Electrolyte and Water Balance

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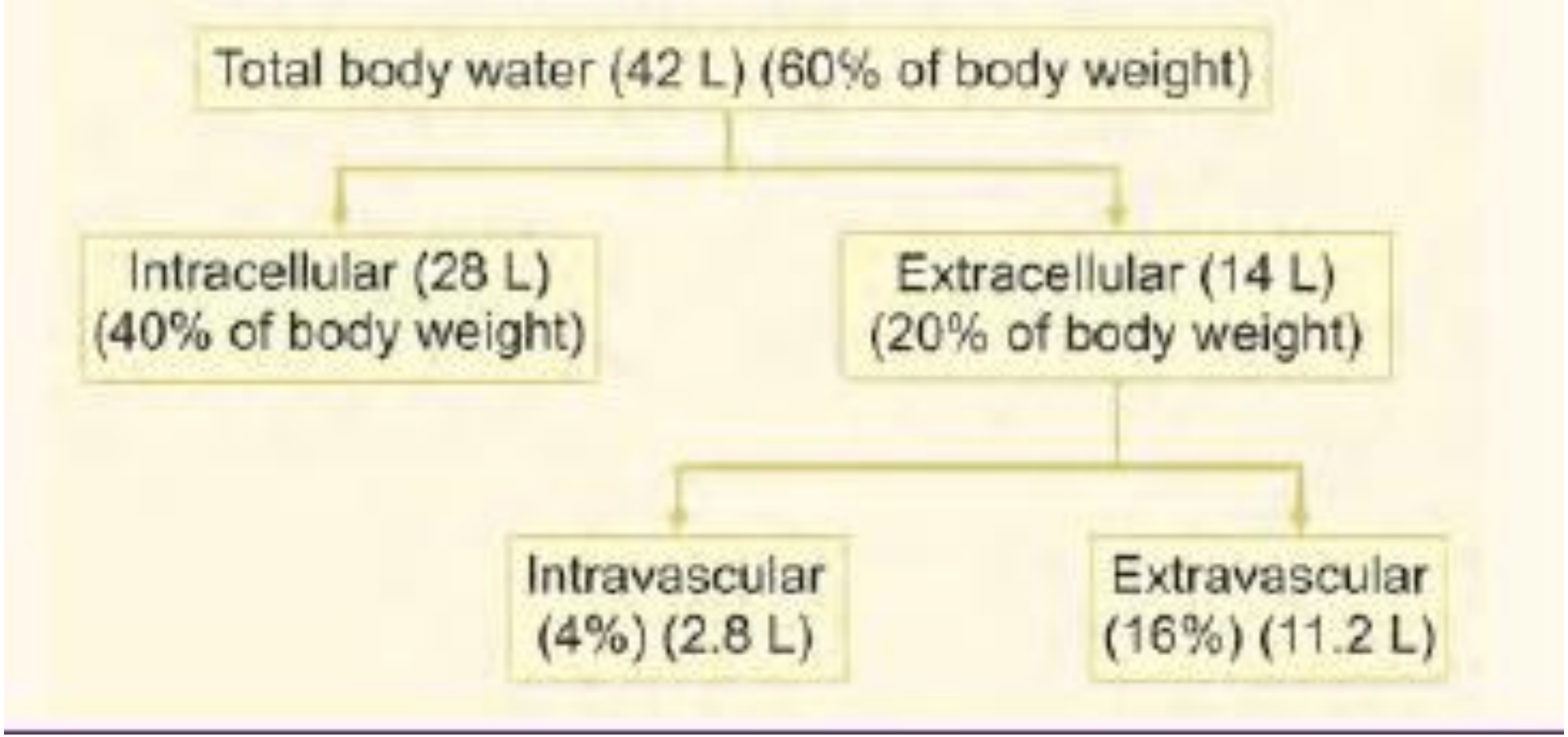
Case Report

- A 55-year-old man was brought to the emergency with severe multiple injuries in a road traffic accident and crush injuries, fractures of the legs and scalp lacerations. He was conscious and breathing spontaneously. Pulse 130/min, BP 60/40 mm Hg, serum sodium 142 mmol/L, potassium 7.9 mmol/L, chloride 110 mmol/L, Blood urea 40 mg/dL, and serum creatinine 1.2 mg/dL.
- Interpret the laboratory data?
- What is the basis of the changes?

The body water compartments



- During oxidation of foodstuffs,
  - 1 g carbohydrate produces
    - 0.6 mL of water,
  - 1 g protein releases
    - 0.4 mL water and
  - 1 g fat generates
    - 1.1 mL of water.

- major factors controlling the intake :
  - thirst and
  - the rate of metabolism.

Water balance in the body

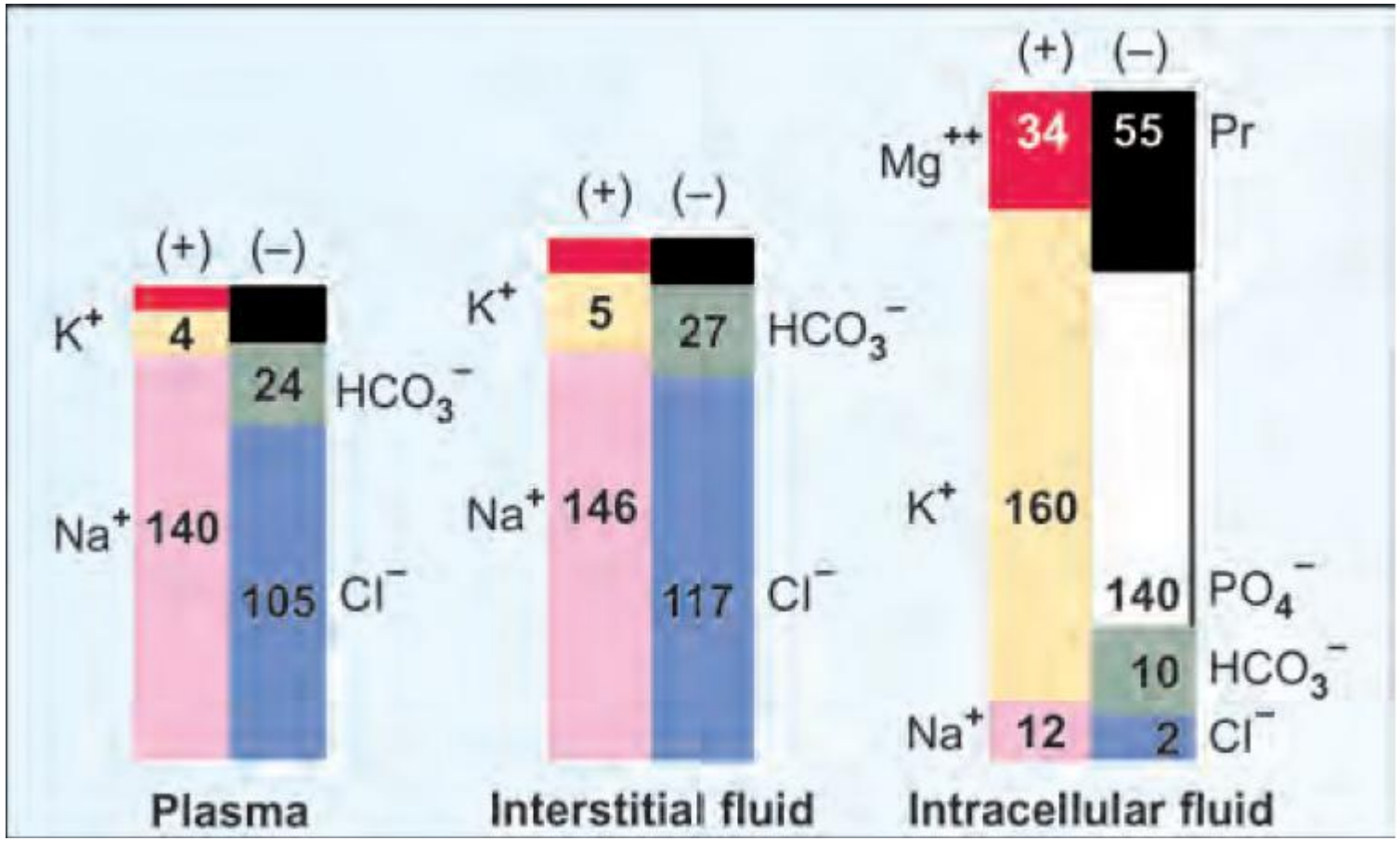
Intake per day		*Output per day*	
Water in food	1250 mL	Urine	1500 mL
Oxidation of food	300 mL	Skin	500 mL
Drinking water	1200 mL	Lungs	700 mL
		Feces	50 mL
	2750 mL		2750 mL

- **Osmolarity means osmotic pressure exerted by the**
  - number of moles per liter of solution.
- **Osmolality is the osmotic pressure exerted by the**
  - number of moles per kg of solvent.

- osmotic balance is mainly maintained by
  - **Albumin**

- the major determinant factor of osmolality is
  - the **sodium**
- The **osmolality of plasma varies from**
  - **285 to 295** mosm/kg

Gamblegrams showing composition of fluid compartments



Electrolyte and Water Composition of Body Fluid Compartments

Components	Plasma	Interstitial fluid	Intracellular fluid
Volume, H2O (TBW = 42 L)	3.5 L	10.5 L	28 L
Na+	142	145	12
K+	4	4	156
Ca+2	2.4	2-3	2.3
Mg2+	2	1-2	26
Trace elements	1	-	-
Total cations	**155**		
Cl–	103	114	4
HCO–	27	31	12
Protein–	16	-	55
Organic acids–	5		
HPO2 –	2		
SO2 –	1		
Total anions	**154**		

Formulas for Estimating Serum Osmolality and Effective Osmolality

Osmolality	Effective Osmolality
2 x [Na^+ mEq/L]	2 x [Na^+ mEq/L]
+ [glucose mg/dL] / 18	+ [glucose mg/dL] / 18
+ [BUN mg/dL] / 2.8	
= Sosm (mosm/Kg H_2O)	= Sosm (mosm/Kg H_2O)

Regulation of Sodium and Water balance

- ADH
- Renin-Angiotensin system
- Autoregulation

Disturbances in Fluid and Electrolyte balance

- Isotonic contraction- Loss of fluid that is isotonic with plasma--Loss of GI fluid
- Hypotonic contraction—Predominant Na loss– Infusion of fluids with low sodium content like dextrose
- Hypertonic contraction ---Predominantly water depletion---Diarrhoea

- Isotonic expansion---Secondary to hypertension
- Hypotonic expansion---ADH excess
- Hypertonic expansion---Conns syndrome & Cushings syndrome_ Excess mineralocorticoid- sodium retention

Reference interval of Sodium:

136-145 mmol/L (Adult)
128-148 mmol/L (New born at 48 h)
Approx 127 mmol/L (From Umbilical cord)

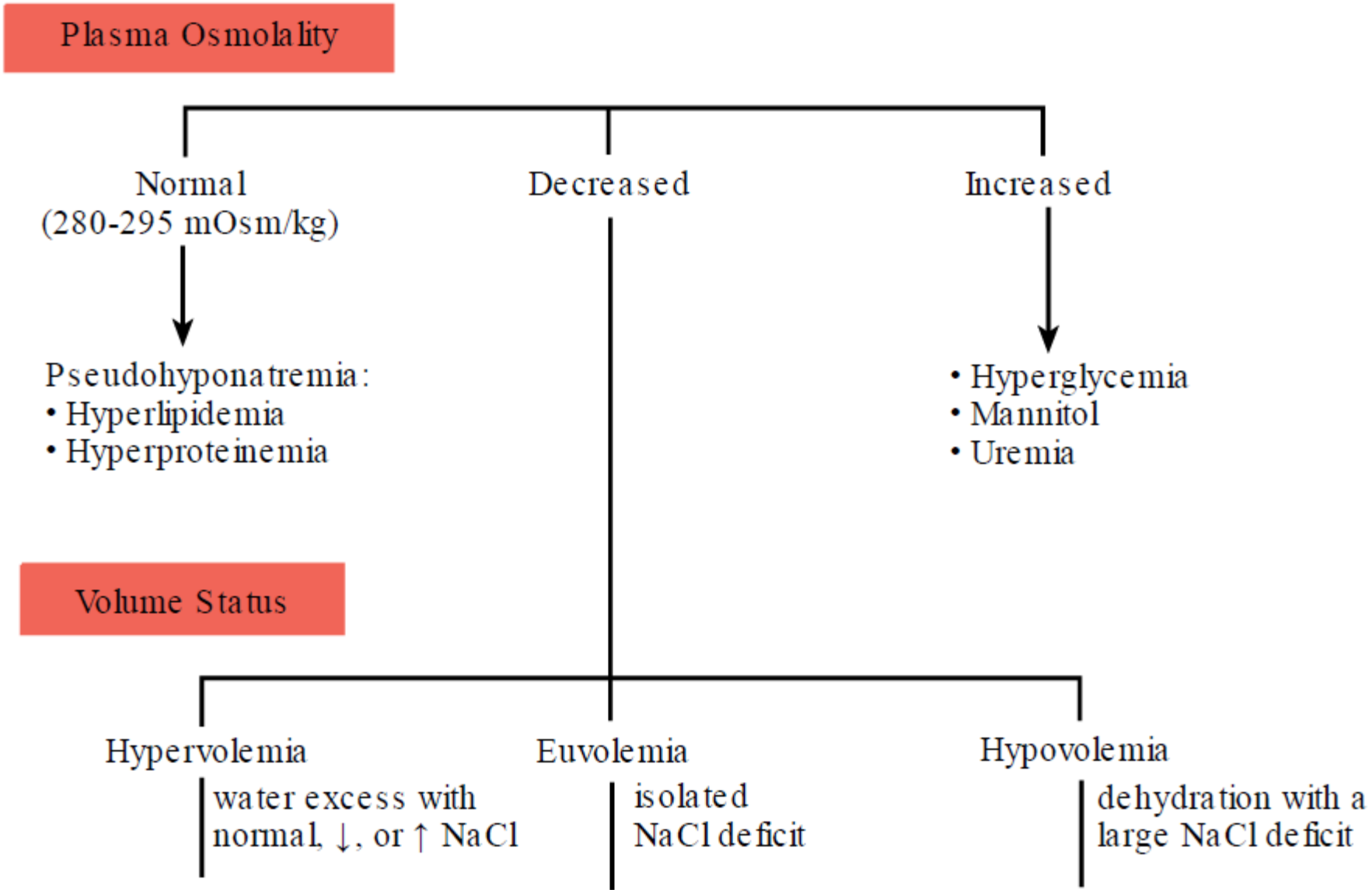
Urinary sodium excretion = 120-240 mmol/day with large diurnal variation
At night = 20% of the peak

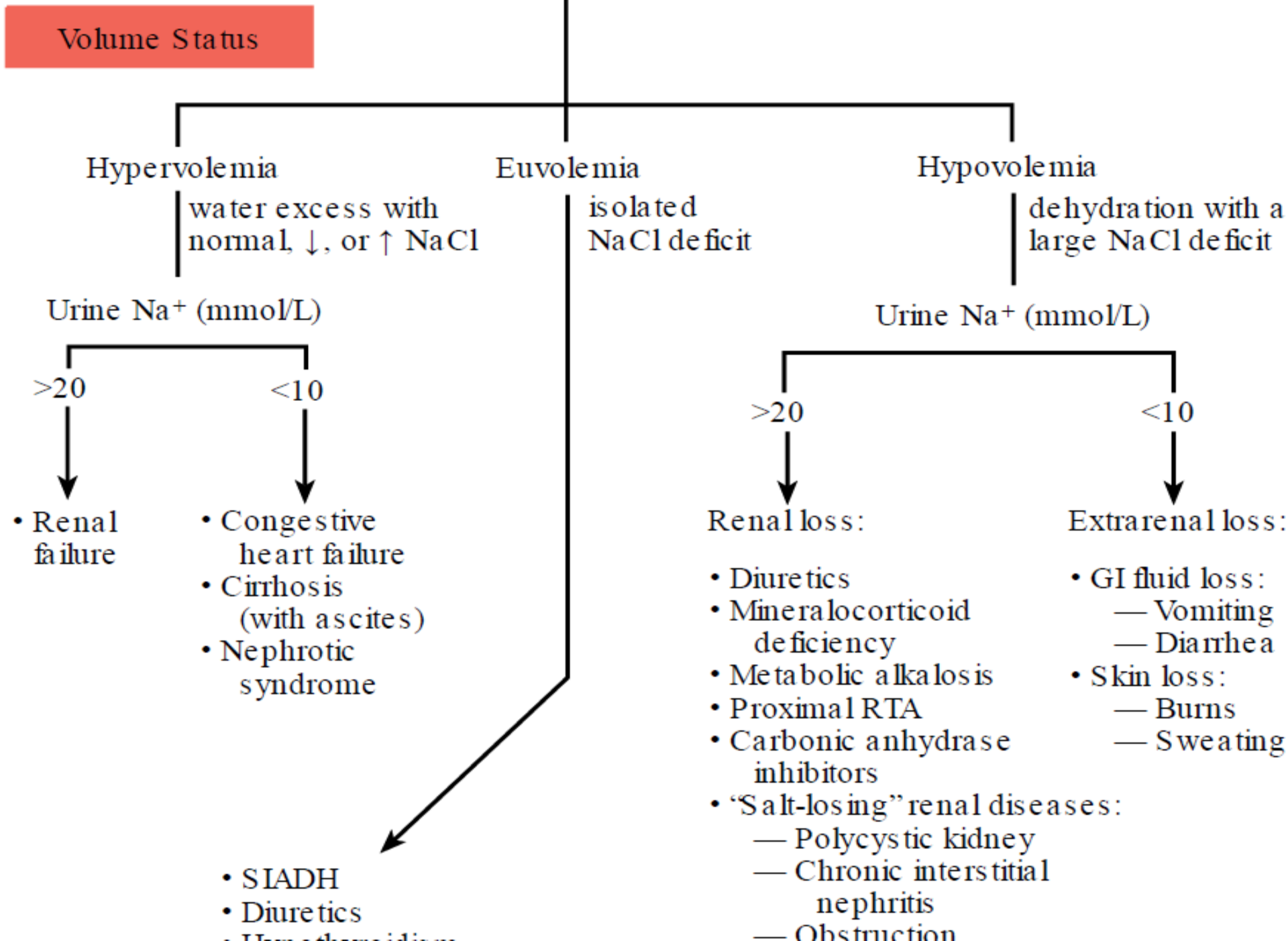
Hyponatremia typically manifests clinically as

(1) nausea,
(2) generalize weakness, and
(3) mental confusion.

<120 mmol/L: mental confusion
<110 mmol/L : Ocular palsy
90-105 mmol/L: Severe mental impairment

Algorithm for the differential diagnosis of hyponatremia.



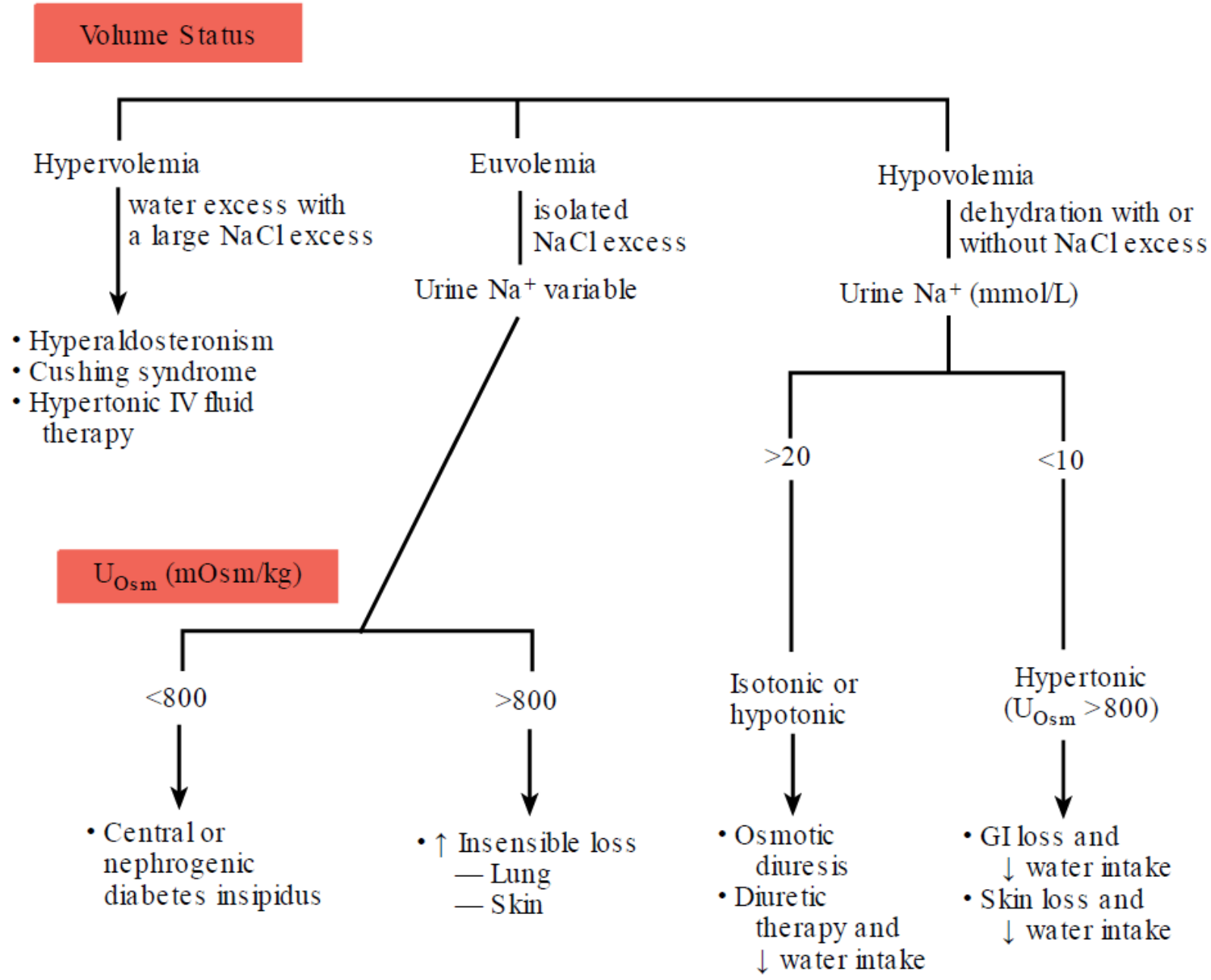

Volume Status
Hypervolemia
water excess with normal, ↓, or ↑ NaCl
Euvolemia
isolated NaCl deficit
Hypovolemia
dehydration with a large NaCl deficit
Urine Na+ (mmol/L)
>20
<10
• Renal failure
• Congestive heart failure
• Cirrhosis (with ascites)
• Nephrotic syndrome
• SIADH
• Diuretics
Urine Na+ (mmol/L)
>20
<10
Renal loss:
• Diuretics
• Mineralocorticoid deficiency
• Metabolic alkalosis
• Proximal RTA
• Carbonic anhydrase inhibitors
• "Salt-losing" renal diseases:
— Polycystic kidney
— Chronic interstitial nephritis
Extrarenal loss:
• GI fluid loss:
— Vomiting
— Diarrhea
• Skin loss:
— Burns
— Sweating

Hypernatremia Plasma sodium > 150 mmol/L

Symptoms are primarily neurologic
(because of neuronal cell loss of H_2O into the ECF)

1. Tremors
2. Irritability
3. Ataxia
4. Confusion
5. coma

Hypernatremia



HYPOKALEMIA

1. Muscle weakness
2. Irritability
3. Paralysis
4. Tachycardia
5. Cardiac conduction defect
6. Flattened T wave
7. Cardiac arrest

Reference interval of K+:

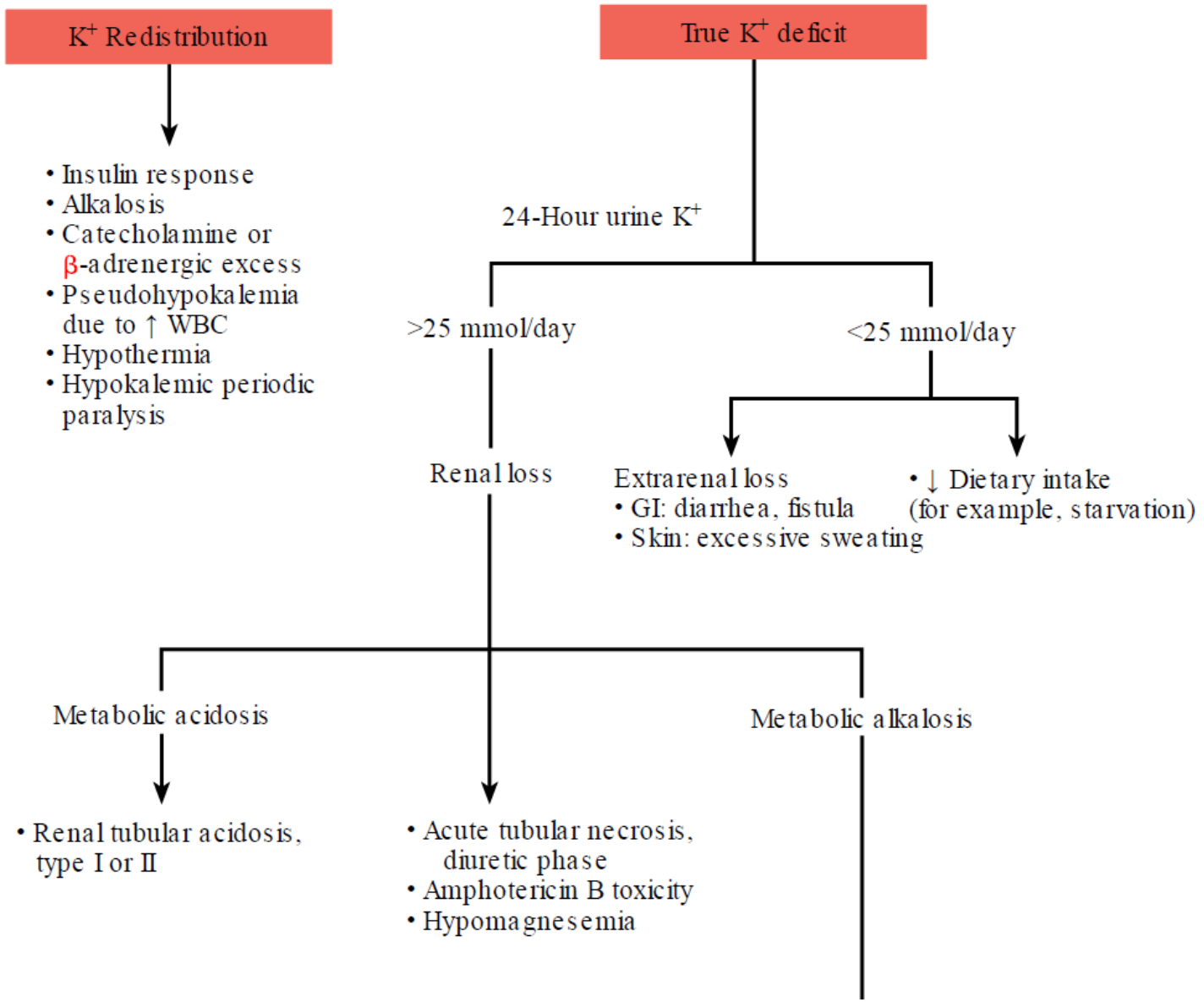
Serum=3.5-5.0 mmol/L (Adult)

Plasma= 3.4-4.8 mmol/L (Adult)

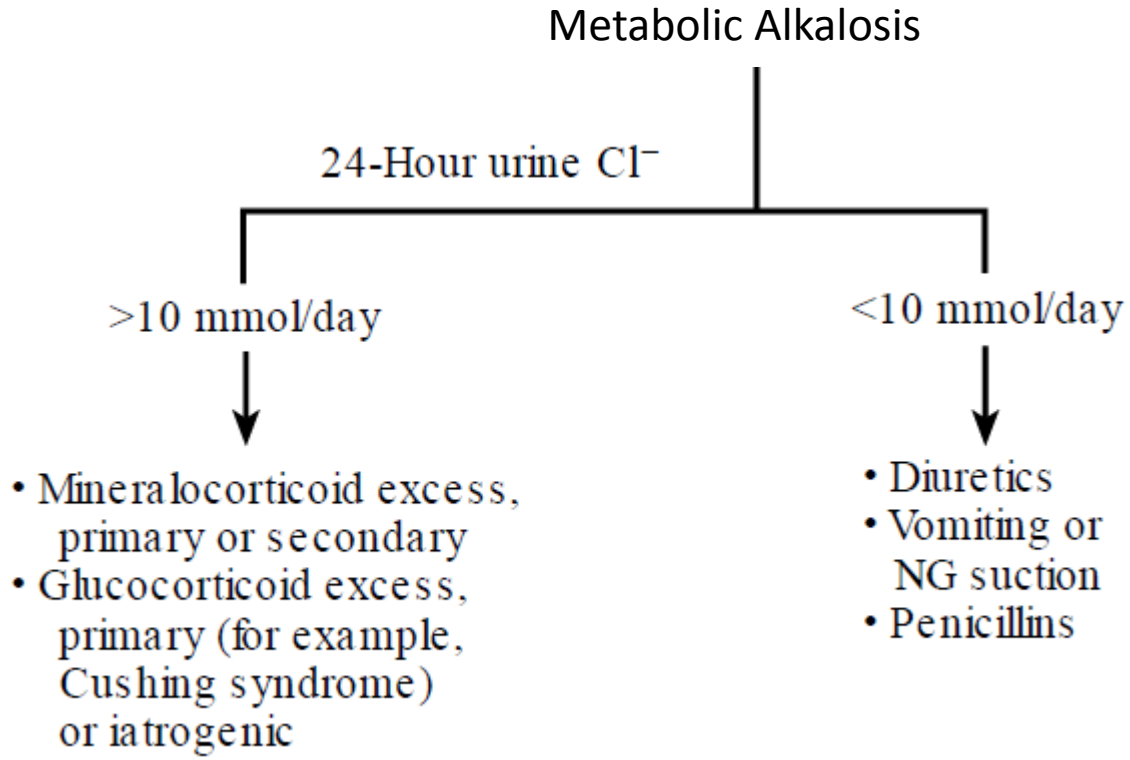
3.7-5.9 mmol/L (Newborn)

CSF= 70% that of plasma

Hypokalemia



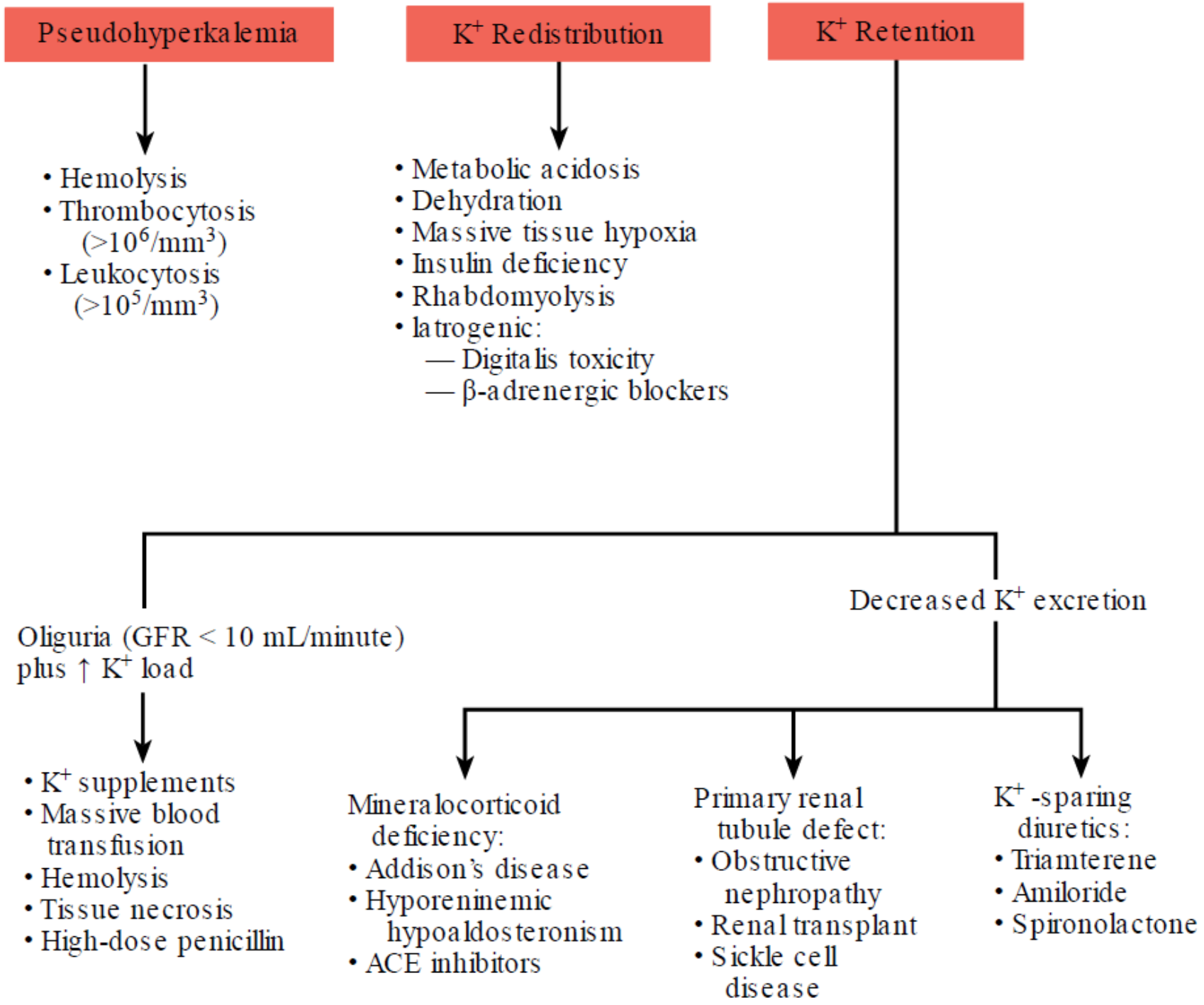
Hypokalemia (continued)



HYPERKALEMIA

1. Mental confusion
2. Weakness
3. Tingling
4. Flaccid paralysis of the extremities
5. Weakness of the respiratory muscles
6. Bradicardia
7. Conduction defects
8. Peripheral vascular collapse : Prolonged severe hyperkalemia >7 mmol/L
9. Cardiac arrest

Hyperkalemia



MCQ 1

- A patient with diarrhoea may have all the following abnormalities except:
  - A. Metabolic acidosis
  - B. Hypertonic contraction of ECF
  - C. Urine with a high specific gravity
  - D. Isotonic contraction of ECF

MCQ 2

- Which of the following is the major intracellular cation?
- A. Magnesium
- B. Sodium
- C. Calcium
- D. Potassium

MCQ 3

- All 5the following hormones affect fluid and electrolyte balance except:
- A. Aldosterone
- B. ADH
- C. Cortisone
- D. Thyroxine

References

- DM Vasudevan, textbook of medical biochemistry, 7th Edition,
- Tietz fundamentals of clinical chemistry and molecular diagnostics, 7th edition