myoglobinuria sindromes

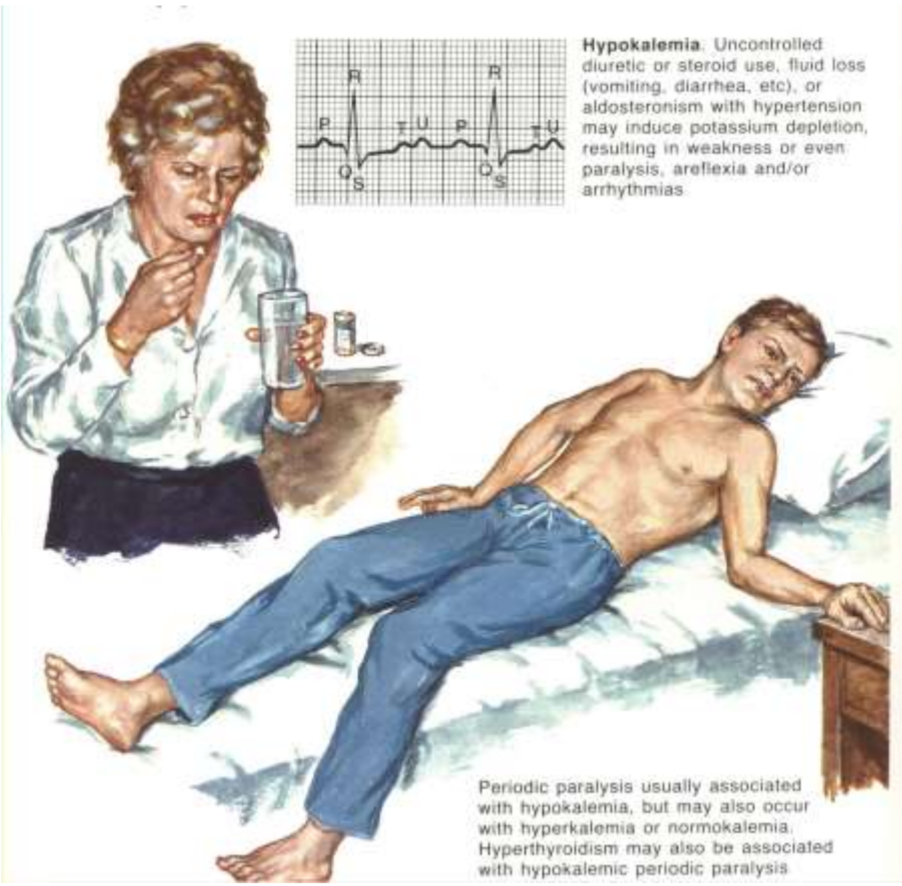


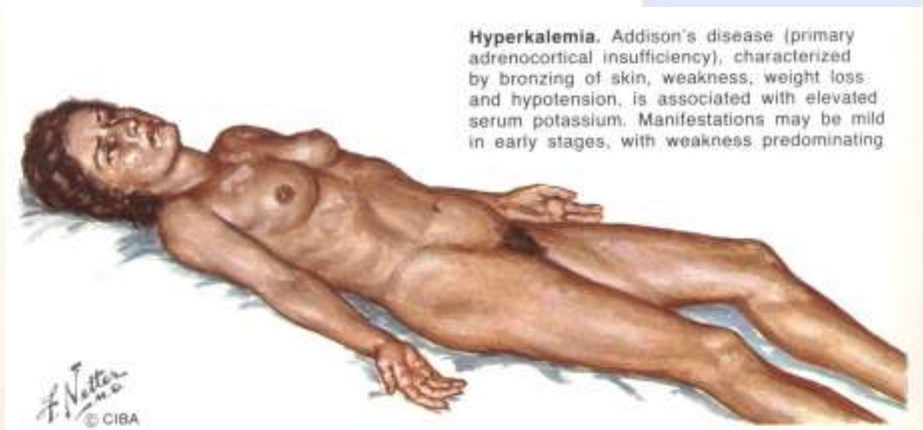
- Paroxistic rhabdomyolisis: severe muscle pain, exericise collaps
- Malignant hyperthermia
- Rhamdomiolysis due to heroin overdose

(Kumar, BJA 1999;83:496-498)

PPF periodic familial paralysis

UNIVERSITATEA DE
MEDICINĂ ŞI FARMACIE
TÎRGU MUREŞ





HEL status assessment

UNIVERSITATEA DE
MEDICINĂ ŞI FARMACIE
TÎRGU MUREŞ

Volemia assessment

- BP supine + sitting
- HR
- Mucosal Humidity
- Skin fold
- Urinary output

Assessment of plasmatic concentration

- Na serum
- serum osmolality

Assessment of electrolyte composition

Serum electrolites, BUN, glycemia, ABG, pH