Hypernatraemia and Challenges in the Diagnosis of Salt Poisoning:

Dr Dean Wallace

Consultant Paediatric Nephrologist

Haemodialysis Unit and specialist Bladder service

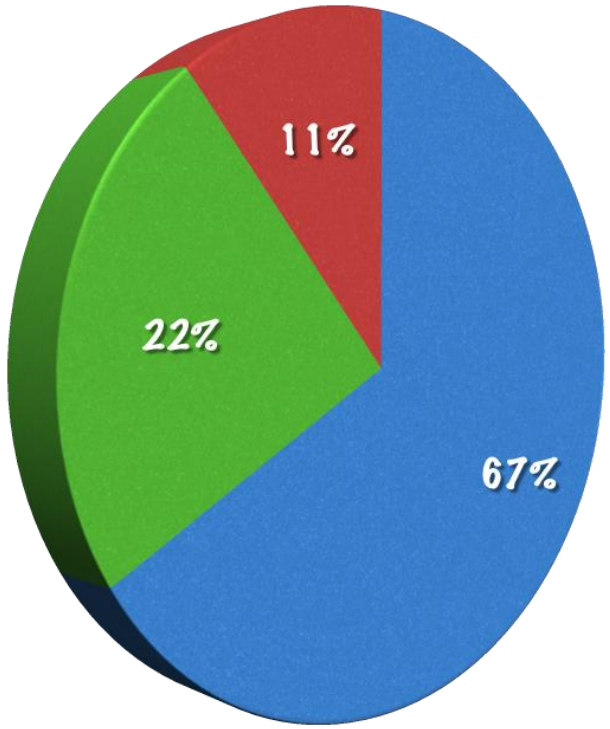
Honorary Clinical Lecturer, UoM

Royal Manchester Children's Hospital

Objectives

- Understand the common causes of hypernatraemia
- To understand the rationale of assessing, investigating and treating
- Understand the importance of paired electrolytes/osmolalities
- To develop an awareness of the importance of serial assessment
- To develop an awareness of the possibility and investigation of salt poisoning in hypernatraemia

Body water content 60-70% total weight



ICF

ECF

Plasma

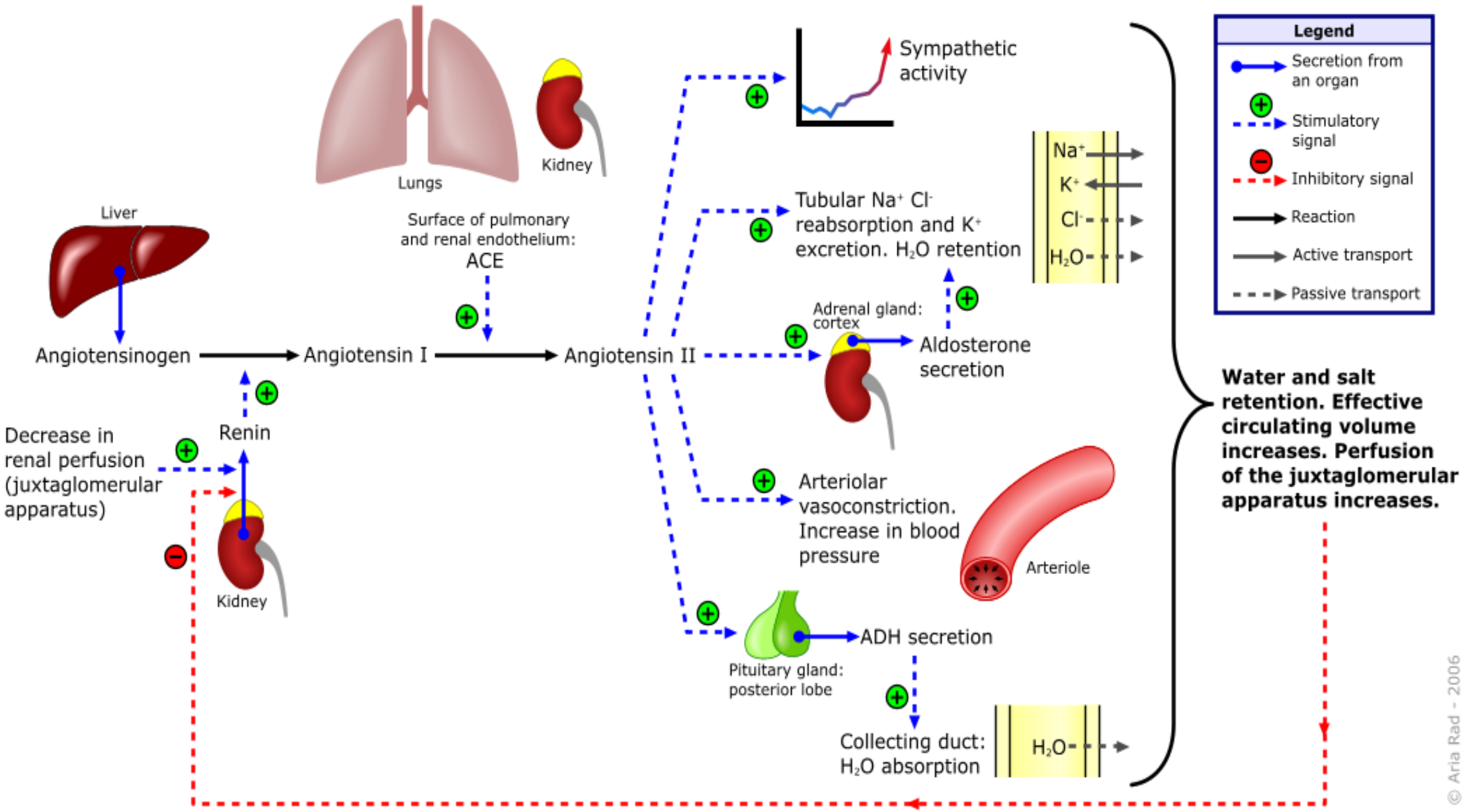
Background:

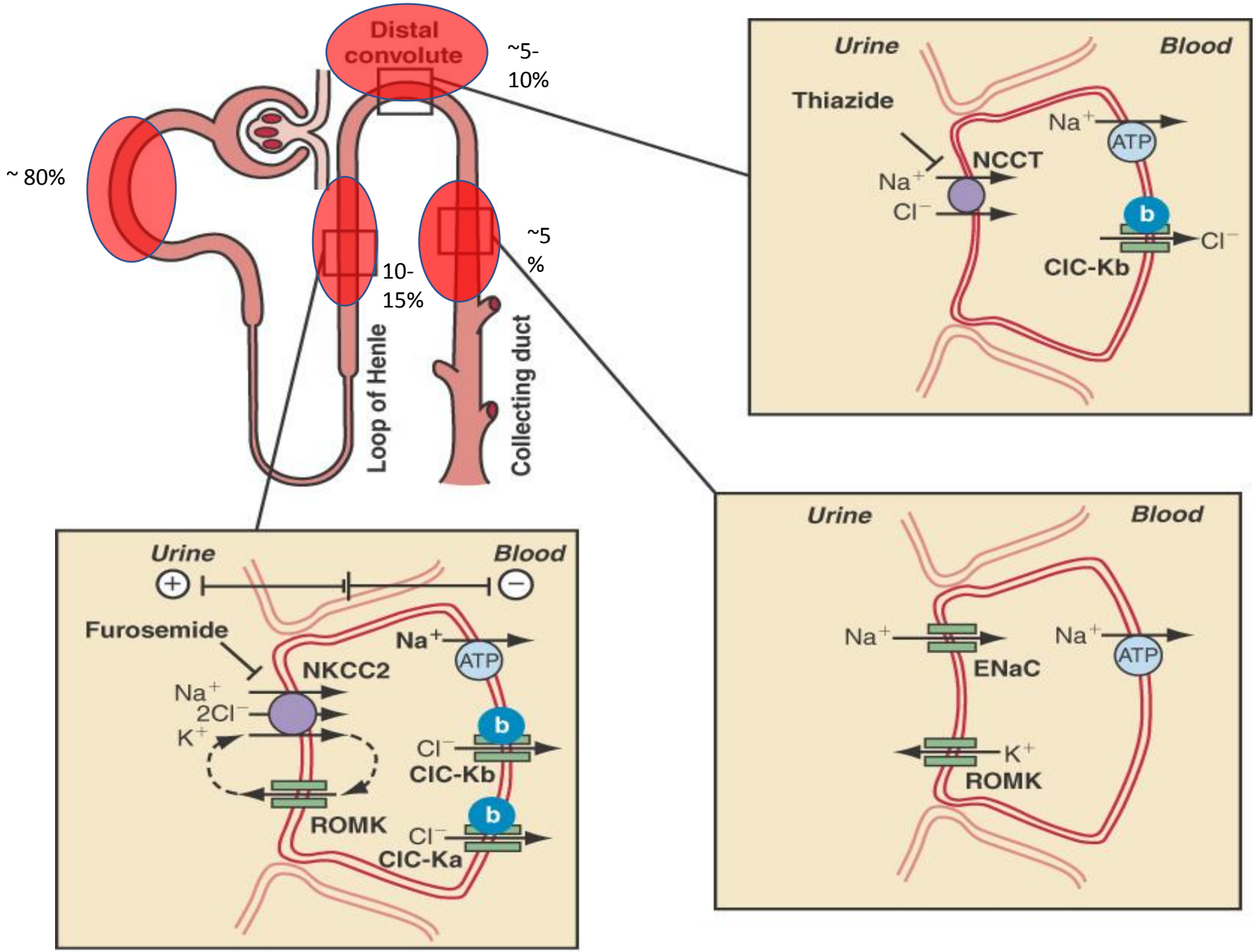
- Hypernatraemia itself is actually rare outside the neonatal period 1 in 2228 children in secondary care
- 176 admissions with hypernatraemia over 10 years: 1 attributed to salt poisoning[1] (1 in 200 cases hypernatraemia RCPCH[2])
- Understanding of tubular physiology and salt:volume control required
- Thorough clinical grasp of volume status and awareness of the evolving nature of the presentation is required

Some Amazing Facts!!!!!!!

- Adult Kidneys filter circa **150 Litres** of plasma per day
- Equivalent of **1.25 Kg** of pure salt
- Under normal condition **≥ 99%** reabsorbed with final excretion **≤ 1%** (FeNa)
- Kidney itself has no means of sensing serum sodium, only renal perfusion
- Evolutionary goal is preservation of **VOLUME** over **TONE**
- In practice most issues with Na are 2nd to fluctuations in plasma volume

Renin-angiotensin-aldosterone system




Distal convolute
~5-10%
~ 80%
10-15%
~5 %
Loop of Henle
Collecting duct
Urine
Blood
Thiazide
Na+
ATP
NCCT
Na+
Cl−
b
Cl−
ClC-Kb
Urine
Blood
Furosemide
Na+
ATP
NKCC2
Na+
2Cl−
K+
b
Cl−
ClC-Kb
ROMK
b
Cl−
ClC-Ka
Urine
Blood
Na+
Na+
ATP
ENaC
K+
ROMK

Measuring Sodium

- Serum values mmol/l
- Absolute urine values ≥20mmols/l
- **Fractional excretion of sodium (FENa)**

$$FE_{Na} = 100 \times \frac{\text{sodium}_{\text{urinary}} \times \text{creatinine}_{\text{plasma}}}{\text{sodium}_{\text{plasma}} \times \text{creatinine}_{\text{urinary}}}$$

Normal values ≤ 1% (down to 0.3% in dehydration)

Free Deficit of water calculation:

0.7 (body water) × weight × (observed Na-140)/140

Calculates free water loss required to elevate sodium to observed levels

Related Equations:

▾ Acid-Base Disturbance

- Anion Gap
- Arterial Blood Gas (ABG) Analyzer
- Bicarbonate Deficit
- Fractional Excretion of Urea (FEUrea)
- Serum Osmolality/Osmolarity
- Sodium Correction Rate in Hyponatremia
- Urine Anion Gap
- Winters' Formula for Metabolic Acidosis Compensation

▸ Renal Failure

Fractional Excretion of Sodium (FENa)

Determines if renal failure is due to pre-renal, post-renal, or intrinsic renal pathology.

SI

Sodium mmol/L: 183

Your value might be a little too large.

Creatinine µmol/L: 29

Urine Sodium mmol/L: 260

Your value might be a little too large.

Urine Creatinine µmol/L: 1100

3.7 %

FENa

How To Use | Next Steps | About | From the Creator

Therefore in hypernatraemic dehydration, urine Na excretion will be low in an attempt to reduce water loss

‘Maintenance fluid’

- Free Water loss related to caloric expenditure in hospitalised children
- To replace insensible losses plus urinary losses calculated 100mls per 100Kca per day
- Using nomogram
- 100mls/Kg 10Kg
- 50mls/kg 20Kg
- 20mls/kg therafter

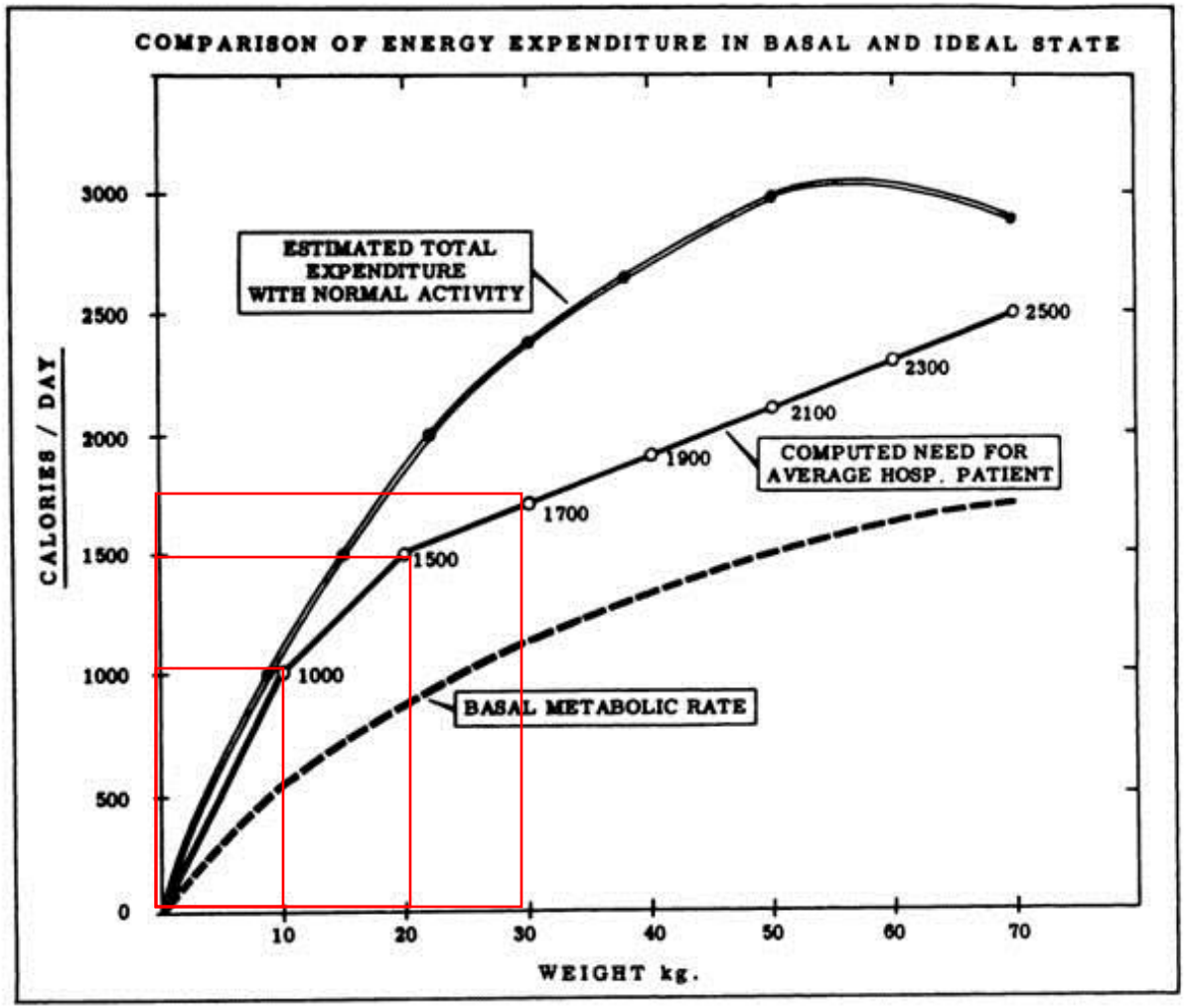


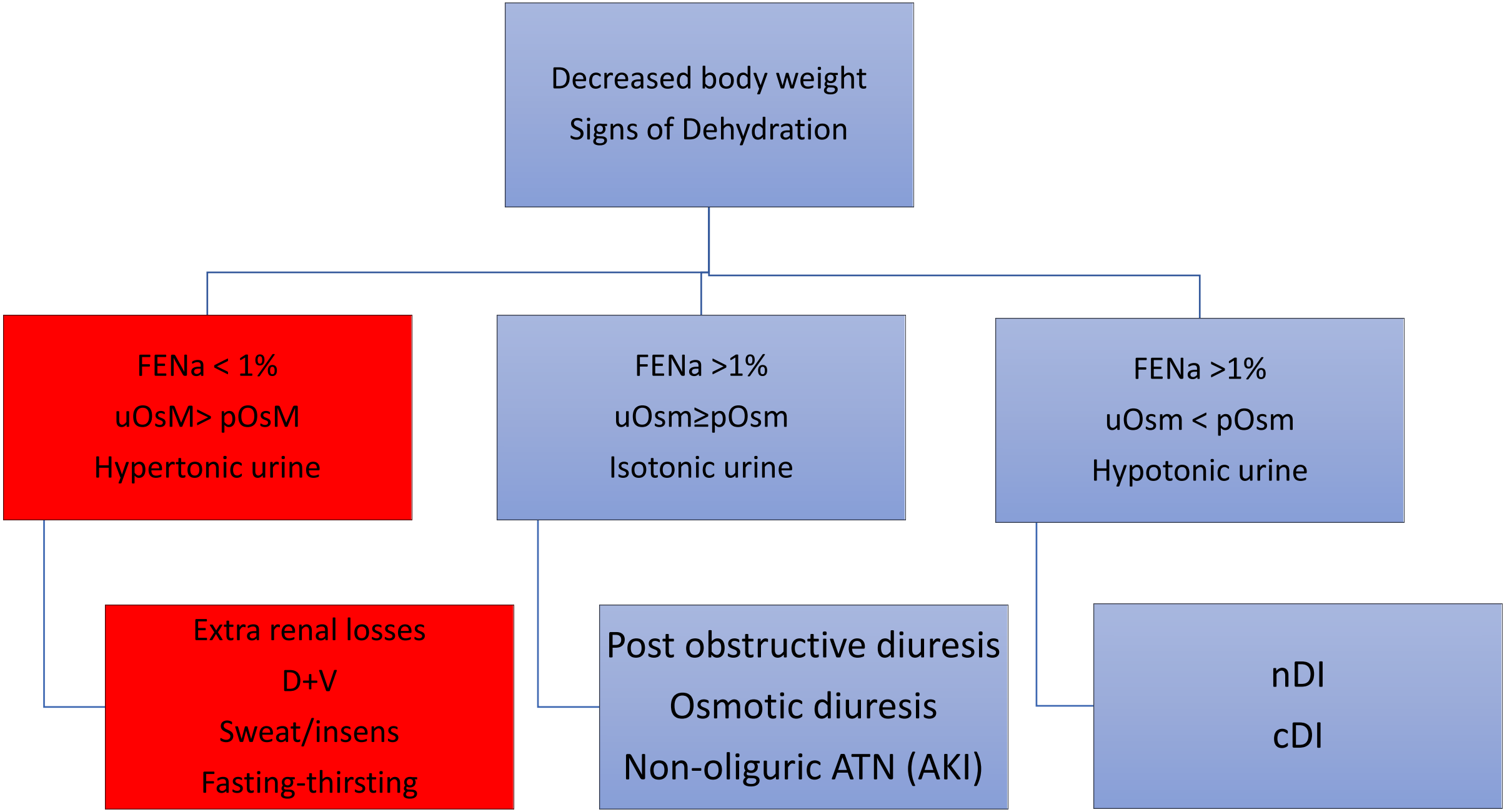
FIG. 1. The upper and lower lines were plotted from data of Talbot.[3] Weights at the 50th percentile level were selected for converting calories at various ages to calories related to weight. The computed line was derived from the following equations:

1. 0-10 kg–100 cal/kg.
2. 10-20 kg–1000 cal + 50 cal/kg for each kg over 10 kg.
3. 20 kg and up–1500 cal + 20 cal/kg for each kg over 20 kg.

"The maintenance need for water in parenteral fluid therapy", *Pediatrics* 1957.

Hypernatraemia (> 145mmol/l)

- Uncommon outside neonatal period
- Access to free water and intact thirst (brain injury, PEG, burns, PN, renal)
- Majority related to water volume loss
- Rarely salt excess
- Signs often masked as H_20 moves to ECF spaces
- Urine concentrating defect is diagnosis not to be missed
- Clinical approach to categorise


Decreased body weight
Signs of Dehydration
FENa < 1%
uOsM> pOsM
Hypertonic urine
FENa >1%
uOsm≥pOsm
Isotonic urine
FENa >1%
uOsm < pOsm
Hypotonic urine
Extra renal losses
D+V
Sweat/insens
Fasting-thirsting
Post obstructive diuresis
Osmotic diuresis
Non-oliguric ATN (AKI)
nDI
cDI

Principles of management

- Rate of correction ∝ rate of decline
- Enteral better than IV (even faster drops)
- Ideally ≤ 0.5mmols/hr (over three to four days if Na > 170)
- Correct intravascular depletion/shock with 0.9% saline
- Can start with 0.9% saline (consider the Na gradient) mostly 0.45%
- Review Na 4-6 hourly and adjust
- NB in urine concentrating defects, fluid replacements should be no more tonic than the urine osmolality i.e. 0.45%, 0.18%, free water 5% dextrose

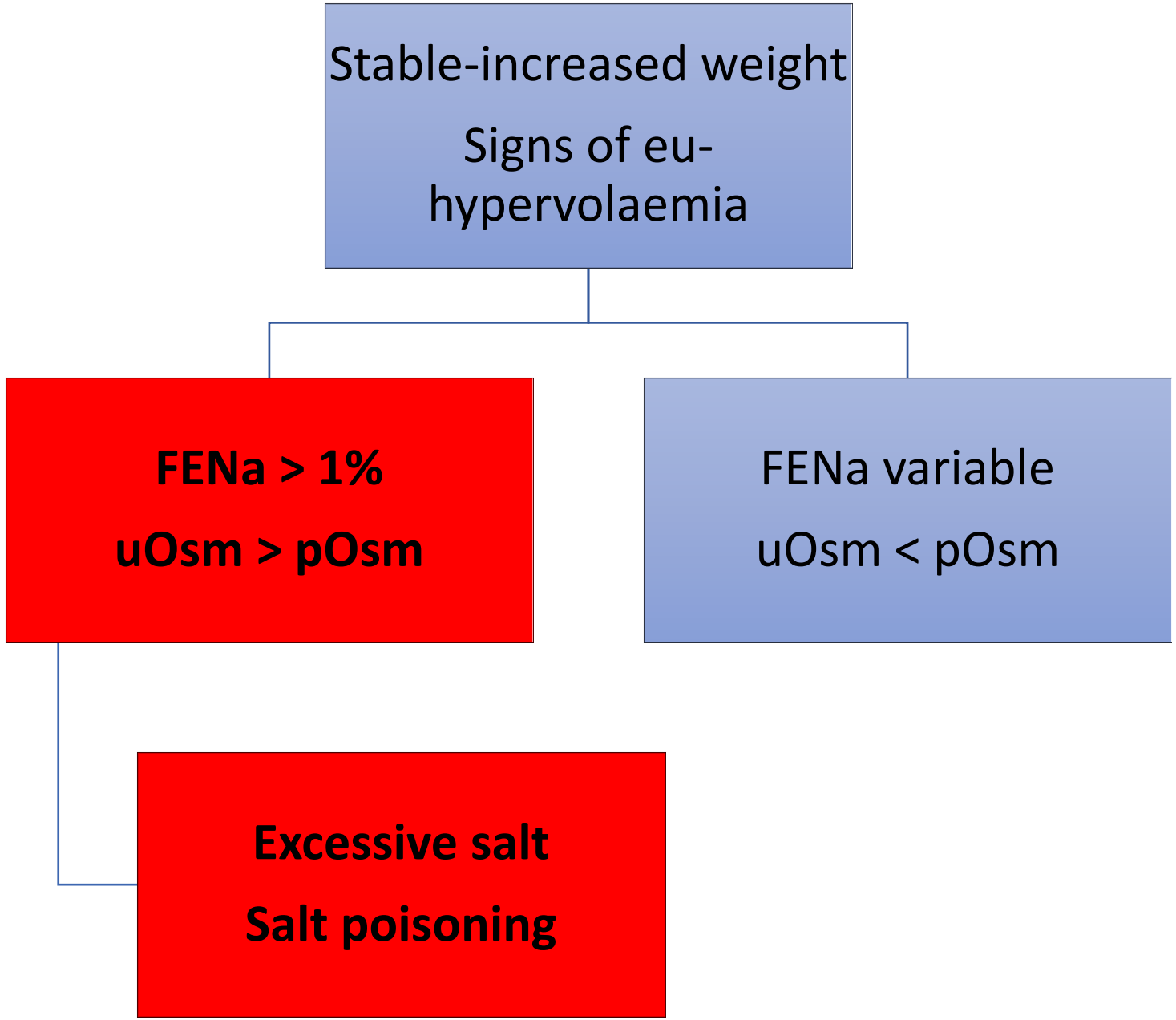
Example calculation

- 10 Kg 2yo child with cerebral palsy
- D+V for 5 days - PEG fed
- 1Kg weight loss
- Na 160mmol/l FENa 0.3% uOsm 900mOsm
- ‘Maintenance’ = (1000mls/day) (deficit 1000mls) = 5,000mls over 4 days (96hrs) = 52mls/hr plus ongoing losses.

  OR
- 0.7*10* (160-140/140) = 1.25 L of free water i.e minimum deficit

Salt Poisoning

First Challenge is to even consider the diagnosis


Stable-increased weight
Signs of eu-hypervolaemia
FENa > 1%
uOsm > pOsm
FENa variable
uOsm < pOsm
Excessive salt
Salt poisoning

Clinical Assessment

- Clinical assessment fundamental
- Repeated serial assessment is key in understanding evolving picture and the results of interventions.

- Weight!
- CVS: HR, BP, CRF, temperature, UO, JVP, Skin turgor, mucous membranes, oedema, gallop, CCF, hepatomegaly, CNS symptoms
- UEs, serum albumin paired urine electrolytes and osmolalities

Clinical History

Salt poisoning

- Odd explanations
- Rapid onset Sx
- Idea that infants will not take salty drinks is wrong
- Beware NG/PEG – easier to administer
- Recurrence
- Weight changes not reliable
- Medical knowledge in carers

Hypernatraemic dehydration

- History of losses
- Diarrhoeal
- Vomiting
- Developmental delay/disability cannot get to a tap or complain of thirst
- Unrecognised acute on chronic excaerbations (GORD)

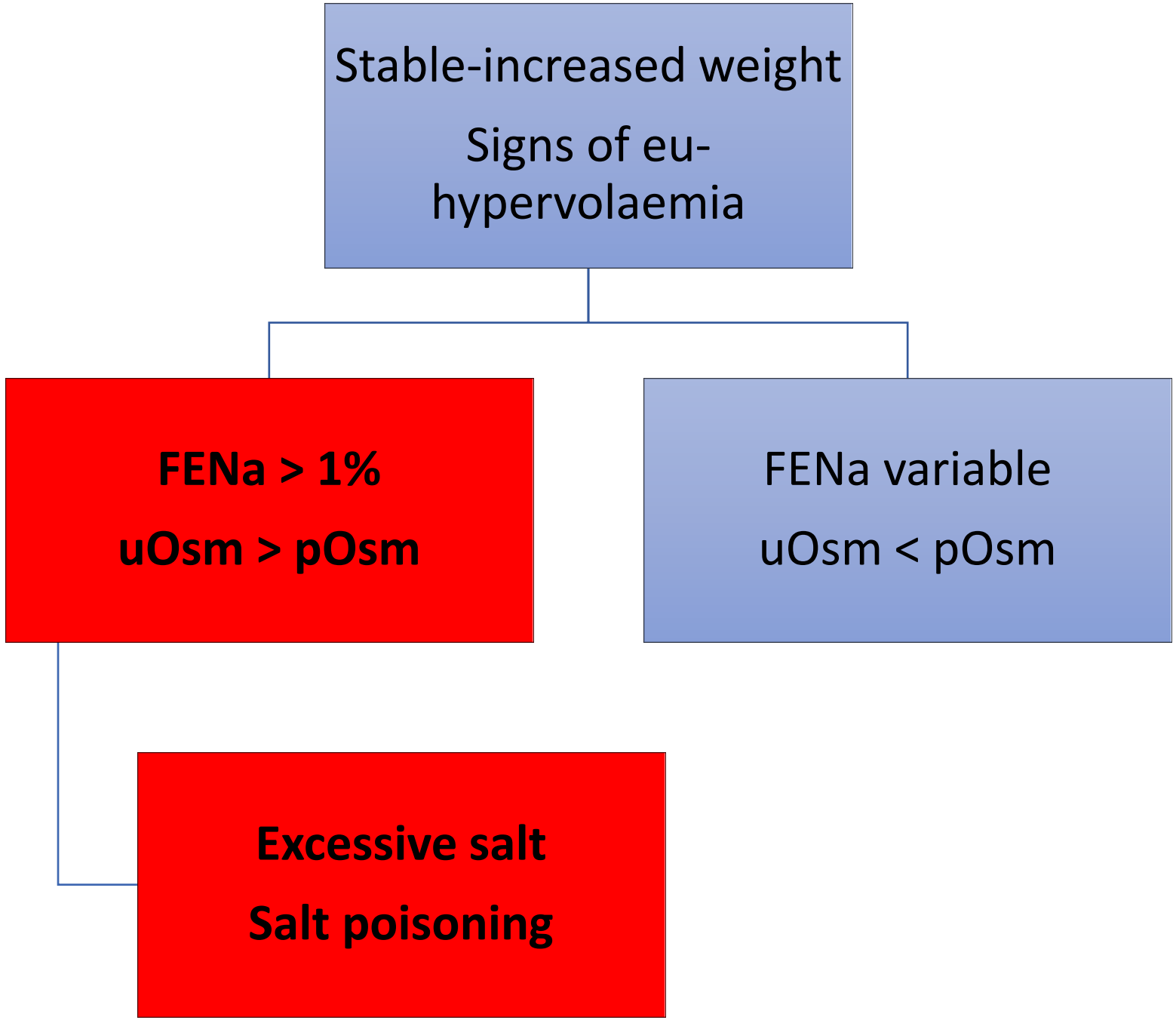
Biochemistry

Salt poisoning

- Large/normal volume circulation
- Usually maintains GFR
- ‘Normal’ Urea and Creatinine
- Normal or increased BP
- Bicarbonate often normal
- Stable/Increased/mild weight loss

Hypernatraemic dehydration

- Hypovolaemia
- Weight loss by definition
- Reduced GFR
- Raise pCr - lags
- Calculate eGFR
- Absolute Cr values misleading
- BP variable
- Bicarb may be low


Stable-increased weight
Signs of eu-hypervolaemia
FENa > 1%
uOsm > pOsm
FENa variable
uOsm < pOsm
Excessive salt
Salt poisoning

Case 1:

- 2 y female
- ESRF 2nd to solitary dysplastic kidney
- On Peritoneal Dialysis
- Recurrent episodes mild hypernatraemia in low 150s
- Issues with PD bag seal breaks?
- Brought to PD clinic h/o waking 5hr into feed with excessive thirst, screaming and irritability
- Na 165mmol/l – BP unable due to distress
- Weight up 300g in 48 hours: 12 to 12.3Kg

Case 1 Continued:

- Admitted and PD continued with sodium normalising over 48 hours
- UNABLE to calculate FENa or rely on serial weights, urinary indices on (PD)
- Mother was asked to bring in the powdered milk feed to the ward
- Forensic analysis of feed container requested contained 713mmol/l Na (expected 14.8mmol/l)
- Child protection proceedings

Case 2

- 6w female infant
- multiple GP/PED attendance vomits (GORD, ALTEs, aspiration LRTI)
- During LRTI admission Na 153mmol/l not investigated
- Fluoroscopy: unsafe swallow NGT fed exclusively
- Admitted 11w 4 day h/o D+V, weight loss, Na183 (gas) absolute uNa 321mmol/l
- Normal UO, perfusion, BP, uOsm 700mOsm: given saline boluses: NO urine Cr sent
- Suspicious – discharged with serial RV and biochemistry

Date	Weight	Na	K	Ur	Cr	Cl	pOsm	uOsm	uNa	uCr	FEna
15th month 1	?	153	4.7	2.6	20		?	?	?	?	?
Findings during an admission with LRTI											
24th Month 1	4.05Kg (-270g)	176	4	3.8	24	154	361	700	361	?	?
Treated with IV 0.9% bolus and 8% IV/NGT correction with weight increasing and biochem slowly normalising											
6-27th Month 2– weekly review of appropriate weight increase and completely normal sodium/Osm/biochemistries											

Opinion?

- Probable salt poisoning/Ingestion
- Preserved circulation
- Normal GFR
- Preserved tissue perfusion and UO
- Less than half of minimum weight loss predicted by free water deficit calculation
- Enormous absolute urinary sodium value of 321mmol/l
- Cannot be sure in absence of FENa and uCr indices for calculations
- Saline boluses given on admission

Free deficit of Water

- 0.7 (body water) × weight × (observed Na 176-145 ÷ 145)

- Derives the minimum free water loss (litres) required to elevate the sodium to that observed
  - FWD = 0.647 Litres (minimum)
  - Observed weight loss = 0.270L
- Therefore the weight loss was less than half of the minimum expected

Date/ Time	Wt-Kg	Na	K	Ur	Cr	Cl	Hb	Alb	pOsm	uOsm	uNa	uCr	FENa
29-th Month 2 1255	4.82	177	4.7	3.2	29	148	114	35		512	222	<1	3.6%
20mls/kg 0.9% Nacl		175	4.1	4.6	33	145			369				
31-Month 2 0600	5.15	168	3.9	2.2	37	138			340	612	282	1	6.2%
31-Month 2 1200		162	4.2	1.2	29	133			333		313	1.7	3%
01-Month 3 1257	5.32	150		2.2	28	121	100	33		319	84	1.6	1%
2051	5.29	155	4.3	1.5	24				321	396	166	<1	2.6%

Take Home points

- Na poisoning may be less less rare/ under-reported
- Serial weight, clinical review, paired electrolytes/osmolalities
- FENa!
- Described two cases that challenged diagnosis with regards FENa and weight changes
- Free deficit of water calculation can be useful in considering the kind of weight loss you should be seeing
- Chain of evidence procedures to be initiated immediately
- Unique role of nephrologist in recognition and response

- Salt is a potent gastric irritant and may cause some degree of weight loss, history of losses and acidosis
- Patients at highest risk of harm (least classical signs) are infants without access to free water
- Postulated that 13 to 51mmol/kg administered can be lethal (c17mmol/kg in case 1 -22mmol/kg case 2)
- Aggregating enough circumstantial evidence before confronting is nuanced and sensitive issue

Thank You

References and further reading

- Coulthard MG, Haycock GB: Distinguishing between salt poisoning and hypernatraemic dehydration in children. *BMJ*.2003;326(7381):157-160.
- Meadow R. Non accidental salt poisoning in children. *Arch Dis Child* 1993; 68: 448-52
- Baumer JH, Coulthard M, Haycock G, McIntosh N, Rammal R, Haines L. *The diagnosis of salt poisoning leading to hypernatraemia in children with particular reference to salt poisoning. An evidence-based guideline*. London: RCPCH; 2009.
- Wallace D, Lichtarowicz-Krysnka E, Bockenhauer D. Non Accidental salt poisoning. *Arch Dis Child*. 2017; 102:119-122