Approach to Hypernatremia
Nephkids 2025 - Electrolytes workshop

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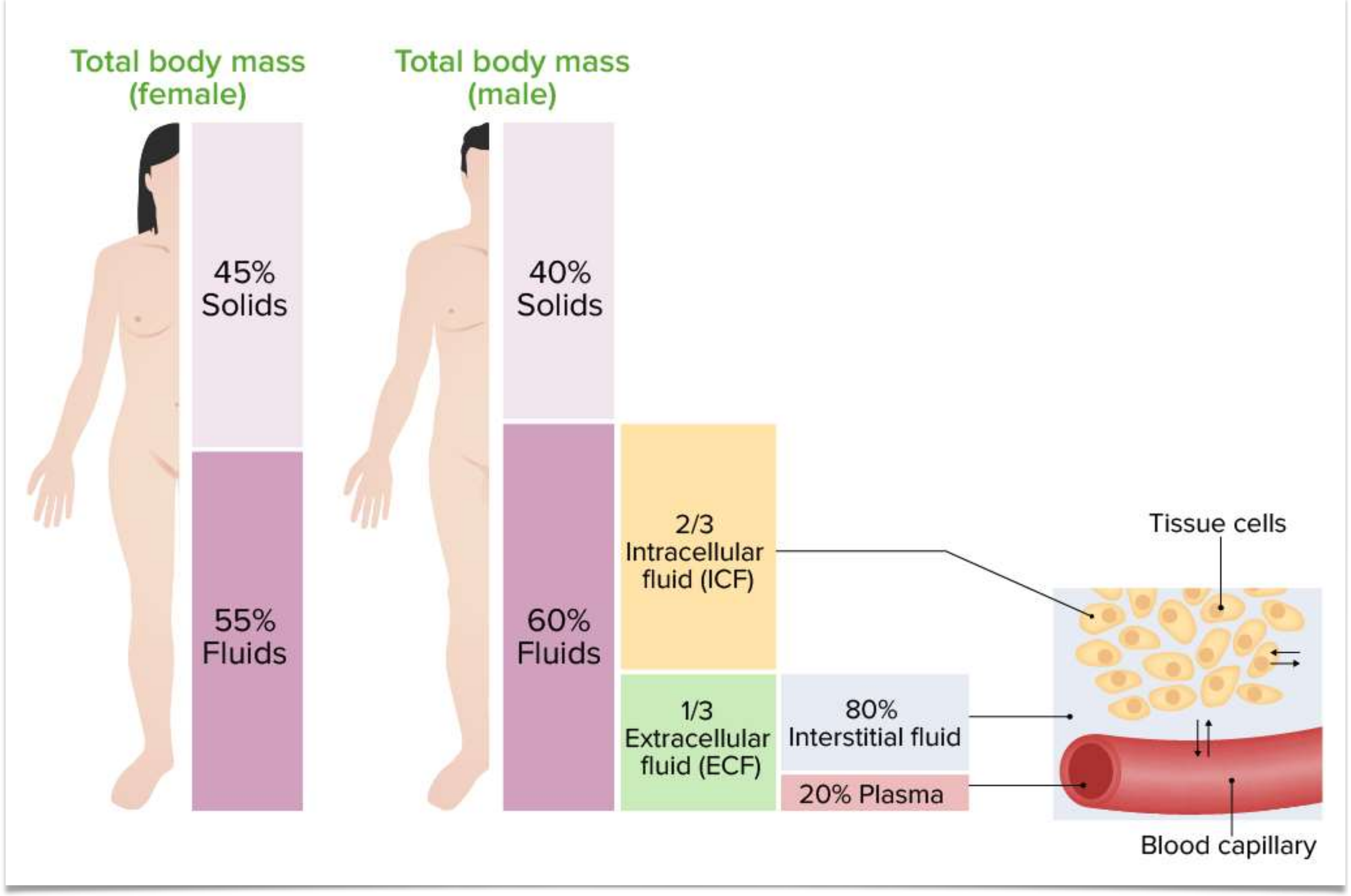
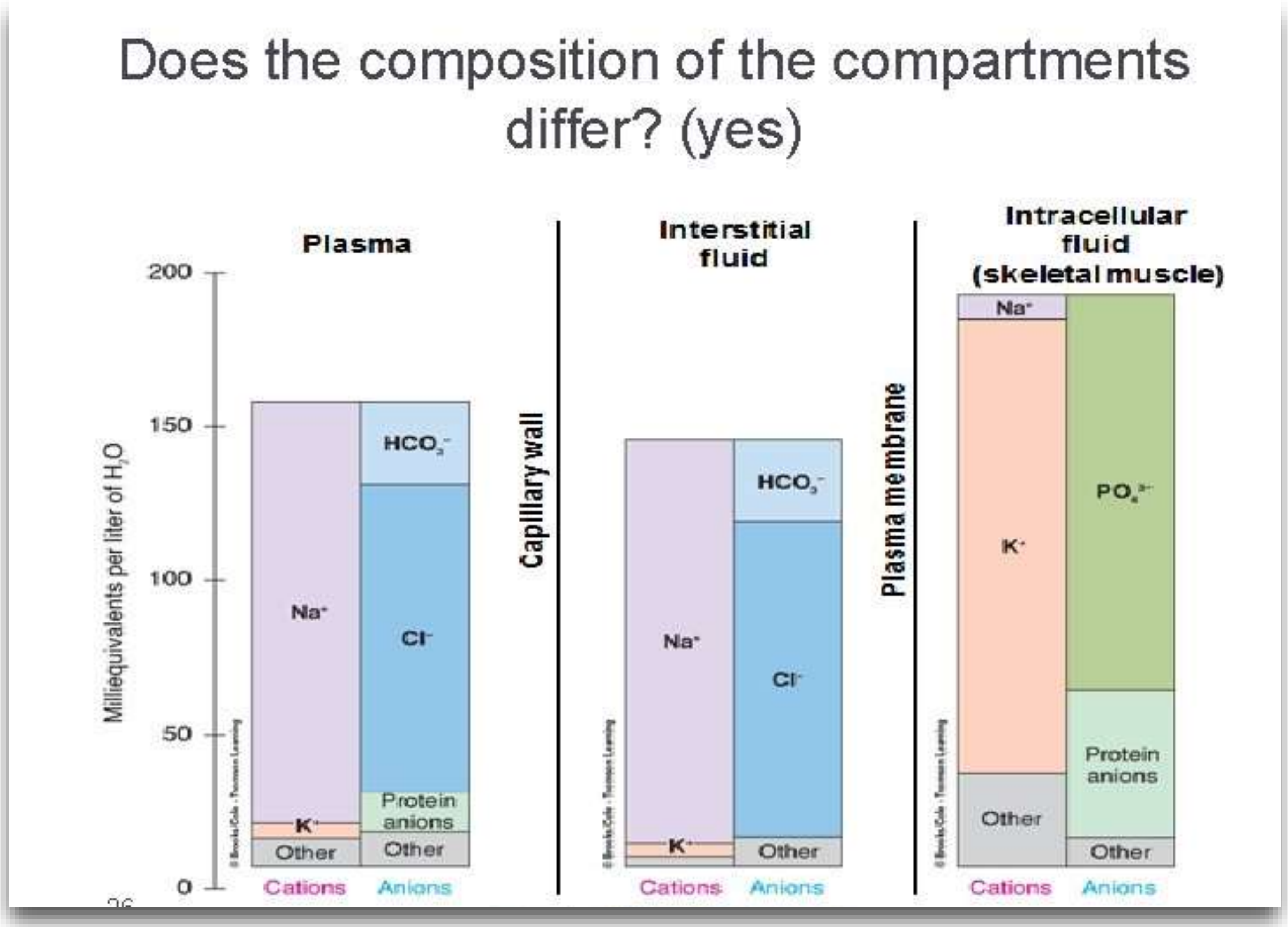
Composition of body fluids

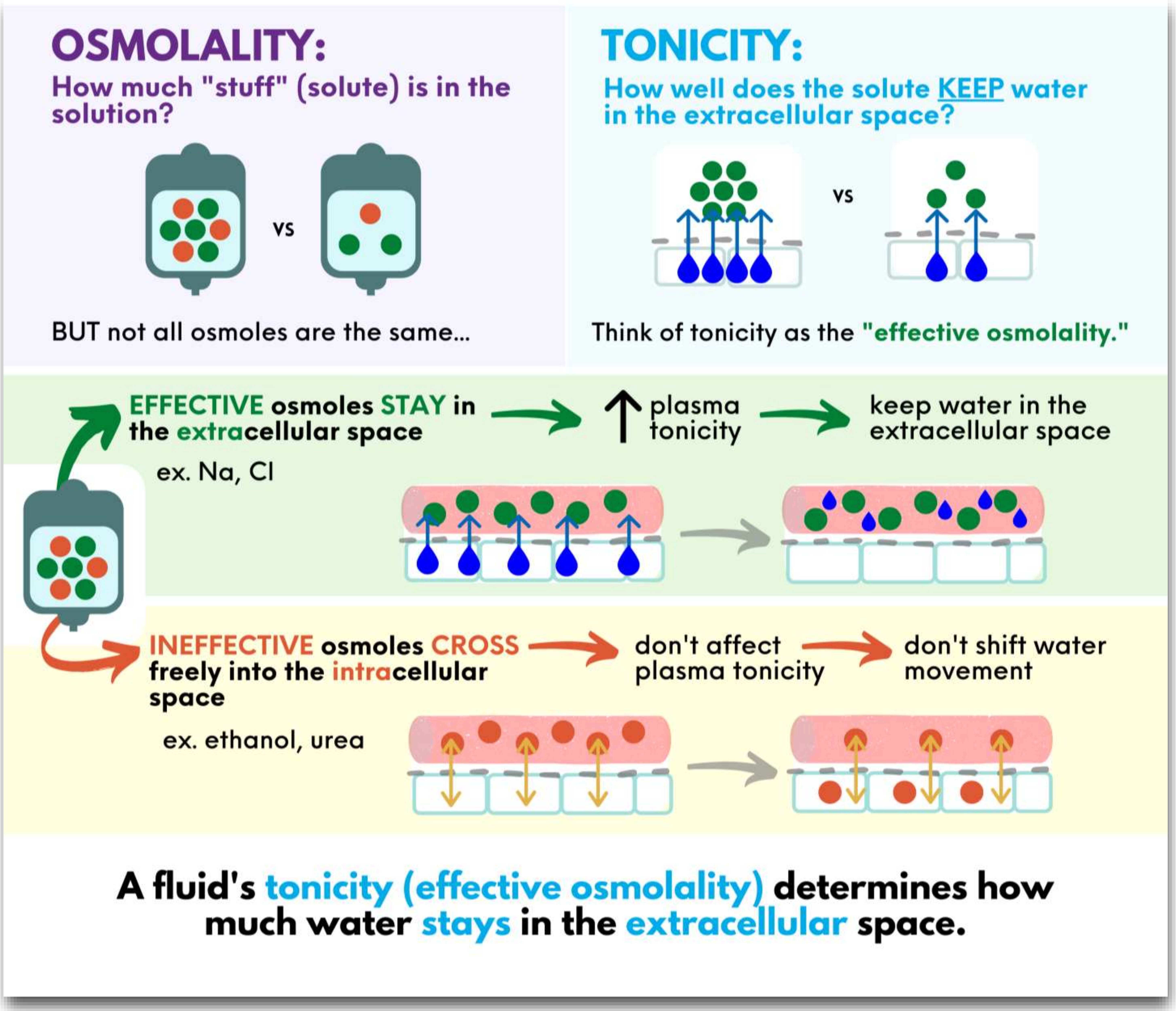




Sodium

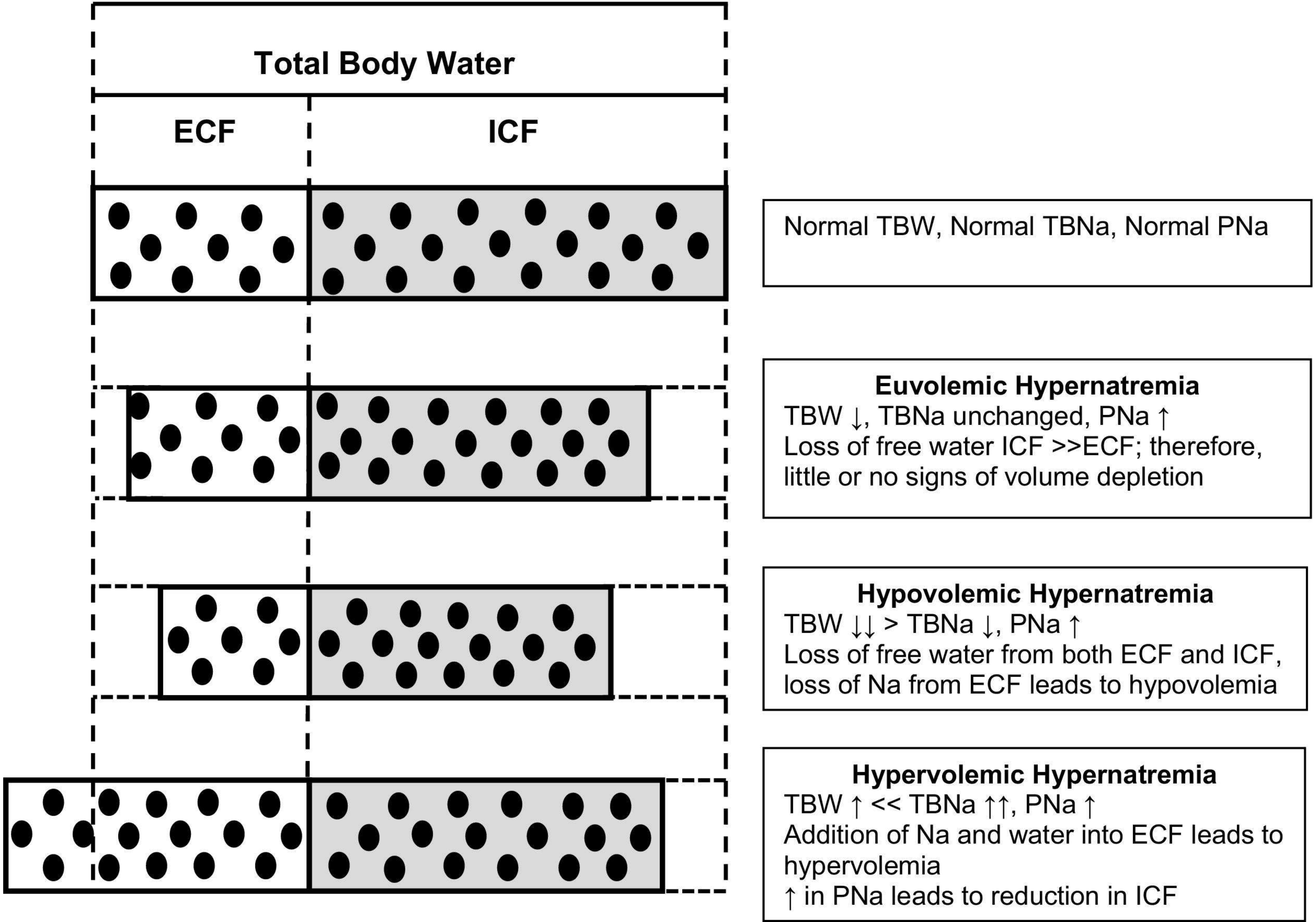
Basics

- Se. Na & osmolality - closely controlled by water homeostasis
- Regulated by thirst, AVP, kidneys
- Na is impermeable solute, contributes to tonicity, induces water movement across cell membrane
- Hypernatremia denotes hypertonic hyperosmolality and always causes cellular dehydration, at least transiently
- Resultant morbidity may be inconsequential, serious, or even life-threatening.
- Complications result not from the disorder itself but from inappropriate treatment of it


OSMOLALITY:
How much "stuff" (solute) is in the solution?
vs
BUT not all osmoles are the same...
TONICITY:
How well does the solute KEEP water in the extracellular space?
vs
Think of tonicity as the "effective osmolality."
EFFECTIVE osmoles STAY in the extracellular space
↑ plasma tonicity
keep water in the extracellular space
ex. Na, Cl
INEFFECTIVE osmoles CROSS freely into the intracellular space
don't affect plasma tonicity
don't shift water movement
ex. ethanol, urea
A fluid's tonicity (effective osmolality) determines how much water stays in the extracellular space.

Pathophysiology of hypernatremia

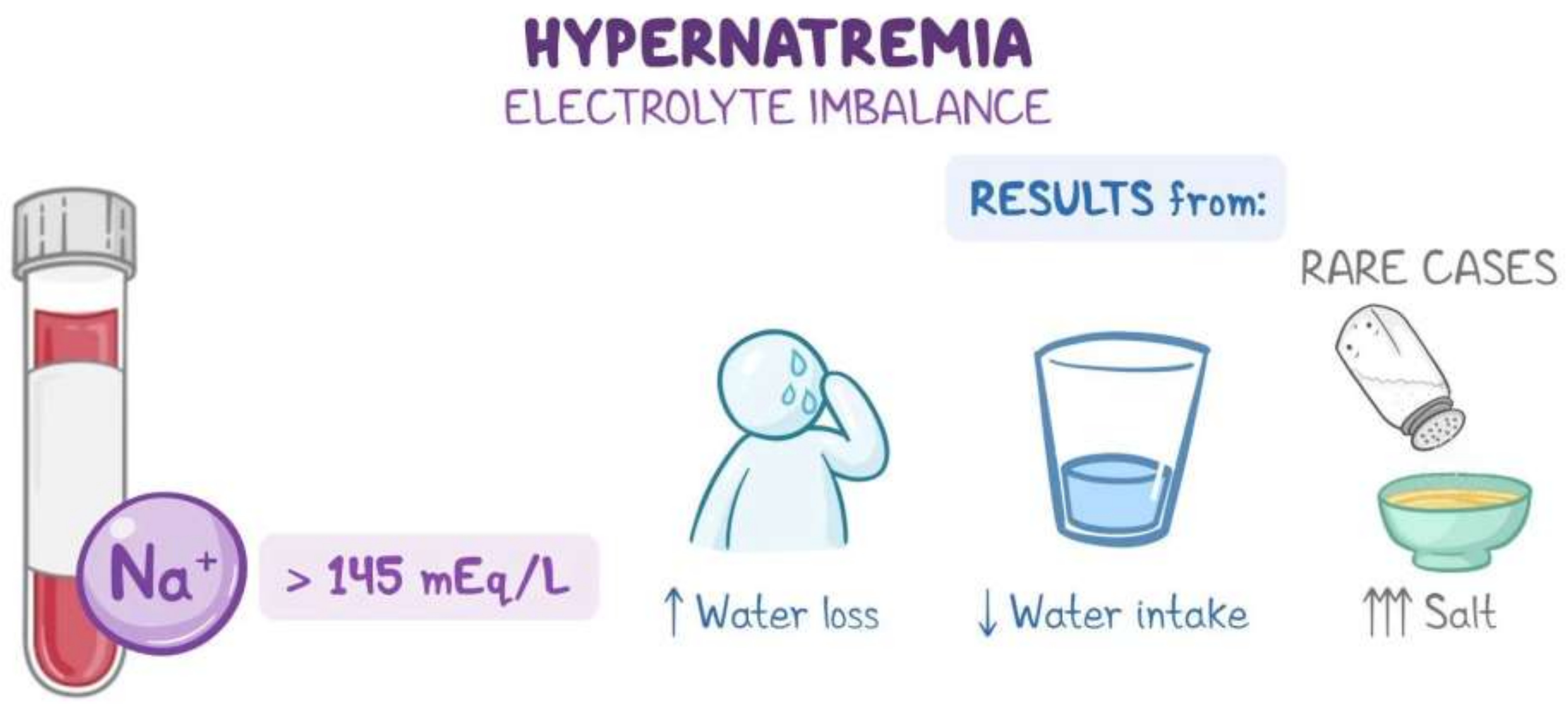
- Imbalance in body's handling of water; relative excess of plasma osmolality (tonicity)
  - Plasma tonicity = 2 x [Na] + [glucose]/18 (if glucose is measured in mg/dL)
  - Plasma tonicity = 2 x [Na] + [glucose] (if glucose is measured in mmol/L)
- Causes
  - Water loss that is not replaced
  - Excessive salt intake relative to water ingestion


Total Body Water
ECF
ICF
Normal TBW, Normal TBNa, Normal PNa
Euvolemic Hypernatremia
TBW ↓, TBNa unchanged, PNa ↑
Loss of free water ICF >>ECF; therefore, little or no signs of volume depletion
Hypovolemic Hypernatremia
TBW ↓↓ > TBNa ↓, PNa ↑
Loss of free water from both ECF and ICF, loss of Na from ECF leads to hypovolemia
Hypervolemic Hypernatremia
TBW ↑ << TBNa ↑↑, PNa ↑
Addition of Na and water into ECF leads to hypervolemia
↑ in PNa leads to reduction in ICF

Introduction

- Hypernatraemia is classified as:
    - Mild (146-149 mmol/L)
    - Moderate (150-169 mmol/L)
    - Severe (≥170 mmol/L)
- Acute < 48 hours
- Chronic > 48 hours
- Clinical suspicion (neurological signs) or high sodium value in a hospitalised child
- Not very common
- Incidence in neonates 0-14 days is 10 times higher than general incidence
- Infants - more at risk; higher ISWL and don’t have access to water

Etiology



Water deficit

Common:

- **Gastrointestinal loss** eg diarrhoea, stomal losses
- **Skin loss** (excess sweating/burns)
- **Renal losses** eg osmotic diuretics, diabetes mellitus, polyuria of acute tubular necrosis
- Inability to obtain water, including breastfed babies due to inadequate milk supply

Less Common:

- Diabetes insipidus (central, nephrogenic, systemic disease, drugs)
- Increased insensible losses
- Impaired thirst mechanism secondary to underlying neurological abnormalities or hypothalamic dysfunction

Sodium Excess

- Ingestion of high sodium (inappropriate formula concentration, high osmolality rehydration solutions, salt poisoning)
- Iatrogenic (hypertonic saline, sodium bicarbonate)
- Hyperaldosteronism
  - Primary (Conn's)
  - Secondary (CCF, nephrotic syndrome, steroids)

Step 1

Detailed history

- Fluid intake: detailed breast/formula/PEG feeding history – check feed concentration
- Fluid losses: GI, renal (polyuria), skin, ostomy
- History of a midline brain defect
- History of renal disease
- Medications (consider diuretics, desmopressin, hypertonic fluids)
- Iatrogenic

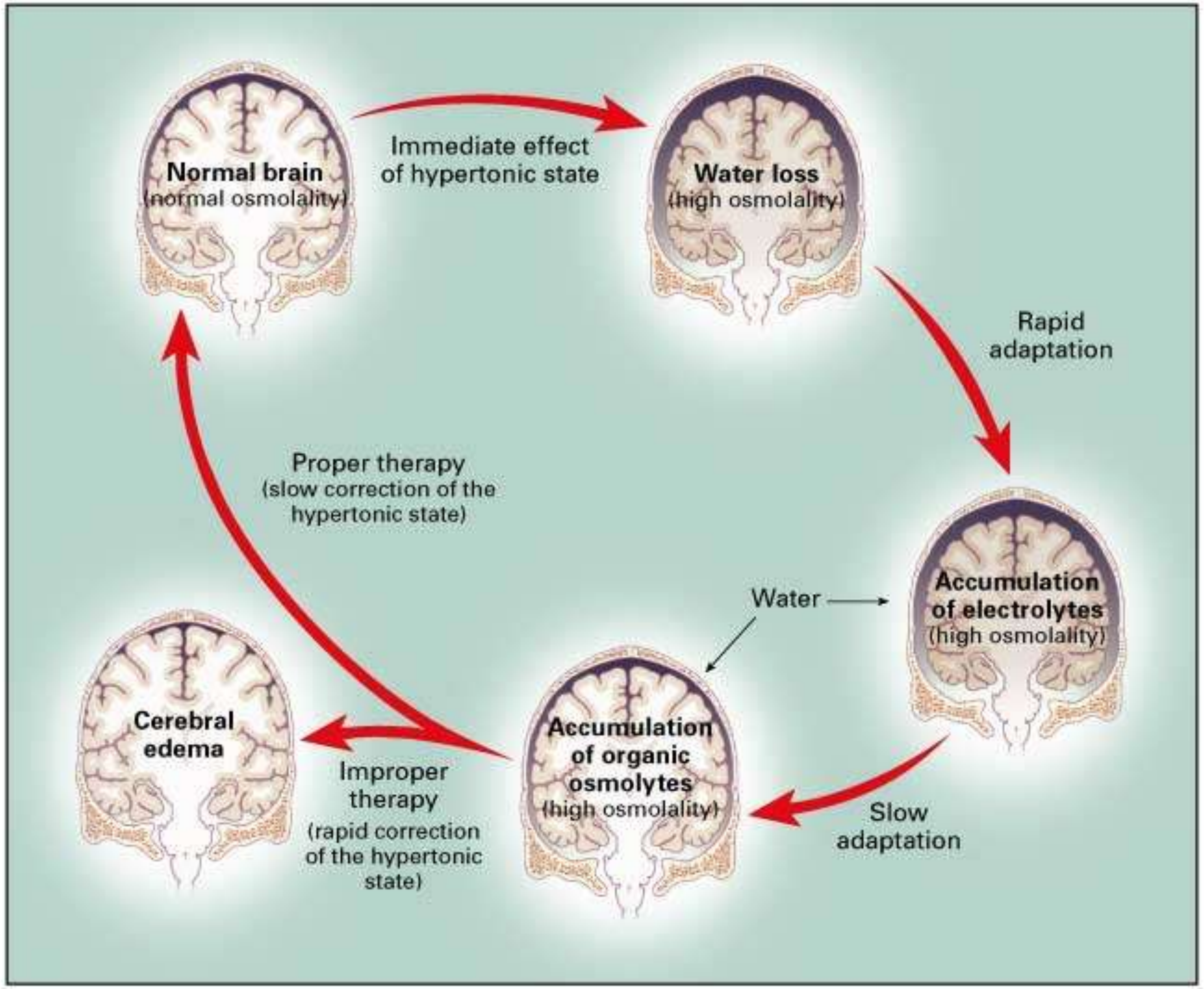
Step 2

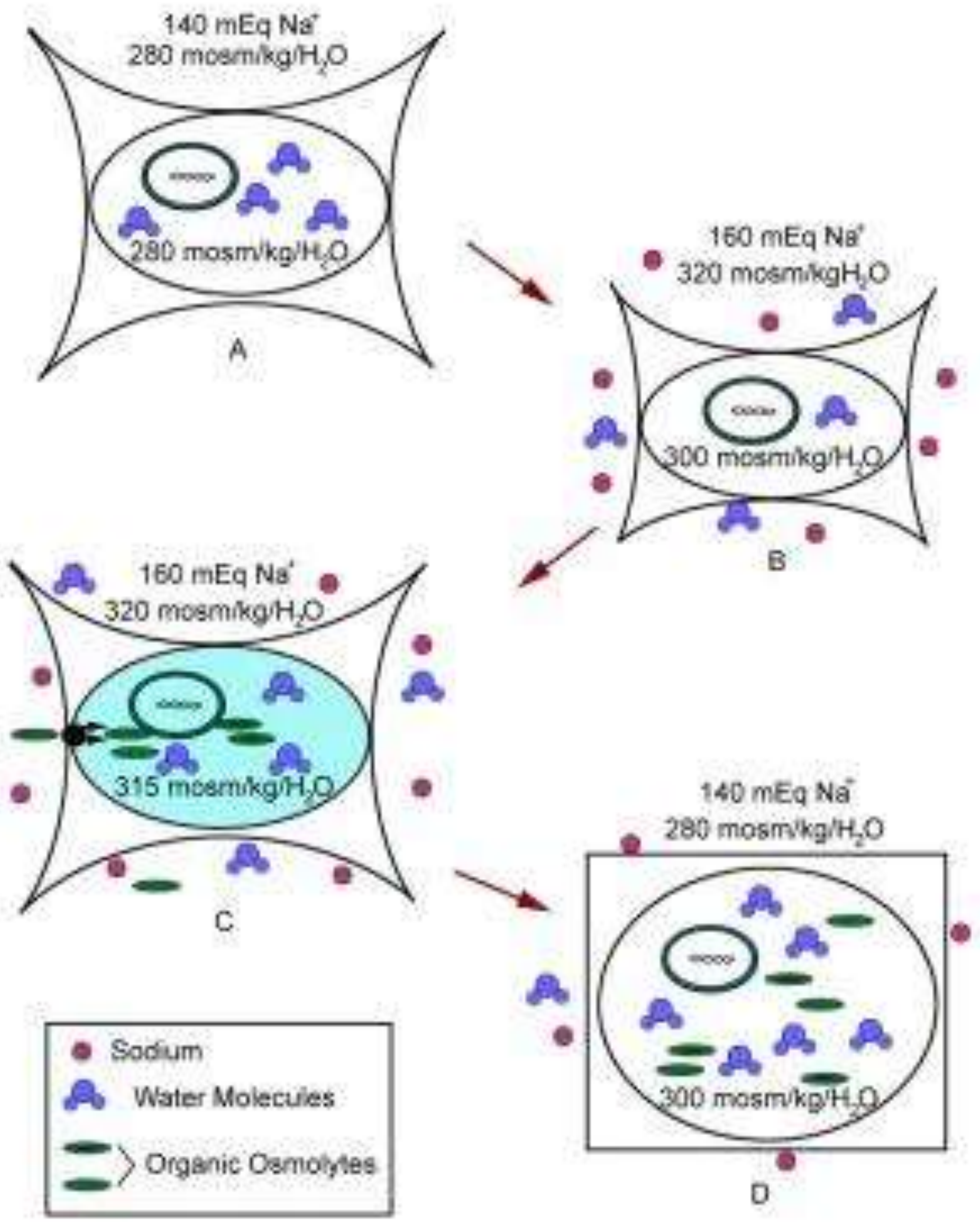
Clinical assessment

- Assess hydration status - signs of hypovolemia
- Weigh bare child and compare with recent (within 2 weeks) weight recording
- Serial weight measurements during treatment (up to every 6 hours depending on severity)
- Hypervolemia with signs of oedema (eg periorbital, genital, sacral, peripheral) suggests sodium excess
- Hydration assessment may be unreliable in chronic or severe hypernatraemia where clinical signs may underestimate degree of hypovolaemia

- Nonspecific initial signs:
  Irritability, restlessness, weakness
- Followed by:
  Vomiting, muscular twitching, fever, doughy skin
- High pitched crying, tachypnoea in infants
- Severe signs (develop with acute rise of sodium >160 mmol/L)
  - Altered mental status
  - Lethargy
  - Seizures (during rapid correction)
  - Hyperreflexia
  - Coma
- Chronic - asymptomatic

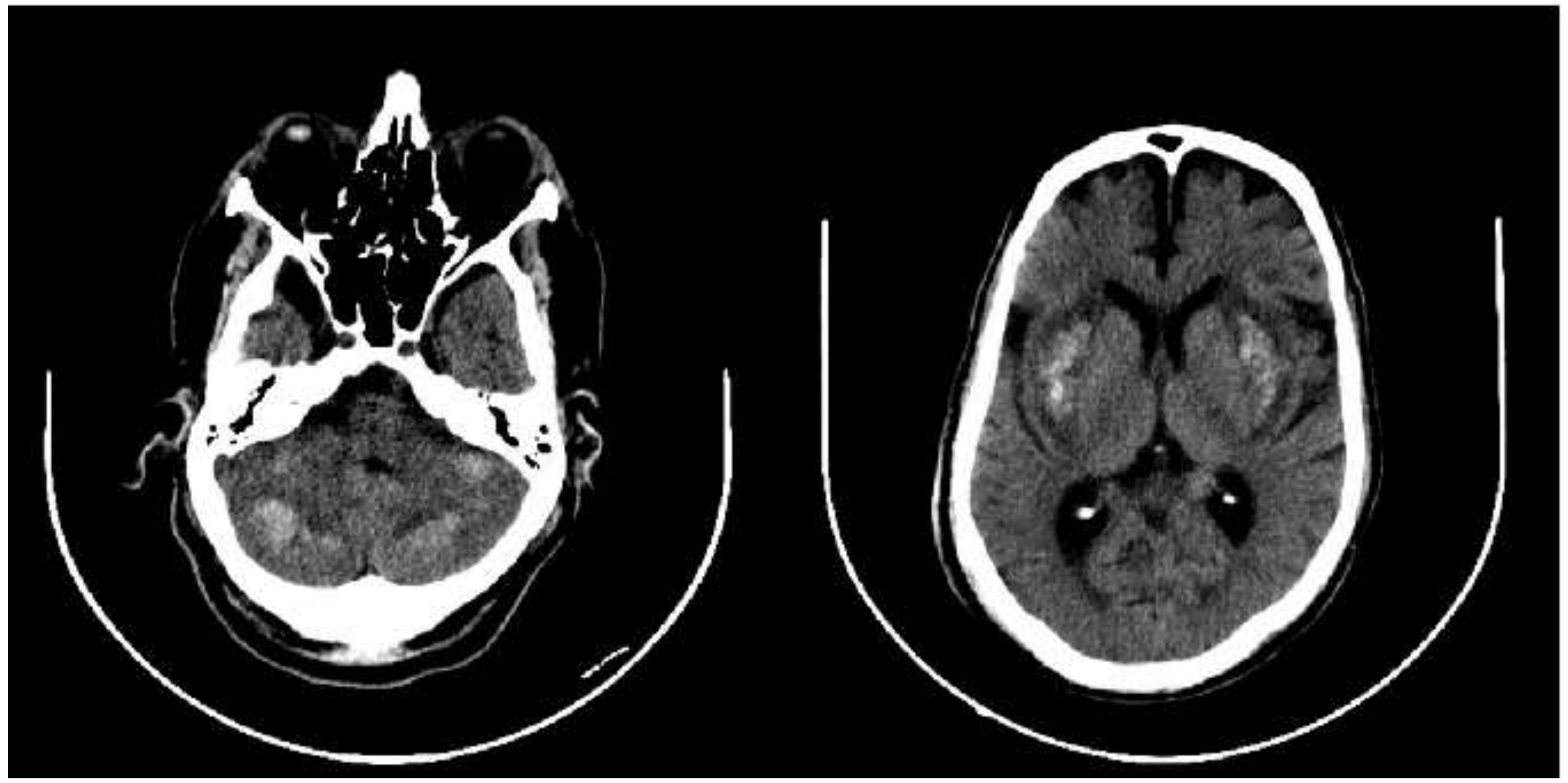
Cerebral adaptation to hypernatremia





CNS effects

- Acute severe cases -
  - Vascular rupture
  - SAH and cerebral hge
  - Demyelination -CPM
  - Irreversible neurological injury



Step 3

Lab evaluation

- UEC, calcium, magnesium, phosphate and glucose.
- Initial paired serum and urine sodium, creatinine and osmolality (or Specific gravity)
- Urine sodium <20 mEq/L and FeNa < 1% = extra renal losses.
- Urine Na > 20 mEq/l and FeNa > 2% = renal losses / sodium gain
- Urine sodium exceeds 200 mEq/L in patients with salt poisoning

Urine osmolality < serum osmolality	**Urine osmolality > serum osmolality**
Indicates urinary concentrating defect	Indicates intact urinary concentration
Causes: central DI, nephrogenic DI, renal disease, osmotic diuresis	Causes: gastrointestinal losses, increased insensible losses eg burns, excess sodium intake

Step 4

Management of underlying cause

- Stopping gastrointestinal fluid losses
- Controlling pyrexia, hyperglycemia, and glucosuria
- Withholding lactulose and diuretics
- Treating hypercalcemia and hypokalemia
- Moderating lithium-induced polyuria
- Correcting the feeding preparation

Step 4

Fluid management

- Priority - correct shock and fluid deficit - **Isotonic fluids**
  - Hydration itself lowers Se. Na
- Fluid prescription = Deficit correction + Maintenance + Replace ongoing losses
- Free water deficit in milliliters = Current total body water x ([current plasma Na/140] - 1)
- Free water deficit in milliliters = (4 mL/kg) x (weight in kg) x (desired change in plasma Na)
- Rate of correction - 0.5 mEq/l per hour (not more than 10 mEq/l per day)
- Acute conditions (saline loading) - can be corrected more rapidly
- Adrogue Madias formula predicts the change in Na achieved with 1 litre of chosen fluid

$$\text{Change in serum } (\text{Na}^+) = \frac{\text{infusate } (\text{Na}^+) + \text{infusate } (\text{K}^+) - \text{serum } (\text{Na}^+)}{\text{total body water} + 1}$$

Example

- 6 kg child, sodium 160 mEq/l
- Free water deficit in milliliters = Current total body water x ([current plasma Na/140] - 1) =(0.6 L/kg) x (6 kg) x ([160/140] – 1) = 0.51 liters or 510 mL.
- Free water deficit in milliliters = (4 mL/kg) x (weight in kg) x (desired change in plasma Na) =(4 mL/kg) x (6 kg) x (20 mEq/L change) = 480 ml
- The 500 mL free water deficit in the example above could be delivered with the administration of 1 liter of 0.45 percent saline.
- Adrogue Madias formula = 75 - 160 / (0.6 x 6) +1 = -18
    - 1 litre of 1/2 saline will reduce Na by 18, 500 ml will reduce it by 9

Treatment- Choice of fluid

Infusate	Infusate Na^+	Extracellular-Fluid Distribution
	mmol per liter	%
5% Dextrose in water	0	40
0.2% Sodium chloride in 5% dextrose in water	34	55
0.45% Sodium chloride in water	77	73
Ringer's lactate	130	97
0.9% Sodium chloride in water	154	100

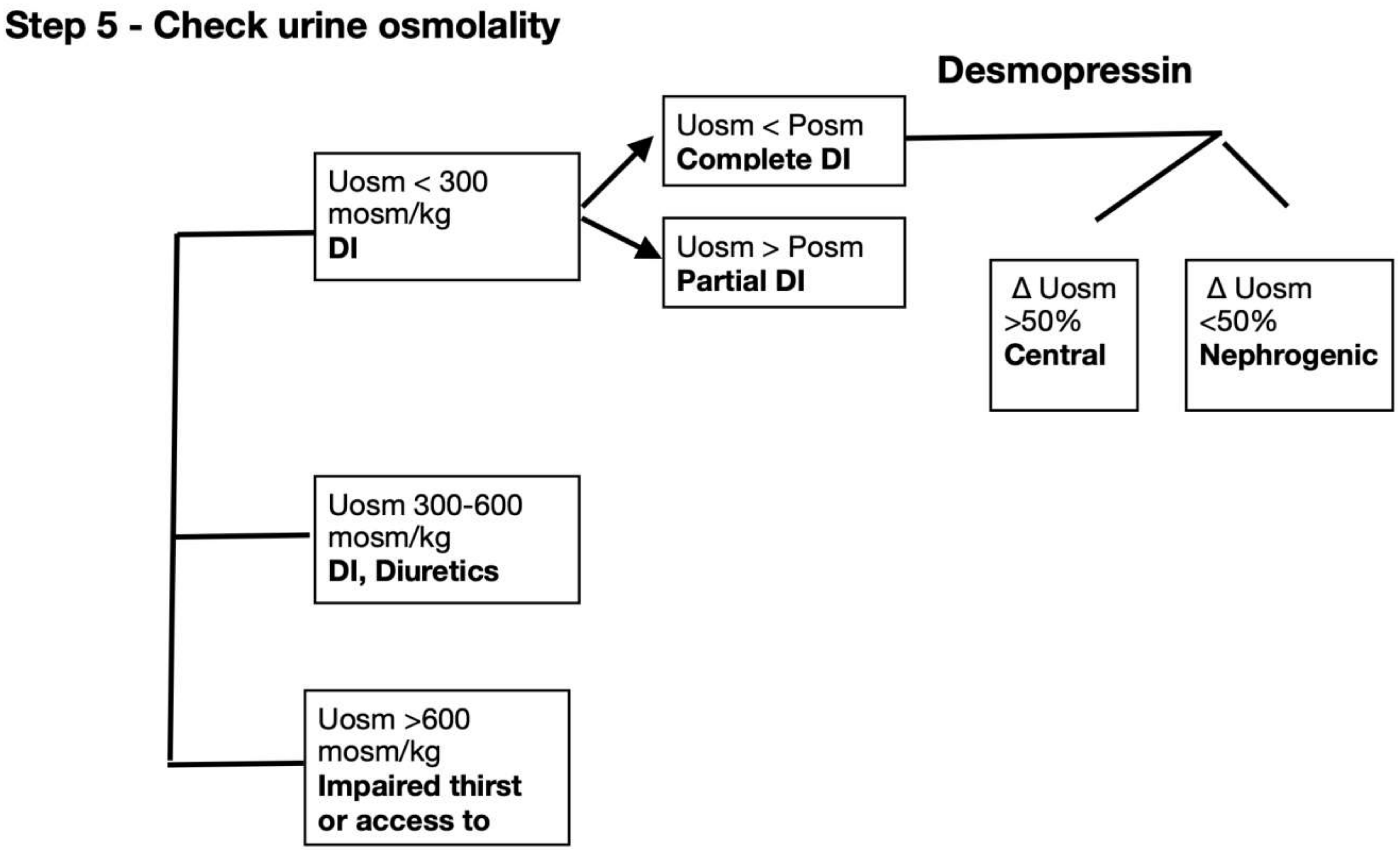
- Hypotonic fluids are appropriate - pure water, D5, 0.2 % NaCl, 0.33% NaCl, and 0.45 % NaCl
- The more hypotonic the infusate, the lower the infusion rate required.
- Isotonic saline is unsuitable for correcting hypernatremia, except to correct shock
- Can be used for deficit correction
- Avoid overcorrection and volume overload
- Most hypotonic fluid, least amount of fluid
- Reassess fluid prescription at regular intervals in the light of laboratory values and the patient's clinical status

- If Na falls ≥ 0. 6- 1mEq / hr , slow IV rate
- If Na falls < 0.5 mEq / hr , increase IV rate
- Rapid sodium fall during therapy, and/or neurological symptoms, short infusion of 3% NaCl (3-5 ml/kg) over 1-2 hours.
- Dialysis may be required in extreme cases especially when associated with acidosis

Step 5

Check urine osmolality

- Diabetes insipidus - Nephrogenic or central
    - Desmopressin



Water deprivation test

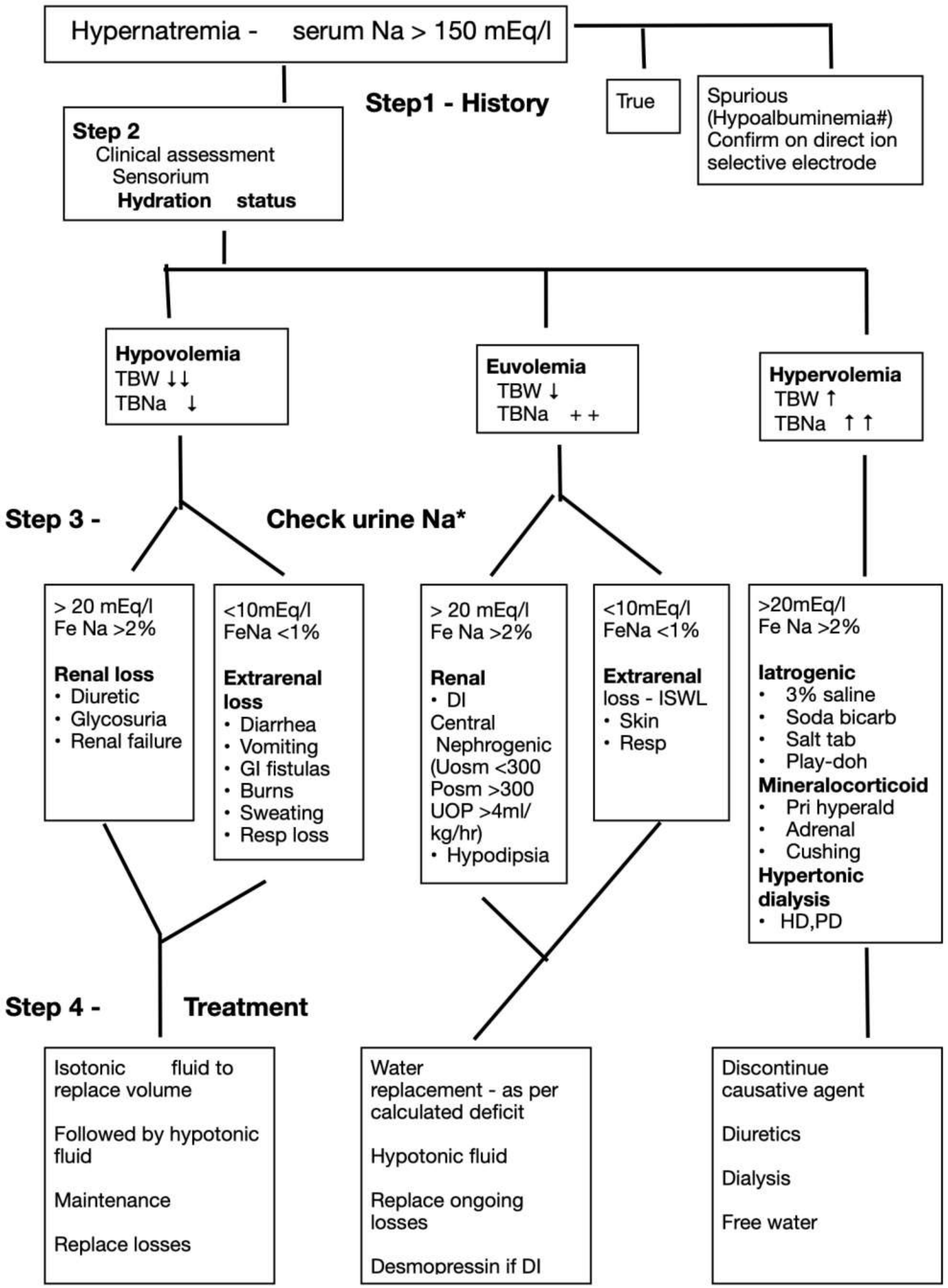
- A water deprivation test will distinguish central DI from nephrogenic DI and primary polydipsia.
- Potentially dangerous
- Start test at 8 am, weigh child
- After voiding, test starts
- Baseline ACTH, cortisol, TFTs, LFTs, and IGF-I, urine and plasma U+E and osmolality
- Hourly vitals, 2nd hourly serum and urine osmolality
- Till weight loss of 5%, dehydration, Uosm >700
- Desmopressin dose

Time	Time (h) since start	Weight (kg)	Weight loss	Urine volume (mls)	Plasma Na (2 hourly)	Plasma Osmo (2 hourly)	Urine Osmo (every urine passed)
	0						
	1						
	2						
	3						
	4						
	5						
	6						
	7						

Total Weight loss............................(kg) Total Urine volume.........................(mls)

Post-dehydration osmolality (mOsm/kg)		Post DDAVP osmolality (mOsm/kg)	Diagnosis
plasma	urine	urine	
283-293	> 750	> 750	normal
> 293	< 300	< 300	nephrogenic diabetes insipidus
> 293	< 300	> 750	cranial diabetes insipidus
< 293	300-750	< 750	chronic polydipsia
< 293	300-750	< 750	partial nephrogenic DI or primary polydipsia
> 293	300-750	> 750	partial cranial DI

Algorithm


Hypernatremia - serum Na > 150 mEq/l
Step1 - History
True
Spurious (Hypoalbuminemia#) Confirm on direct ion selective electrode
Step 2 Clinical assessment Sensorium Hydration status
Hypovolemia TBW ↓↓ TBNa ↓
Euvolemia TBW ↓ TBNa + +
Hypervolemia TBW ↑ TBNa ↑↑
Step 3 -
Check urine Na*
> 20 mEq/l Fe Na >2%
Renal loss
• Diuretic
• Glycosuria
• Renal failure
<10mEq/l FeNa <1%
Extrarenal loss
• Diarrhea
• Vomiting
• GI fistulas
• Burns
• Sweating
• Resp loss
> 20 mEq/l Fe Na >2%
Renal
• DI
Central
Nephrogenic
(Uosm <300
Posm >300
UOP >4ml/ kg/hr)
• Hypodipsia
<10mEq/l FeNa <1%
Extrarenal loss - ISWL
• Skin
• Resp
>20mEq/l Fe Na >2%
Iatrogenic
• 3% saline
• Soda bicarb
• Salt tab
• Play-doh
Mineralocorticoid
• Pri hyperald
• Adrenal
• Cushing
Hypertonic dialysis
• HD,PD
Step 4 -
Treatment
Isotonic fluid to replace volume
Followed by hypotonic fluid
Maintenance
Replace losses
Water replacement - as per calculated deficit
Hypotonic fluid
Replace ongoing losses
Desmopressin if DI
Discontinue causative agent
Diuretics
Dialysis
Free water