Electrolytes (and fluids, a bit)

UH CMC Internal Medicine Bootcamp
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So… why am I making you do this?

- We assess Electrolytes ALL THE TIME!
  - How many BMPs/RFPs/CMPs per day?
  - *Do you even use this, bro?* – or just "Electrolytes look fine"?
  - Many hate the subject → ignore pushing further

- Management of disturbances: common but dangerous!
  - Do you have a system? Can you make a plan?
  - Do you know what resources to look up?

- IV Fluids: So, so many patients get a bolus or mIVF
  - What's our evidence?

Informal Objectives

- Secondary goals:
  - Pique your interest
  - Help you know stuff reflexively
- Primary goal:
  - Help identify, evaluate, correct common issues faster
  - Give you a process to talk through to stall attendings
  - Know where to look things up
- Save some lives, *mostly save time and stress*…

Formal Learning Objectives

- Sodium Imbalances:
  - Apply patient eval to narrow the broad differential
  - Learn approach to management and resources to use
- Potassium Imbalances:
  - Evaluate options for best, practical corrective steps
- Chloride, Calcium, Phos, Mg:
  - Review some quick tidbits about these
- Fluids
  - Learn some of the data behind NS vs LR vs Albumin
    - Logic vs clinical outcome studies

Paul's Case 1

- 65 yo male, active EtOH x30 years (6 pack of beers daily and a 5th of vodka), presents w/ 2 months of falls.
- No other family, medical or social history.
- Only medication is celexa, started 3 months ago.

- Daughter brought him to PCP.
- Vitals stable (HR 74, BP 116/74), exam below
- Got the following labs:

- BMP 120/4.1/87/28/6/0.64<108. Negative CXR & UA.
  - He was admitted for further work-up.

Differential Diagnosis?

- Beer Potomania
- SIADH
- Cirrhosis
- Pancreatitis
- Surreptitious Diuretic Use
- Renal losses
- GI losses
- Glucocorticoid Deficiency
- Hypothyroidism
- Drug use
- Acute or Chronic Kidney failure
- Third spacing of fluids
- Type 2 RTA
- DKA
- Osmotic diuresis

Working Up Hyponatremia

Who has a system for narrowing this down?

Also, why do we care? For fallers vs non-fallers, fall risk OR >5 if you compare Na ≤125 vs >134.

Fehlberg EA, Lucero RJ, Weaver MT, *et al.* Associations between hyponatraemia, volume depletion and the risk of falls in US hospitalised patients: a case–control study *BMJ Open* 2017;**7**:e017045. doi: 10.1136/bmjopen-2017-017045

Working Up Hyponatremia

1. History: risks, time course?
   - *Is this over hours, weeks, months??*

Working Up Hyponatremia

1. History: risks, time course?
   - *Chronic (2 months) and symptoms are possibly related—severe!*

2. Exam: Volume status: Hypovolemic, Euvolemic, Hypervolemic?
   - *Based on both History & Physical*

   - *What do <u>you</u> use on exam for volume status?*
     - *History: Intake, output*
     - *Physical Exam: Weights, HR, resting BP (late), orthostatic vitals (sort of), orthostatic SYMPTOMS, mucus membranes (rule out), axillary sweat, JVD, skin turgor, cap refill, mentation, passive leg raise (45 degrees)*
     - *Further: CVP (poor), PCWP, IVC collapsibility, bioimpedance even—fancy!*

Ooi WL, Barrett S, Hossain M, Kelley-Gagnon M, Lipsitz LA. Patterns of Orthostatic Blood Pressure Change and Their Clinical Correlates in a Frail, Elderly Population. *JAMA.* 1997;277(16):1299–1304. doi:10.1001/jama.1997.03540400049030

McGee S, Abernethy III WB, Simel DL. Is This Patient Hypovolemic?. *JAMA.* 1999;281(11):1022–1029. doi:10.1001/jama.281.11.1022

Mackenzie DC, Noble VE. Assessing volume status and fluid responsiveness in the emergency department. Clin Exp Emerg Med. 2014;1(2):67–77. doi: 10.15441/ceem.14.040.

Smith JJ, Porth CM, Erickson M. Hemodynamic response to the upright posture. *J Clin Pharmacol.*1994;34:375-386.

Case Continued, Na 120

- Looking back, no data but patient thinks he's at baseline weight
- Exam: pale man, A&Ox3, NAD. Normal cardiac, respiratory and abdominal exam. JVP not elevated.
- Skin exam with normal turgor and multiple ecchymoses on body.
- Neurologic exam showed b/l nystagmus with lateral gaze and impaired b/l propioception in the lower extremities

Working Up Hyponatremia

1. History: risks, time course?
   - *Chronic (2 months) and symptoms are possibly related—severe!*

2. Exam: Volume status: Hypovolemic, Euvolemic, Hypervolemic?
   - *Euvolemic based on physical exam*

3. Labs: Serum Osm and its components: Formula?
   - *Hypertonic: too much Glu, Mannitol, Urea—stop, address THAT*
   - *Isotonic is rarer: Hypertriglyceridemia, Paraproteinemia*
   - *Hypotonic most common—free water overpowers Na… keep working!*

4. Labs: Is the body responding appropriately or inappropriately?
   - *Based on Urine Osm, Urine Electrolytes*

Any other labs???

- Serum osmlolarity (Calculated):
  - 2 * Na + BUN / 2.8 + Glu / 18
  - 2 (120) + (28 / 2.8) + 108 / 18 = 256
- Serum osmolarity (Measured) – 258
- Urine osmolarity – 600
- Urine sodium - 166

Working Up Hyponatremia

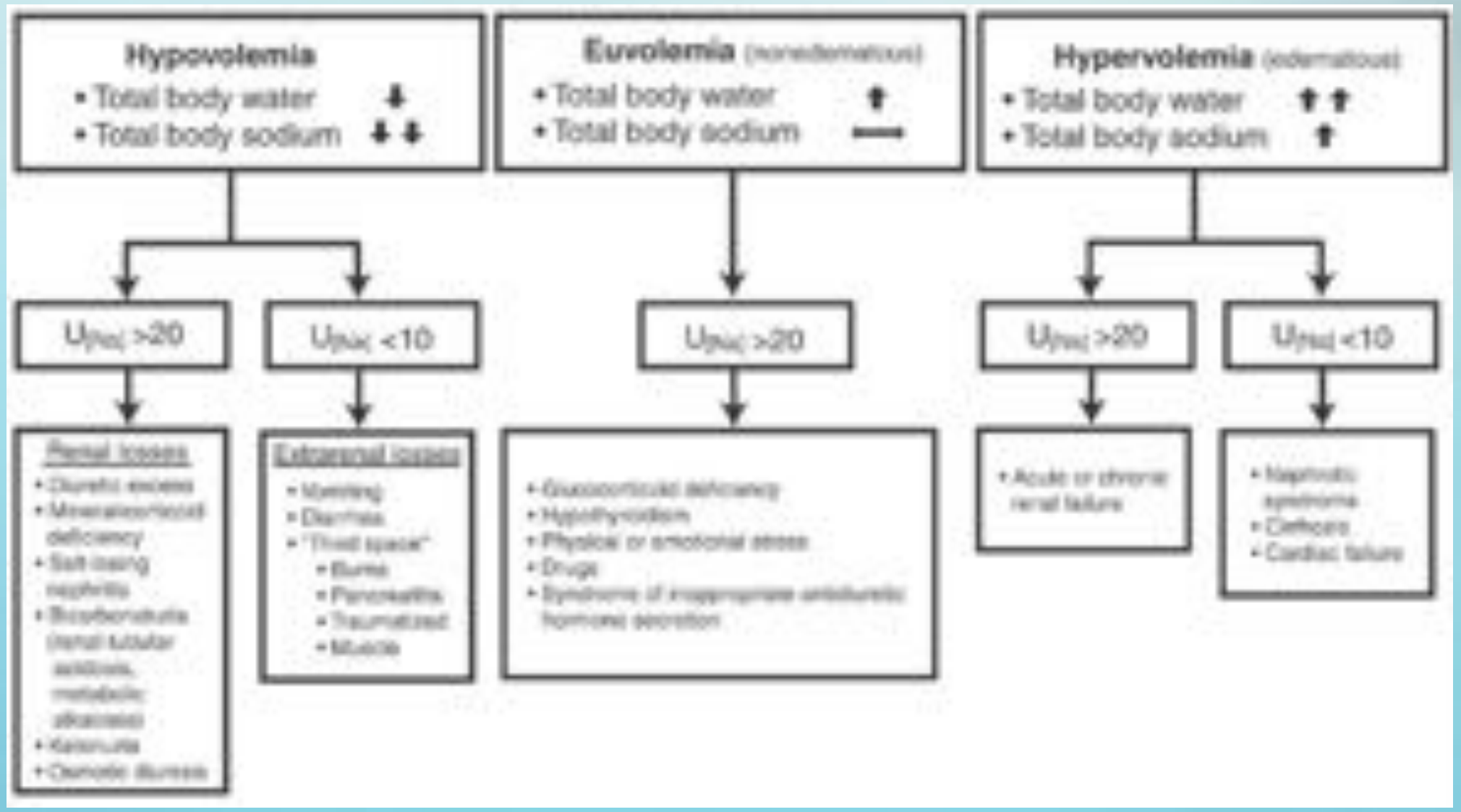
1. Think about risks, time course–over weeks or over hours?
   - *Chronic (2 months) and symptoms are possibly related—severe!*

2. Volume status: Hypovolemic, Euvolemic, Hypervolemic?
   - *Euvolemic based on physical exam*

3. Think about Serum Osm and its components
   - Serum Osm: 2(Na) + (BUN/2.8) + (Glu/18)
   - *Not hypertonic by calc—256—nor by measurement—258*
   - *Measured Serum Osm is truly low… how should the body adapt?*

4. Is the body responding appropriately or inappropriately?
   - *High Urine Osm, Na means body is dumping salt or resorbing water*
     - *Points to renal losses by renal failure or inappropriate actions on kidney*

Sodium: Hyponatremia



Case Conclusion

- Dx: SIADH
- Most likely to be due to his celexa.

- Confounders:
  - Maybe baseline hyponatremia due to alcohol use?
  - Cirrhosis would be hypervolemic
  - Beer potomania: Urine Osm/Na would be low

- Tx for this?
  - Patient improved with fluid restriction to 1.5 L a day & holding celexa

Case Conclusion

- The patient was diagnosed with SIADH, most likely deemed to be due to his celexa.
- SIADH causes:
  - Pulmonary disease—what kind?
  - Surgery
  - Hormone deficiencies/administration
  - CNS disturbances
  - Malignancies
  - Meds:
    - Antiepileptics
    - Antidepressants
    - Haldol
    - Bromocriptine
    - Chemotherapy agents

Paula's Case

- A 90 y/o female w/ advanced dementia brought to ED
- Non-verbal, difficulty w/ clear liquids and solid foods
- Family saying more confused, urine is rare and dark
- VS 37.2, HR 110, BP 90/60, RR 14, SpO2 93% RA, wt 40kg
- ED gave NS 1L bolus, admitted to Wearn.

Case 2 Continued

- Exam: a frail, elderly female who is responsive only to painful stimuli and loud voice, but does open her eyes. A&Ox1.
- Dry, cracked mucus membranes, severely decreased skin turgor, incontinent of dark urine, stage 2 sacral ulcer
- RFP 161/4.6/129/22/45/2.2 (baseline 1.4) <80
- Serum Osm 330, Urine Osm 400, Urine sodium 100

Working Up Hypernatremia

1. Think about risks, time course–over weeks or over hours?
   - *History*

2. Volume status: Hypovolemic, Euvolemic, Hypervolemic?
   - ***Almost always hypovolemic***

3. Is the body responding appropriately or inappropriately?
   - **Is the urine concentrated?**
     - **Yes – free water deficit from poor intake, high losses (insensible, GI, renal)**
     - **No – diuretics or diabetes insipidus (either central or nephrogenic)**

Case 2 Continued

- Given NS 1L bolus then NS @ 100 cc/hr for admission
- Upon arrival to the floor, repeat RFP shows a sodium of 160.
- What do you calculate next?
  - Free water deficit (TBW x (1–(goal sodium/serum sodium)))
    - ~3.1L for her
- Change [Na]/L of fluid= ([Na](solution)– [Na](serum)) / (TBW+1)
  - Let's call her current TBW ~22kg … Wait, oh god, math

Sodium Corrections

Sex	Female	Male	
Age range	Child	Adult	Elderly
Weight	Norm: 100 - 250	lbs ⇋	
Sodium	Norm: 136 - 145	mEq/L ⇋	

Result:

Please fill out required fields.

MedCalc: Hyponatremia & Hypernatremia

Patient's Sodium :	160 mEq/L	Correct for:	
Target Sodium :	140 mEq/L	Fever?	
Rate of Na Correction :	-0.5 mEq/L/hr over 40 hours	Insensible Loss?	
Patient's Weight :	40 kg		
Patient is a :	woman		
Calculate using :	Adrogue formula		

Calculate Fluids | Reset

IVF Rate : 65.6 cc/hr for 40 hours

IV Fluids : 5% Dextrose in water (D5W)

Classic Formulas:

Hypernatremia

$$\text{Total } H_2O \text{ deficit (L)} = \text{total body water} \times \left(1 - \frac{\text{desired } Na^+}{\text{serum } Na^+}\right)$$

Hyponatremia

$$Na^+ \text{ requirement (mmol)} = \text{total body water} \times (\text{desired } Na^+ - \text{serum } Na^+)$$

$$\text{Rate of infusion (cc/hr)} = \frac{Na^+ \text{ requirement (mmol)} \times 1000}{\text{infusate } Na^+ \text{ (mmol/L)} \times \text{time (hours)}}$$

Adrogue Formula:

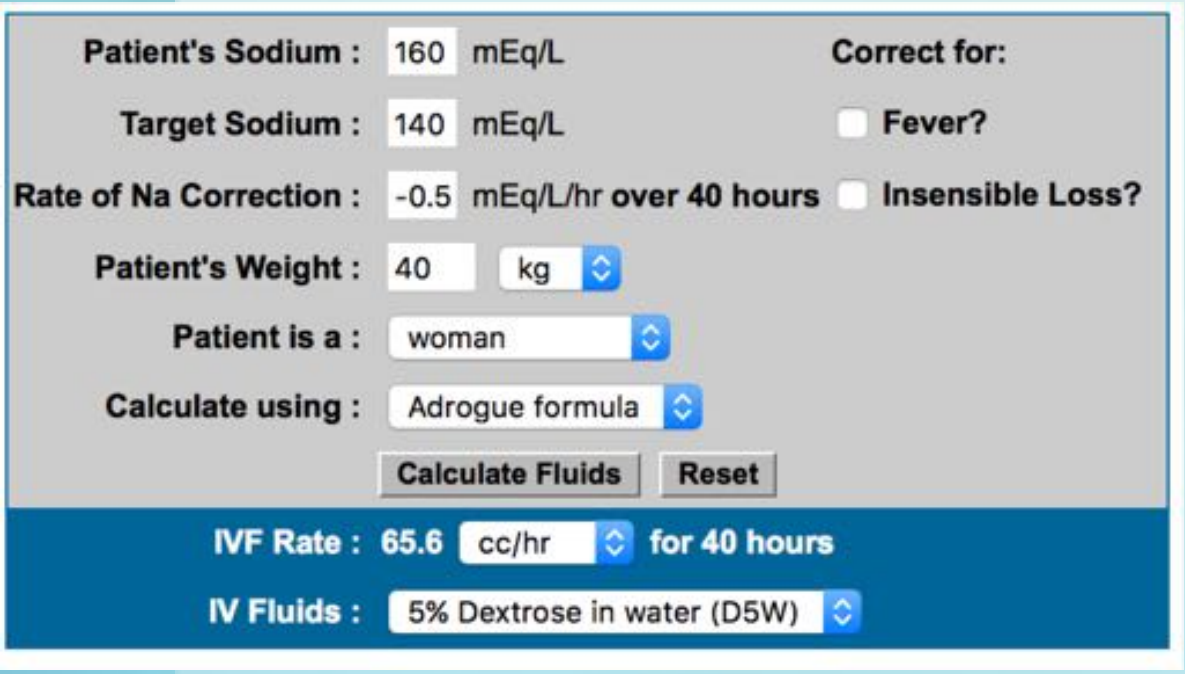
$$\text{Change in serum } Na^+ = \frac{(\text{infusate } Na^+ + \text{infusate } K^+) - \text{serum } Na^+}{\text{total body water} + 1}$$

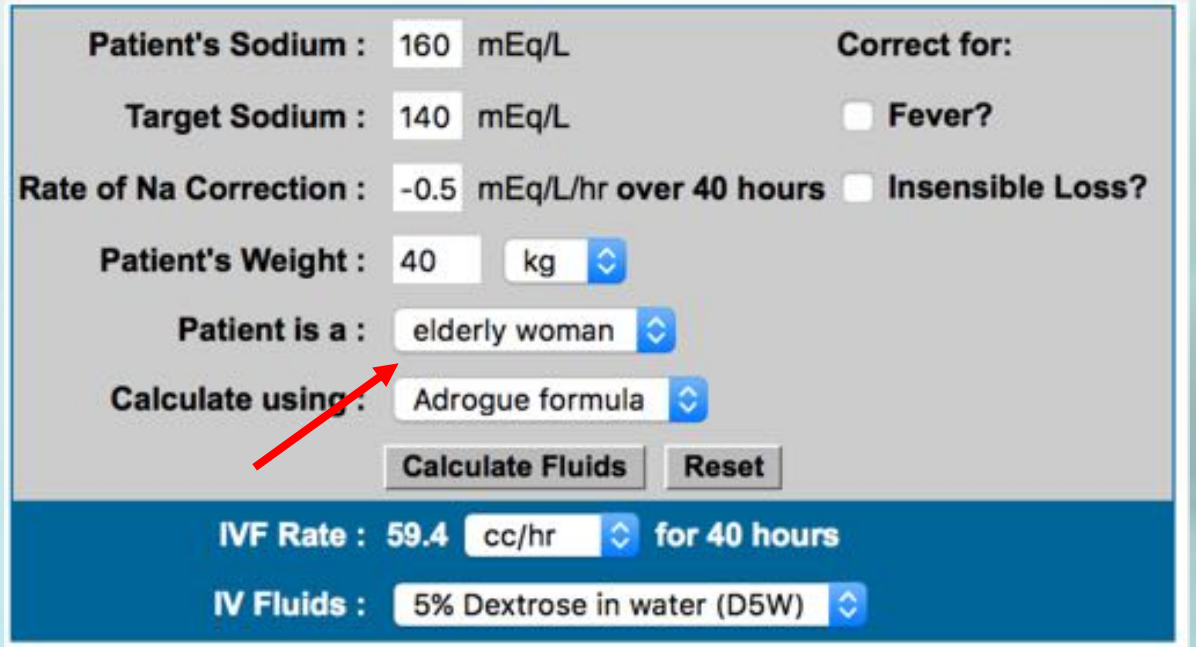
Infusate	Infusate Na^+ (mmol/L)
5% NaCl	855
3% NaCl	513
0.9% NaCl (NS)	154
Lactate Ringer's	130
0.45% NaCl (½ NS)	77
0.2% NaCl (¼ NS)	34
5% Dextrose in water (D5W)	0

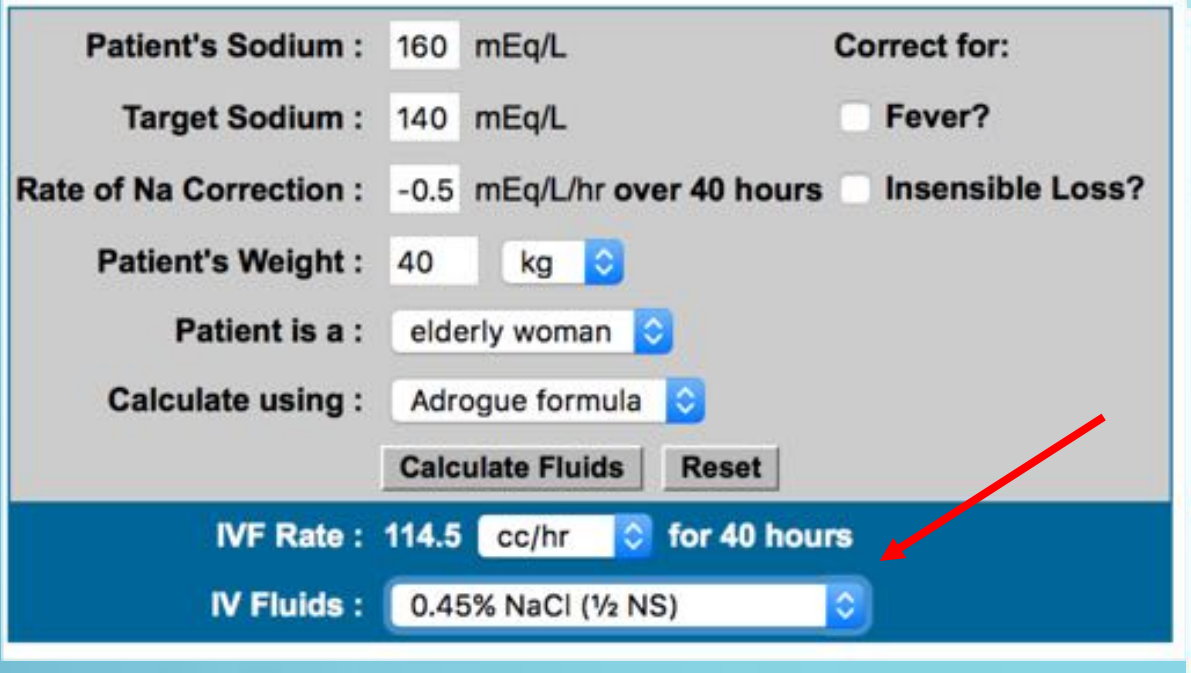
Total Body Water (in liters) :	
Children	0.6 x weight
Women	0.5 x weight
Men	0.6 x weight
Elderly Women	0.45 x weight
Elderly Men	0.5 x weight

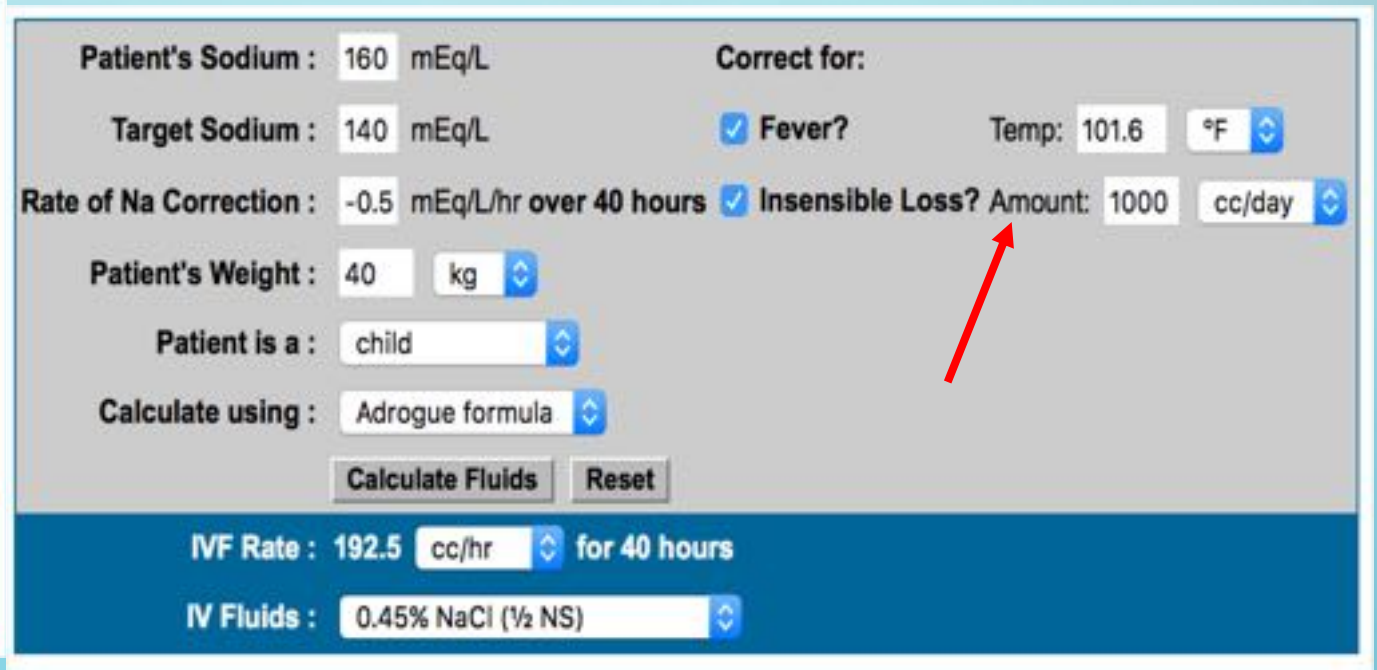
Fluids To Intervene

Fluid	[Na]	[K]	[Cl]	Buffer	Ca	Mg	Kcal/L	Osm (mOsm /L)	pH
Plasma	*135-145*	*3.5-5*	*95-105*	*23-30*	*2.5*	*1*		*290*	*7.35-7.45*
LR	130	4	109	28	2.7			273	6.0-7.5
NS	154	0	154	0	0	0	0	308	4.5-7.0
½ NS	77	0	77	0	0	0	0	154	
D5W	0	0	0	0	0	0		252	3.5-6.5
3% HTS	513	0	513	0	0	0		513	


Patient's Sodium : 160 mEq/L
Correct for:
Target Sodium : 140 mEq/L
Fever?
Rate of Na Correction : -0.5 mEq/L/hr over 40 hours
Insensible Loss?
Patient's Weight : 40 kg
Patient is a : woman
Calculate using : Adrogue formula
Calculate Fluids
Reset
IVF Rate : 65.6 cc/hr for 40 hours
IV Fluids : 5% Dextrose in water (D5W)


Patient's Sodium : 160 mEq/L
Correct for:
Target Sodium : 140 mEq/L
Fever?
Rate of Na Correction : -0.5 mEq/L/hr over 40 hours
Insensible Loss?
Patient's Weight : 40 kg
Patient is a : elderly woman
Calculate using : Adrogue formula
Calculate Fluids
Reset
IVF Rate : 59.4 cc/hr for 40 hours
IV Fluids : 5% Dextrose in water (D5W)

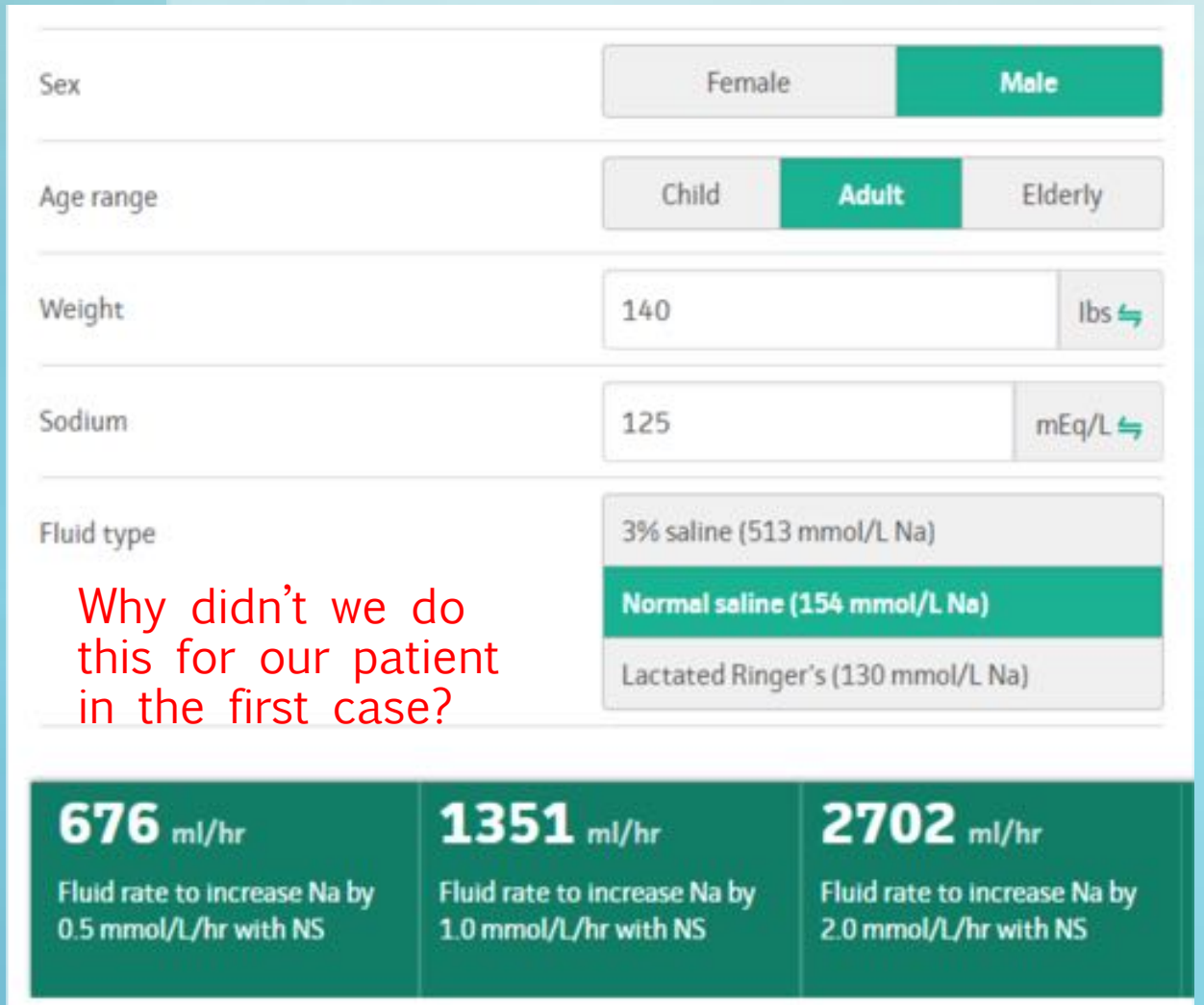

Patient's Sodium : 160 mEq/L
Correct for:
Target Sodium : 140 mEq/L
Fever?
Rate of Na Correction : -0.5 mEq/L/hr over 40 hours
Insensible Loss?
Patient's Weight : 40 kg
Patient is a : elderly woman
Calculate using : Adrogue formula
Calculate Fluids
Reset
IVF Rate : 114.5 cc/hr for 40 hours
IV Fluids : 0.45% NaCl (½ NS)


Patient's Sodium : 160 mEq/L
Correct for:
Target Sodium : 140 mEq/L
Fever?
Temp: 101.6 °F
Rate of Na Correction : -0.5 mEq/L/hr over 40 hours
Insensible Loss?
Amount: 1000 cc/day
Patient's Weight : 40 kg
Patient is a : child
Calculate using : Adrogue formula
Calculate Fluids
Reset
IVF Rate : 192.5 cc/hr for 40 hours
IV Fluids : 0.45% NaCl (½ NS)

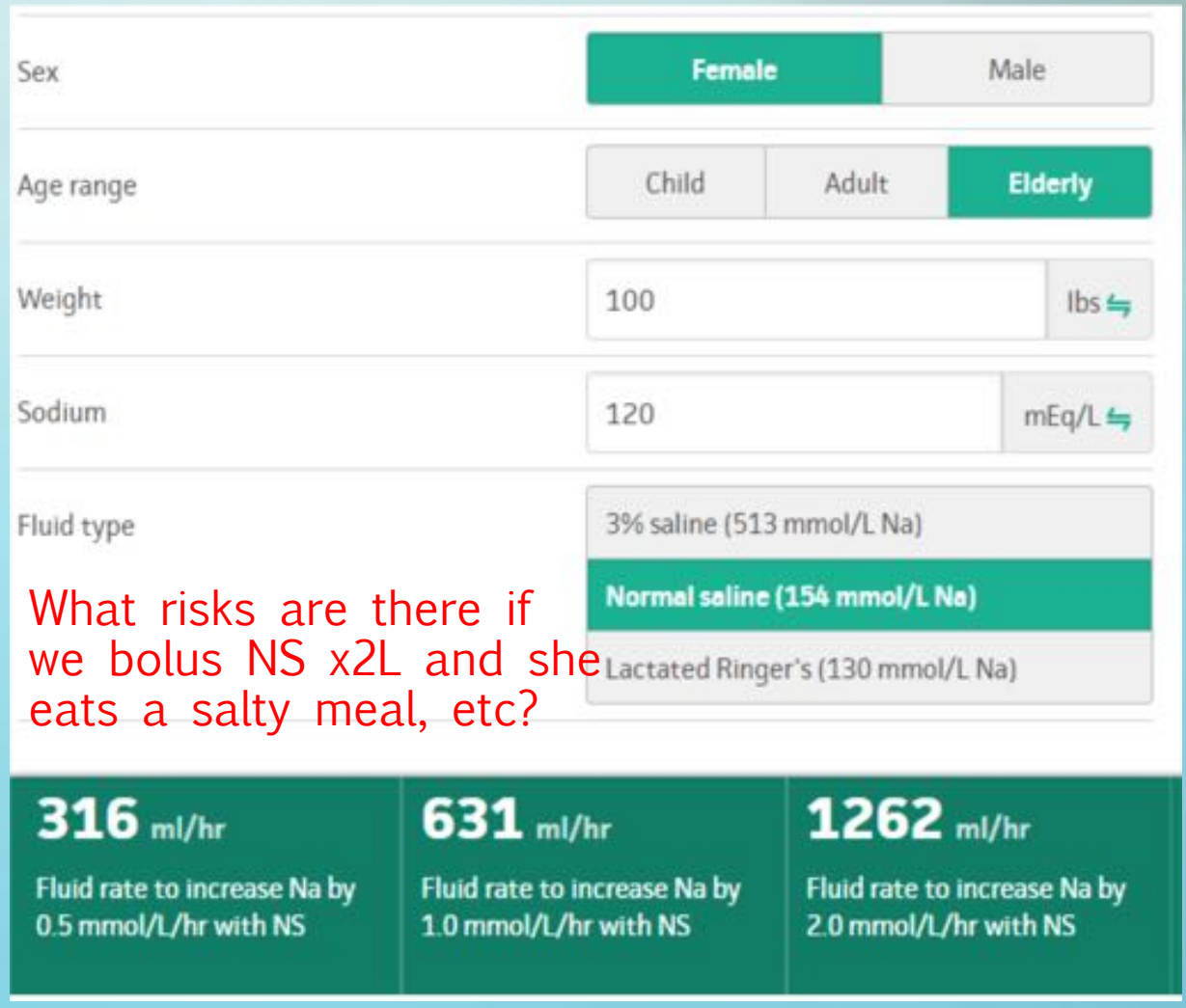
Case Conclusion

- You start the patient on D5 1/2NS infusion
  - At 115 cc/hr
  - Monitoring RFPs Q8H.
- Her deficit improves appropriately over 72 hrs as does her mental status
- Speech therapy finds that the patient has mild dysphagia and she is discharged to SNF on a dysphagia diet.

Sodium: Hyponatremia

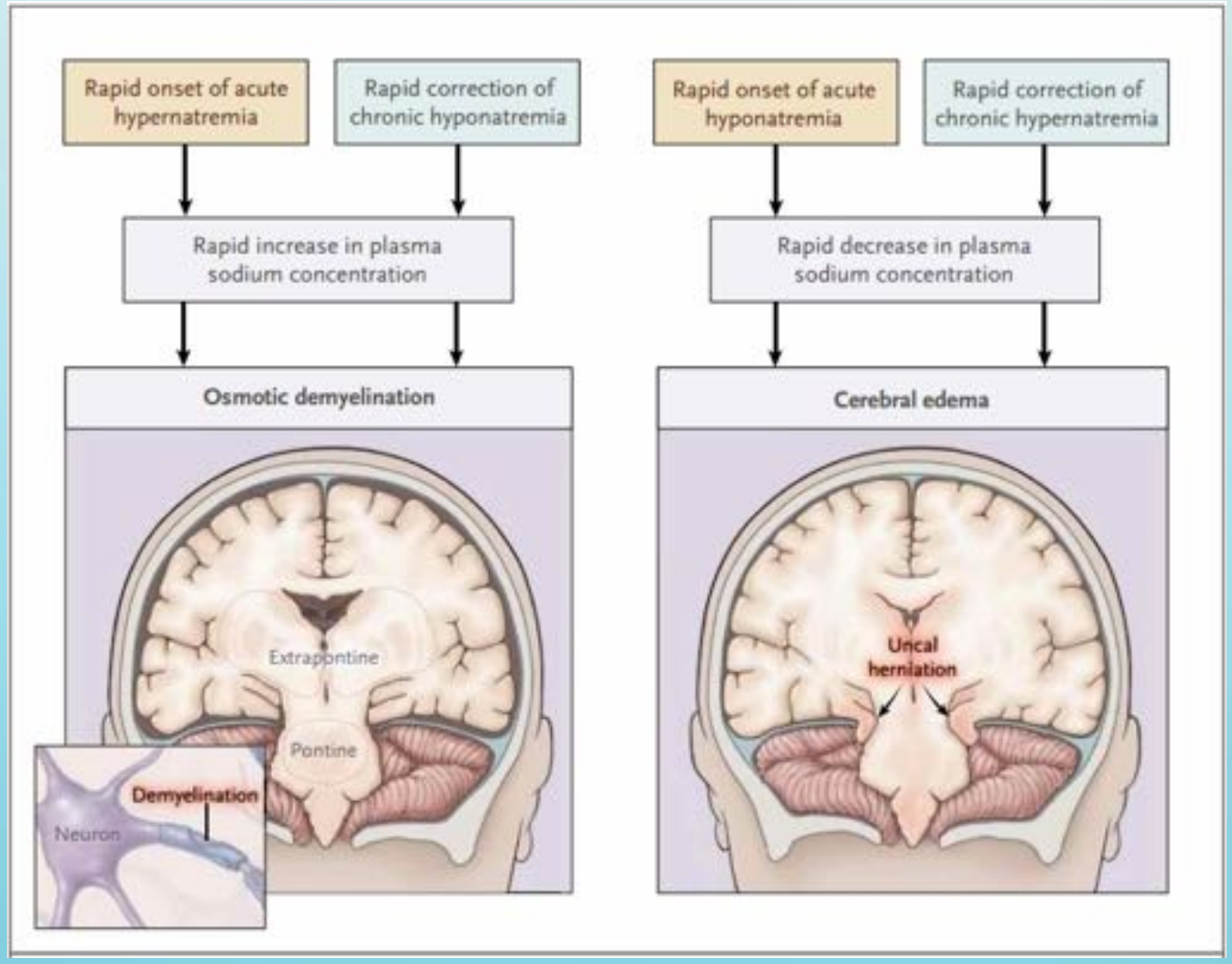


Why didn't we do this for our patient in the first case?



What risks are there if we bolus NS x2L and she eats a salty meal, etc?

Sodium: If you correct >0.5mEq/hr…



Conclusions so far:

- **Sodium: “Easy” for the body; body in trouble, so is brain**
  - **Process: Timeline, Volume Status, (Osmoles), and Body’s Response**

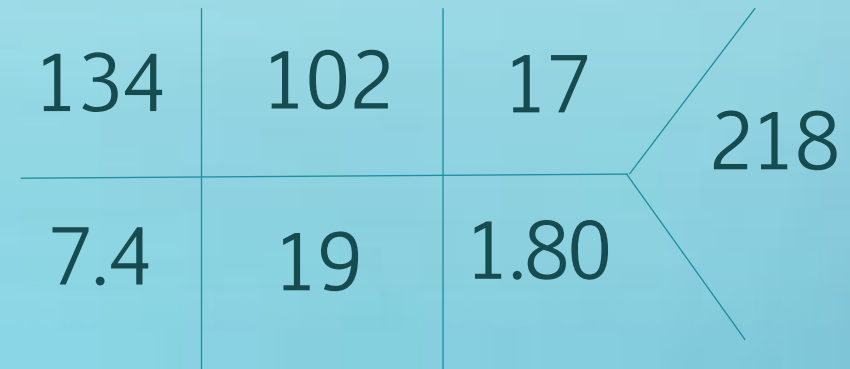
You're on Night Float

- Saturday night, sign out was pretty quick

- "She's fine, just follow up the RFP and CBC"
  - No info about why, or what to do when "following up"

- "6:30pm draw" drawn at 9:48pm, results at 11:58pm

- Your 2nd of 5 pages is the RN with labs



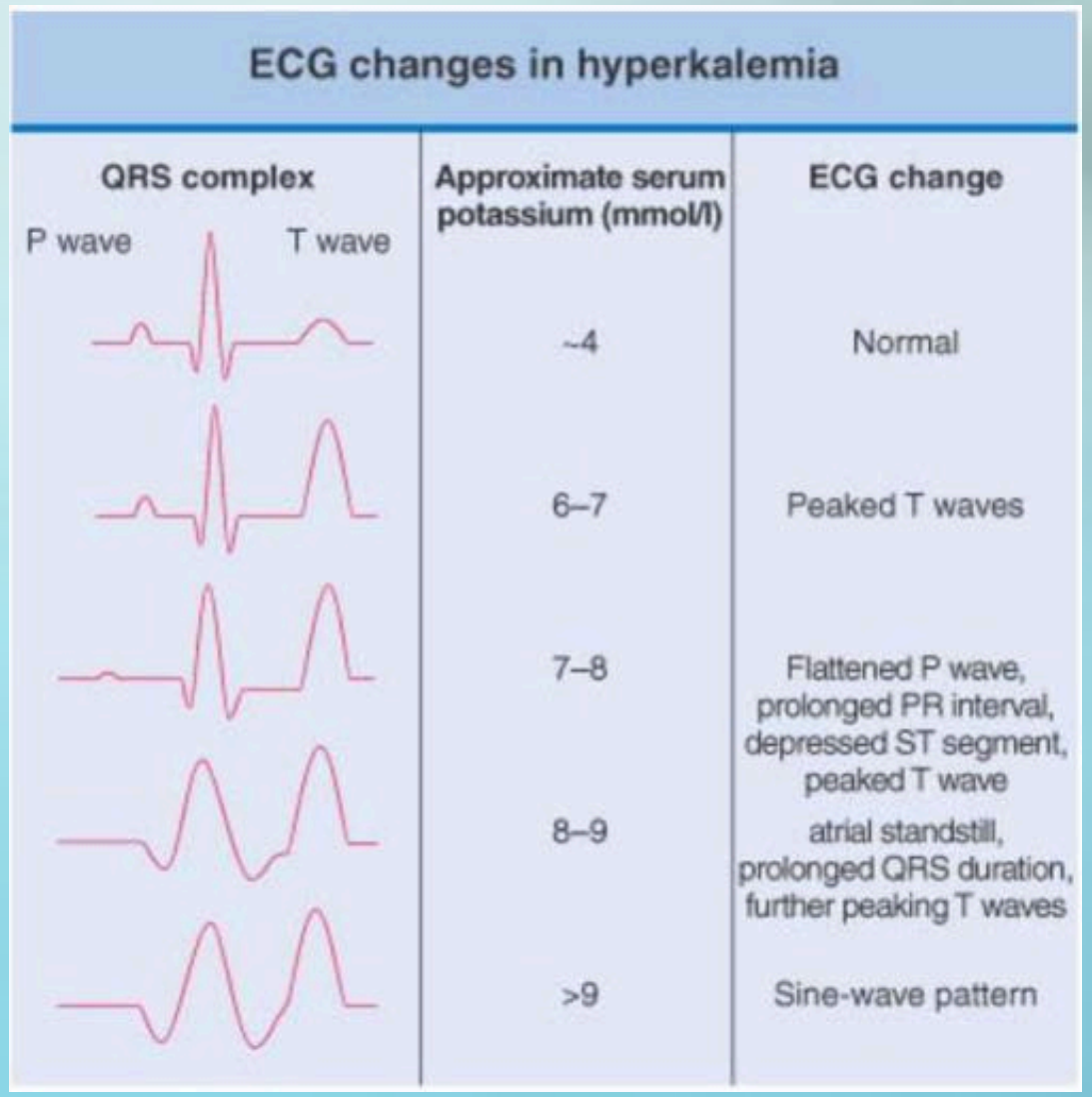
You're on Night Float

- You are the one guiding her care until 0700.
- Is she OK?
- She's in danger? What kind, how much?
- How are you going to make sure she is safe until then?

134	102	17	218
7.4	19	1.80	

Hyperkalemia: Symptoms

- Symptoms
  - Muscle weakness/paresthesias
  - EKG changes:
    - Peaked T waves
    - Prolonged PR interval
    - Widened QRS
    - Sine wave
    - V-fib



Review of EKGs in 90 pts (80% w/ K < 7.2mEq/L), 18% met strict criteria, 52% met any

Montague BT1, Ouellette JR, Buller GK. Retrospective review of the frequency of ECG changes in hyperkalemia. Clin J Am Soc Nephrol. 2008 Mar;3(2):324-30. doi: 10.2215/CJN.04611007

Wrenn, K D, C M Slovis, and B S Slovis. 1991. The ability of physicians to predict hyperkalemia from the ECG. Annals of emergency medicine, no. 11. http://www.ncbi.nlm.nih.gov/pubmed/1952310.

Hyperkalemia: Treatment

Intervention	Dose	Onset	Comment
Calcium gluconate Calcium chloride*	1-2 amps IV	<3 min	Lasts 30-60 min
Bicarbonate	1-3 amps IV	15-30 mins	Lasts 30 mins
B2 agonists (~4-8x neb dose)	Alb 10-20mg inh. Or 0.5mg IV	Full in 30-90 mins	Lasts 120 mins
Insulin/Glucose	10U IV with 1-2 amps D50W	Full in 15-30 mins	Lasts 60 mins
Kayexalate	30-90g PO/PR	1-2 hours	***Lasts 6 hours***
Diuretics	Lasix >40mg IV	30 mins	***Lasts 6 hours***
Hemodialysis		Whenever access can be attained	AEIOU, right?

MICU rounds…

- 36yo in septic shock (DIC, acute heart failure, cirrhosis, intubated)
- s/p loads of fluids and ABX for treatment—anasarca set in
- Now diuresing rapidly, has diarrhea, w/ B2-agonists often
- K 2.6, in a man who was ~150kg even before IVF
- How do you want to fix this?

Fluids To Lose (from Maxwell's)

Fluid	[Na]	[K]	[Cl]	[HCO3]	Volume (mL/day)
Salivary	10	***26***	10	30	500-2000
Gastric	60	***10***	**140**	0	100-4000
Biliary	145	***5***	100	35	50-800
Pancreatic	140	***5***	75	115	100-800
Ileal	130	***5***	100	50	100-9000
Diarrheal	60	***35***	40	**30**	Varies…

Hypokalemia: Treatment

Oral Replacement: May use for asymptomtic hypokalemia. Replace over several days.

Serum Level (mEq/L)	Potassium Chloride (sustained-release tablet, oral powder, or oral solution)
3.3 – 3.5	Potassium Chloride 20 mEq PO x1
3 – 3.2	Potassium Chloride 20 mEq PO Daily x2
2.5 – 2.9	Potassium Chloride 20 mEq PO Daily x3
*** In patients with renal insufficiency (creatinine clearance < 50 mL/min) use 50% or less of the suggested dose.	

May repeat serum level 4 hours after last dose. Repeat replacement boluses as needed.

Oral Product Information: (UHC available products)
Potassium Chloride sustained-release tablet 10 mEq or 20 mEq

Potassium Chloride oral solution 20 mEq

Potassium Chloride oral powder (Klorcon) 20 mEq

Parenteral Replacement:

Serum Level (mEq/L)	Potassium Chloride via PERIPHERAL line	Potassium Chloride via CENTRAL line
3.1 – 3.4	Potassium Chloride 20 mEq IV in 250 mL of **NS** or D5W over 1-2 hours x2	Potassium Chloride 40 mEq IV in 100 mL of **SWFI** (premix) or NS or D5W over 2-4 hours
2.6 – 3	Potassium Chloride 20 mEq IV in 250 mL of **NS** or D5W over 1-2 hours x3	Potassium Chloride 60 mEq IV in 150 mL of **NS** or D5W over 3-6 hours
< 2.5	Potassium Chloride 20 mEq IV in 250 mL of **NS** or D5W over 1-2 hours x4	Potassium Chloride 80 mEq IV in 250 mL of **NS** or D5W over 4-8 hours
*** In patients with renal insufficiency (creatinine clearance < 50 mL/min) use 50% or less of the suggested dose.		

May repeat serum level 2 hours after the infusion is completed. Repeat replacement boluses as needed.

Intravenous Product Information: (UHC available products)
Potassium Chloride injection 2 mEq/mL

University Hospitals of Cleveland Adult Electrolyte Replacement Guidelines (Rev 6/17/2004)

Potassium control and effects

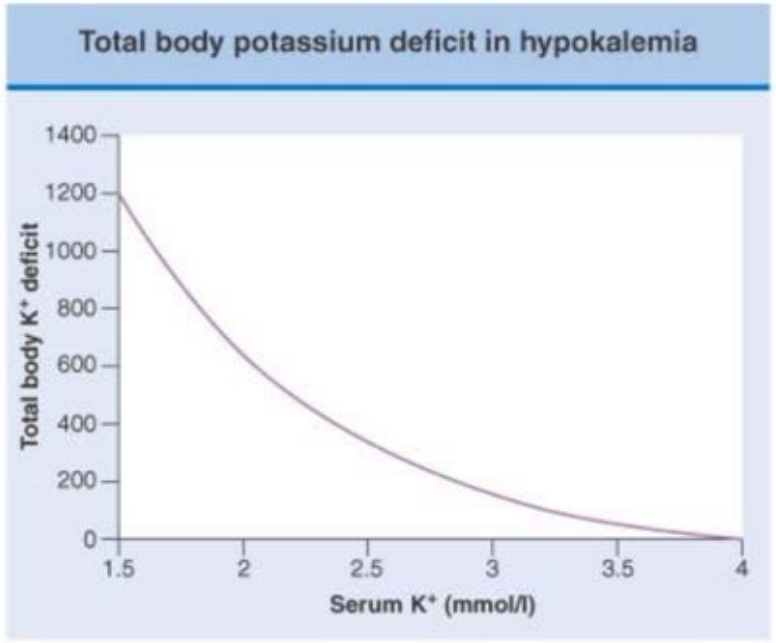
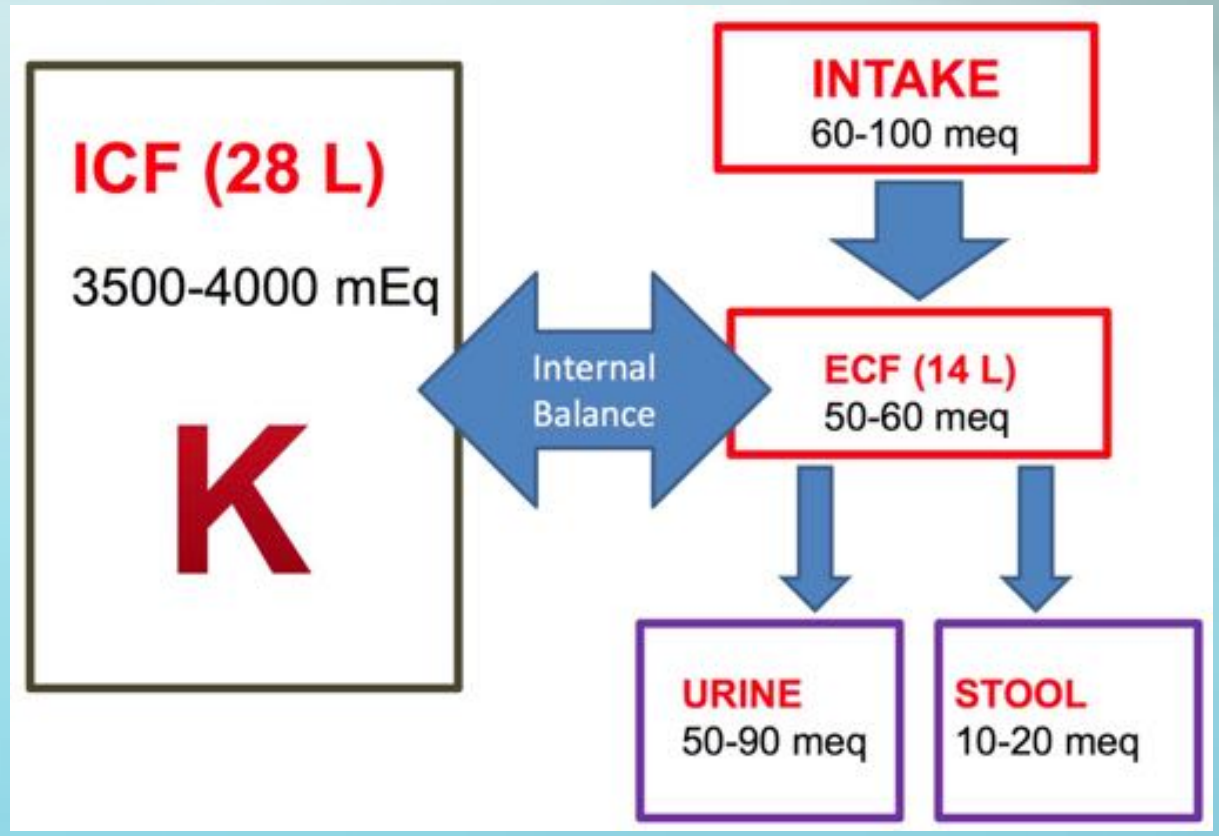


Figure 9.7 Total body potassium deficit in hypokalemia. Because of shift of potassium from the intracellular to the extracellular fluid compartment during chronic potassium depletion, the magnitude of deficiency can be masked and is generally much larger than would be calculated solely from the change in plasma potassium and the extracellular fluid volume.



Hypokalemia: Treatment

PO	Phosphate mg	Sodium mEq	Potassium Meq
K-Phos Neutral	250	13	1.1
Neutra-Phos	250	7.1	7.1
Neutra-Phos K	250	0	14.2
IV	Mmol/ml	mEq/ml	mEq/ml
Potassium phosphate	3	0	4.4
Sodium phosphate	3	4	0

3 mmol/ml of phosphate corresponds to 93 mg of phosphorus

Hypokalemia:

Conclusions so far

- Sodium: Easy for the body; body in trouble = so is your brain
  - Process: Timeline, Volume Status, (Osmoles), and Body's Response
- **Potassium: Heart wants you to know that it's all about balance**
  - **ICF-ECF balance crucial; Shifts vs Depletion/Overload; PO upset, IV burns**

Back on the wards

- Pt recovering from severe gastroenteritis: vomiting, diarrhea
  - PO intake still low despite Zofran IV
  - Some occasional NS boluses to counter diarrheal losses
  - ~120mEq KCl per day, mildly helping

- They complain of hand tremors and tingling today

- RFP: 145/3.2/110/20/20/0.8, Ca 8.3, Phos 2.6, Alb 3.5
  - ***Magnesium level is added on, found to be 0.8***

Magnesium: Hypomagnesemia Tx PO

Oral magnesium pills

Better soluble and less diarrhea:

- Mag tab SR (Mg lactate)
- Slow Mag (Mg Chloride)

In hospital: Magnesium oxide 400-800 mg twice daily

Salt	Solubility	pH	Diarrhea
Sulfate	+	+	++
Chloride	+++	-	+
Oxide	+	+	++
Citrate	+	+	++
Hydroxide	+	+	++
Gluconate	++	+	+
Lactate	++	+	+

University Hospitals of Cleveland Adult Electrolyte Replacement Guidelines (Rev 6/17/2004)

Magnesium: Hypomagnesemia Tx IV

Oral Replacement: May use for asymptomatic hypomagnesemia
Magnesium Oxide tablet 400–800 mg PO BID–TID
Recheck serum magnesium levels daily

Oral Product Information: (UHC available products)
Magnesium Oxide tablet 400 mg = 242 mg elemental magnesium (20 mEq)

Magnesium Gluconate syrup 1000 mg/5 mL = 54 mg/5 mL elemental magnesium (4.8 mEq/5 mL)

Milk of Magnesium (magnesium hydroxide) 24% concentrate suspension10 mL = 1001 mg of elemental magnesium (82 mEq)

Only ~1/6 absorbed / bioavailable

Parenteral Replacement:

Serum Level (mg/dL)	Magnesium Sulfate
1 – 1.5	2 gm Magnesium Sulfate IV in 100 mL of **D5W** or NS over 2 hours
< 1	4 gm Magnesium Sulfate IV in 250 mL of **D5W** or NS over 4 hours
*** In patients with renal insufficiency (creatinine clearance < 50 mL/min) use 50% or less of the suggested dose.	

May repeat serum level 2 hours after the infusion is completed. Repeat replacement boluses as needed.

Go even slower!

Intravenous Product Information: (UHC available products)
Magnesium Sulfate injection 1gm = 98.6 mg elemental magnesium (8.1 mEq)

University Hospitals of Cleveland Adult Electrolyte Replacement Guidelines (Rev 6/17/2004)

Magnesium: Hypermagnesemia

- Causes
  - Renal failure
  - Increased Mg intake—includes MgSO4 (for HypoMg or PIH/eclampsia)
  - Acute adrenocortical insufficiency
  - Hypothermia

- Clinical manifestations:
  - Mg 4-6: N/V, flushing, headache, lethargy, drowsiness; *Diminished DTRs*
  - Mg 6-10: Somnolent, HoTN, bradycardia, ECG changes, HypoCa; ***Absent DTRs***
  - Mg>12: Paralysis/flaccid quadriplegia; Apnea, respiratory failure
    - **Complete heart block**. **Cardiac arrest**

- Treatment
  - IV calcium (chloride or gluconate) to oppose magnesium's dangerous effects
  - Stopping intake
  - Increasing fluids with diuretics or dialysis if renal failure

Magnesium

What to ponder	Hypo	Hyper
Most common situation	Confusion, HypoK, HypoCa	Flushing, headache
Most dangerous situation	Tremor, Sz, Torsades, Death	Respiratory failure, heart block
Most common cause	Renal and GI losses	Renal failure, or Iatrogenic
Most dangerous cause	Alcoholism w/ Renal, GI losses	Renal failure, adrenal insuff
Best way to fix	Replete, IV if possible, PO gently	IV Ca, low intake, high urine

Conclusions so far

- Sodium: Easy for the body; body in trouble = so is your brain
  - Process: Timeline, Volume Status, (Osmoles), and Body's Response
- Potassium: Heart wants you to know that it's all about balance
  - ICF-ECF balance is crucial; Shifts vs Depletion/Overload; PO upset, IV burns
- **Magnesium: Potassium's cousin. Acts like it, moves with it.**
  - **Measure when having K troubles; PO=diarrhea, Slow IV drip is best**

Chloride

What to ponder	Hypo	Hyper
Most common situation		
Most dangerous situation		
Most common cause		
Most dangerous cause		
Best way to fix		

Fluids To Intervene

Fluid	[Na]	[K]	[Cl]	Buffer	Ca	Mg	Kcal/L	Osm (mOsm /L)	pH
Plasma	***135-145***	***3.5-5***	***95-105***	***23-30***	***2.5***	***1***		***290***	***7.35-7.45***
LR	130	4	109	28	2.7			273	6.0-7.5
NS	154	0	154	0	0	0	0	308	4.5-7.0
½ NS	77	0	77	0	0	0	0	154	
D5 ½NS	77	0	77	0	0	0	0	406	3.5-6.5
D5 NS	154	0	154	0	0	0	0	560	3.5-6.5
D5W	0	0	0	0	0	0		252	3.5-6.5
3% HTS	513	0	513	0	0	0		516	
"Plasma-lyte"	140	5	98	50	0	1.5		295	

Chloride

What to ponder	Hypo	Hyper
Most common situation	Agitation, labs off	Weakness, labs off
Most dangerous situation	Coma, Arrhythmia	LOC, Coma
Most common cause	Hypotonic fluids, dehydration	Hypertonic fluids, meds
Most dangerous cause	Metabolic alkalosis (hypochloremic versions)	Metabolic Acidosis
Best way to fix	Salty intake, Tx underlying Dx	Limit salt, consider diuretics

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  - Measure when having K troubles; PO=diarrhea, Slow IV drip is best
- **Chloride: Sodium's shadow, tells you secrets about HCO3**
  - **America loves salt, we love IV fluids! Solutions can be the problem**

NF to Dworken

- Called to room for “feeling numb”
- 70yo w/ CKD-2, DM-2, CHF, EtOH abuse: w/ GI bleed
  - Anemic, overloaded, s/p 4U pRBC and Lasix 80mg IV BID
- Numb lips first, now fingers/legs too, w/ tremors, irritable
- RFP: 132/3.6/88/36/36/1.25, Ca 6.6, Phos 3.2, Alb 2.0
  - Ca Correction = **[Ca] + (0.8*(4.0-Alb)**)
  - so 6.6 + 0.8*(2.0) makes **8.2**

Another case

- 80yo patient w/ cough, R shoulder pain, presents to ED
- Patient appears dehydrated, reports polyuria and constipation
- RFP: 138/3.8/102/24/10/0.4, Ca 9.6, Phos 2.2, Alb 2.0

Calcium

What to ponder	Hypo	Hyper
Most common situation		
Most dangerous situation		
Most common cause		
Most dangerous cause		
Best way to fix		

Calcium

What to ponder	Hypo	Hyper
Most common situation	Numbness: Circumoral first	Weakness, constip, stones
Most dangerous situation	Prolonged QT	Ventricular arrhythmias
Most common cause	Diuresis, CKD, Vit D def	Bone release
Most dangerous cause	Tumor lysis, rhabdomyolysis	Bone release—malig
Best way to fix	Supplements, Tx underlying Dx	Hydration, Phos, Diuresis, HD
	Make sure you fix Mg, Vit D	

Conclusions so far

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- Chloride: Sodium's shadow, tells you secrets about HCO3
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- **Calcium: MSK master, whole body deal, loves proteins**
  - **Low? Replete. High? Dilute, distract, dump… then find a diagnosis**

Last case/wrap up

- 70yo ESRD patient w/ NHL, new on Tx
  - Found down at home on morning of HD, was brought to ED instead.
- Patient dehydrated, tachycardic, extremely anxious, cramping, EKGs scares you
- RFP: 133/5.6/100/18/55/6.0/98, Ca 5.2, Phos 9.6, Alb 3.6

I lied. Last case

- 22yo woman w/ Hx of horrific pharyngitis, now post-op
- IVF initially; now on numerous Boost shakes, scant food
- Day 3: new shortness of breath
- Admit vitals: bradycardia, low BMI
- HR 78, looks “puffy” today, shaky/weak,
- RFP: 142/2.7/102/26/6/0.3/68 Ca 8.0, Phos 1.2, Alb 1.5

More on Phos

- What is phosphorus useful for?
- Several studies suggest that phosphorus-replete patients fare better than insufficient patients esp in regards to one organ

Alsumrain MH1, Jawad SA, Imran NB, Riar S, DeBari VA, Adelman M. Association of hypophosphatemia with failure-to-wean from mechanical ventilation. Ann Clin Lab Sci. 2010 Spring;40(2):144-8.

Aubier M, Murciano D, Lecocguic Y, Viires N, Jacquens Y, Squara P, Pariente R. Effect of hypophosphatemia on diaphragmatic contractility in patients with acute respiratory failure. N Engl J Med. 1985 Aug 15;313(7):420-4.

Phosphate: Hypophosphatemia

Phosphorus content of foods

High (>250 mg)	Medium (150 - 250 mg)	Low (<150 mg)
Milk Products (8 oz) Milk (whole or lowfat); Yogurt; Cheeses (2oz) Cottage cheese Cocoa Meats (4 oz) Liver, Chicken, turkey duck, pork, ham, bacon Lamb, Beef Fish (4 oz) Cereals (8 oz) Bran; Wheat-base Nuts (4 oz)	Beans (8 oz) Shellfish (8 oz) Tofu (8 oz) Ice Cream (8 oz) Lentils (8 oz) Lima Beans (8 oz) Mushrooms (8 oz) Peas (8 oz) Pudding (8 oz) Peanut Butter (2 tbsp)	Bread (1 slice) Most cereals (8 oz) Bacon (1 slice) Egg (1) Most vegetables Fruits Potatoes Rice Condiments (salt pepper) Beverages Soft drinks Tea, coffee Beer, wine

Cogan Fluid and Electrolytes, 1991

PO	Phosphate mg	Sodium mEq	Potassium Meq
K-Phos Neutral	250	13	1.1
Neutra-Phos	250	7.1	7.1
Neutra-Phos K	250	0	14.2
IV	Mmol/ml	mEq/ml	mEq/ml
Potassium phosphate	3	0	4.4
Sodium phosphate	3	4	0

3 mmol/ml of phosphate corresponds to 93 mg of phosphorus

Phosphate: Hypophosphatemia

Oral Product Information: (UHC available products)

Neutraphos packet = sodium 164 mg (7.1 mEq), phosphorus 250mg (14 mEq or 8.1 mmol), potassium 278 mg (7.1 mEq)

Neutraphos-K packet = phosphorus 250 mg (14 mEq or 8.1 mmol), potassium 556 mg (14.2 mEq)

Parenteral Replacement:

Serum Level (mg/dL)	SODIUM or POTASSIUM Phosphate
2 – 2.5	15 mmol SODIUM Phosphate IV in 250 mL of **NS** or D5W over 4 hours or 15 mmol POTASSIUM Phosphate IV in 250 mL of **D5W** or NS over 4 hours
1 – 1.9	21 mmol SODIUM Phosphate IV in 250 mL of **NS** or D5W over 6 hours or 21 mmol POTASSIUM Phosphate IV in 250 mL of **D5W** or NS over 6 hours
< 1	30 mmol SODIUM Phosphate IV in 250 mL of **NS** or D5W over 8 hours or 30 mmol POTASSIUM Phosphate IV in 250 mL of **D5W** or NS over 8 hours

*** If potassium < 4 mEq/L consider POTASSIUM Phosphate for replacement.

*** In patients with renal insufficiency (creatinine clearance < 50 mL/min) use sodium phosphate and 50% or less of the suggested dose.

May repeat serum level 2 hours after the infusion is completed. Repeat replacement boluses as needed.

University Hospitals of Cleveland Adult Electrolyte Replacement Guidelines (Rev 6/17/2004)

Phosphate

What to ponder	Hypo	Hyper
Most common situation	Muscle weakness	Oliguria, Hypocalcemia
Most dangerous situation	Respiratory depression	Irregular HR, Calcifications
Most common cause	Alcoholism, burns	Renal failure
Most dangerous cause	Refeeding syndrome	Rhabdomyolysis, tumor lysis
Best way to fix	High intake, repletion	Low intake, High fluids, HD

Conclusions so far

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- Chloride: Sodium's shadow, tells you secrets about HCO3
  - America loves salt, we love IV fluids! Solutions can be the problem
- Calcium: MSK master, whole body deal, loves proteins
  - Low? Replete. High? Dilute, distract, dump… then find a diagnosis
- **Phosphate: Frenemy of calcium but lets you breathe, move.**
  - **Comes with an RFP; make sure it stays normal; use the diet**

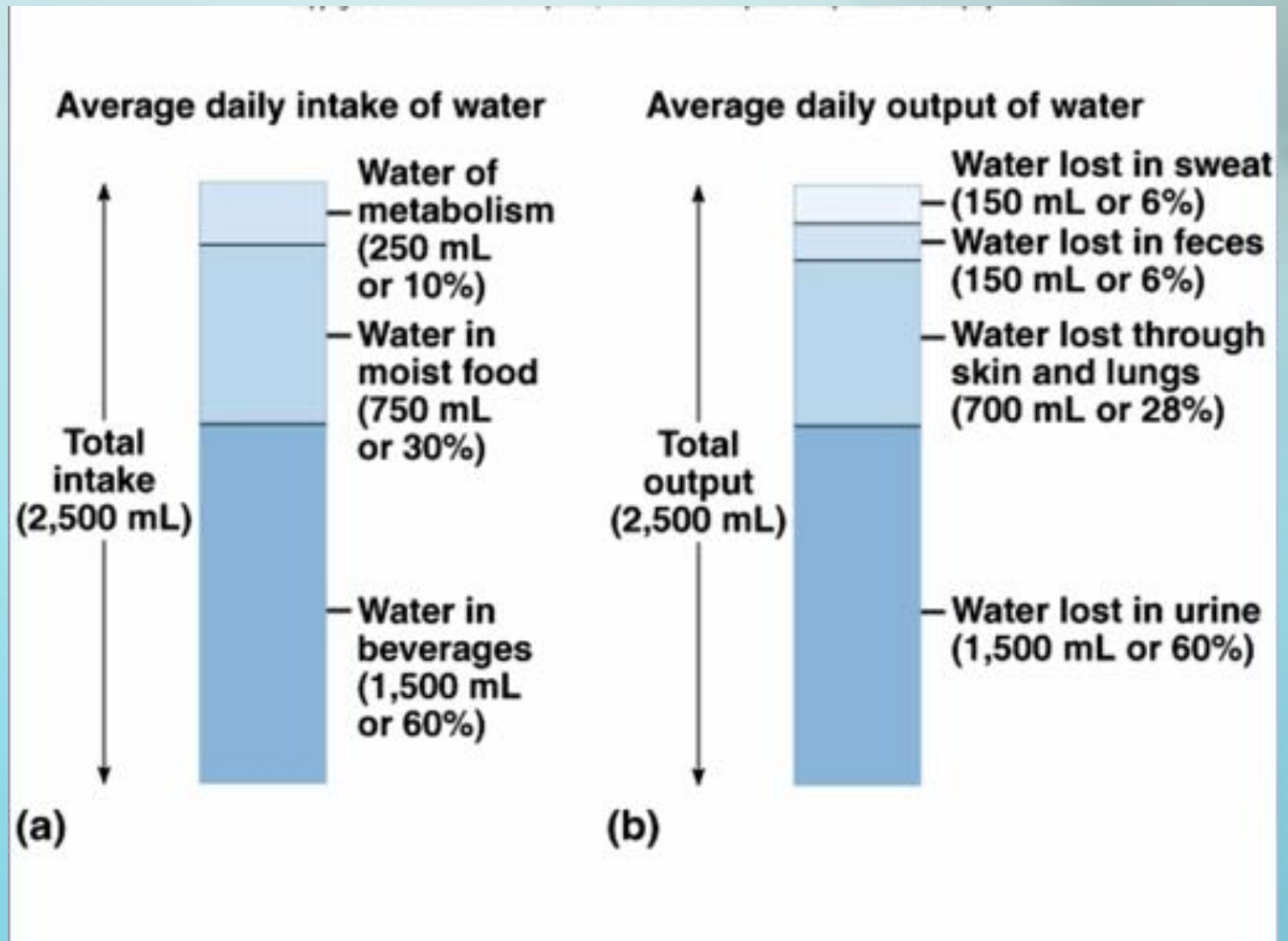
A moment for fluids

(Questions welcome!)

UH CMC Internal Medicine Bootcamp
Keith Torrey, PGY-4, Internal Medicine-Pediatrics

Fluid Losses/Needs

- Maintenance
  - Normal daily outputs
    - Urine = 12-15 cc/kg
    - Stool = 3 cc/kg
    - Sweat = 1.5 cc/kg
    - Respiratory and Skin insensible losses = 10 cc/kg
      - **Increased by 8%/degree F for fever**
  - Normal daily endogenous input
    - Oxidation of carbohydrates and fat = 3 cc/kg



Fluids To Lose (from Maxwell's)

Fluid	[Na]	[K]	[Cl]	[HCO3]	Volume (mL/day)
Salivary	10	***26***	10	30	500-2000
Gastric	60	***10***	**140**	0	100-4000
Biliary	145	***5***	100	35	50-800
Pancreatic	140	***5***	75	115	100-800
Ileal	130	***5***	100	50	100-9000
Diarrheal	60	***35***	40	**30**	Varies…

Fluids To Intervene

Fluid	[Na]	[K]	[Cl]	Buffer	Ca	Mg	Kcal/L	Osm (mOsm /L)	pH
Plasma	***135-145***	***3.5-5***	***95-105***	***23-30***	***2.5***	***1***		***290***	***7.35-7.45***
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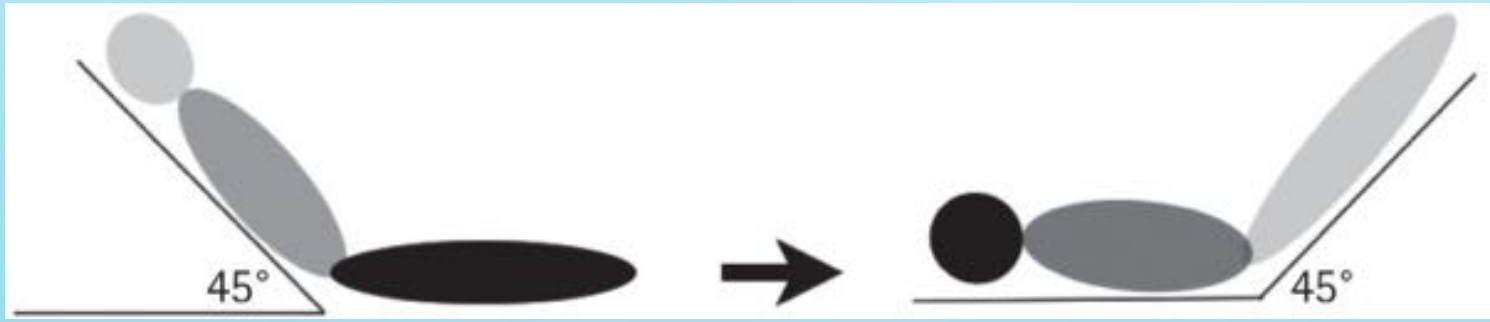
D5 ½NS	77	0	77	0	0	0	0	406	3.5-6.5
D5 NS	154	0	154	0	0	0	0	560	3.5-6.5
D5W	0	0	0	0	0	0		252	3.5-6.5
3% HTS	513	0	513	0	0	0		516	
"Plasma-lyte"	140	5	98	50	0	1.5		295	

Fluid Balance in the Body—eval reminder

- History: Intake, output
- Physical Exam: Weights, HR, resting BP (late), orthostatic vitals (sort of), orthostatic SYMPTOMS, mucus membranes (rule out), axillary sweat, JVD, skin turgor, cap refill, mentation, passive leg raise (45 degrees)



  - Passive leg raise actually predicts response to fluid boluses rather well!
    - Bentzer P, Griesdale DE, Boyd J, MacLean K, Sirounis D, Ayas NT. Will This Hemodynamically Unstable Patient Respond to a Bolus of Intravenous Fluids? JAMA. 2016 Sep 27;316(12):1298-309. doi: 10.1001/jama.2016.12310.

- Further: CVP (poor), PCWP, IVC collapsibility, bioimpedance even—fancy!

So… why not LR?

- Crystalloids: Buffered vs Normal Saline Family
  - Preference vs Experience
- Cochrane review 2012: LR vs NS in peri-operative patients (n~706)
  - **No diff in mortality**, renal fx, blood loss
  - *NS pH lower by 0.06, no diff on POD 1*, higher Cl
- Cochrane review 2017: LR vs NS in peri-operative patients (n~1,000)
  - **No diff in mortality**, renal fx, blood loss
  - *NS: pH lower by 0.05, no diff on POD 1*, higher Cl persisting to POD 1
- Paper comparing LR and NS found LR benefit in pancreatitis…
  - One paper, not a big study, don't extrapolate

So… why not balanced/buffered overall?

- SALT, Semler *et al* 2015 NS vs LR-or-Plasmalyte in ~1,000 ICU pts.
  - MAKE30: "Major adverse kidney event" by 30d or hosp discharge:
    - (Risk of death, new RRT, persistent Cr to ≥200% b/l)
  - Absolutely no difference in MAKE30, p=0.98
- SMART, Semler *et al* (NEJM 2018): 15,800 patients in 5 ICUs
  - MAKE30: "Major adverse kidney event" by 30d or hosp discharge:
  - Composite 14.3% of buffered patients and 15.4% NS; OR 0.91, (0.84-0.99, p=0.04),
  - Death 10.3% vs 11.1%, p=0.06; for RRT 2.5% vs 2.9% p=0.08, Cr elev p=0.60
- Self *et al* (NEJM 2018): 13,347 pts, managed in 1 ED, who got admitted
  - Number of hospital-free days in 28d after admit from ED: No difference!
  - MAKE30 was secondary, adjusted odds ratio, 0.82; 95% CI, 0.70 to 0.95; P=0.01
    - Big caveat? Median IVF volume was 1079mL—rest of hospital course probably bigger factor

Fluid Balance in the Body

- 15% arterial (1-2% of all TBW)
  - This is **where we need fluids** to help perfusion/shock
- 85% is venous (5-7% of all TBW)
  - This is where we get most of our measurements
  - This is **where we infuse fluids**

- If fluids get through heart AND lungs without any changes, we have expanded arterial circulation…

- So how do we get the fluid to stay?
  - (And how do we balance cardiorespiratory concerns?)

Fluid Balance in the Body

- NS: 28 healthy volunteers: 10-30mL/kg bolus in 20 mins
  - After 30 mins, 36% of infused volume left in IV compartment
    - Greenfield et al 1989)
- NS 2L over 1-2 hr, to pre-surgical and healthy volunteers
  - After infusion done, intravascular retention of 18-24% (by Hct), Mullins 1989
  - 6hr after infusion, 60% of fluid volume in body; IV retention of 13%
    - Lobo et al 2001 and 2003)
- Colloids:
  - Stays in IV compartment longer
  - For a given volume of Albumin, we'd need 40% more of NS
    - (Finfer S, et al. N Engl J Med 2004; 350: 2247–2256)

Fluids To Intervene

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Plasma	***135-145***	***3.5-5***	***95-105***	***23-30***	***2.5***	***1***		***290***	***7.35-7.45***
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D5W	0	0	0	0	0	0		252	3.5-6.5
3% HTS	513	0	513	0	0	0		516	
"Plasma-lyte"	140	5	98	50	0	1.5		295	

Colloids vs Crystalloids

- Cochrane review 1998: Albumin vs Crystalloids
  - Albumin conferred higher risk of death, RR of 1.68 ($p<0.01$)
- Cochrane in 2011 redid the Albumin vs NS study *w/ SAFE*
  - No **mortality** difference!
- ...so, how?

Colloids vs Crystalloids

- SAFE 2004: ~7000 ICU-admitted adults, 4% albumin vs NS
  - No mortality difference between NS, Albumin overall
    - Subgroup of Traumatic Brain Injury? **Albumin had higher mortality**
    - Subgroup of Severe Sepsis: **Albumin had lower mortality**
- CRISTAL 2013: 2857 hypovolemic shock ICU patients
  - All colloid vs all crystalloid
  - No difference in 28-day mortality (primary outcome)
  - 90-day mortality lower in colloids (**P=0.03** but RR 0.92, 95% CI 0.86-***0.99***)
- ALBIOS (NEJM 2014), 1818 patients w/ severe sepsis, 100 ICUs
  - Crystalloids-only vs Crystalloids plus Albumin as needed to keep [Alb]>3.0
  - No difference in 28d or 90d mortality.
  - Sub-groups:
    - Improvements in MAP, HR, shorter vasopressor use
    - No difference in volume instilled—and Albumin solution is ~30x costlier

Cost & contents of labs at UH

Test	Contents	Cost	Worth it?
BMP	Na/K/Cl/HCO3/BUN/Cr/Glu/Ca	~~$206~~ now $167	~~No~~ Yes, finally
CMP	BMP + **TProt, Alb, Alk Phos, AST/ALT, TBili**	~~$297~~ now $270	If you need it all
RFP	All of BMP + **Phos, Alb**	~~$96~~ now $257	~~Yes~~ Think about it
HFP	TProt, Alb, Alk Phos, AST/ALT, TBili, *DBili*	$193	If needed

Na $78 K $78 Cl $51 Phos $32 Mg $90 Ca (ionized) $140

- http://www.uhhospitals.org/case/patients-and-visitors/billing-insurance-and-medical-records/patient-pricing-information

One last thought… **Do you NEED Daily Labs**? Hospital Acquired Anemia & Daily Phlebotomy

- A study in JAMA in 2011 evaluated hospital acquired anemia (in patients w/o baseline anemia)
- Moderate to severe HAA developed in 3551 patients (20%).
- The mean (SD) phlebotomy volume was higher in patients with HAA (173.8 [139.3] mL) vs. those without HAA (83.5 [52.0 mL]; $P < .001$).
- For every 50 mL of blood drawn, the risk of moderate to severe HAA increased by 18% (relative risk [RR], 1.18; 95% confidence interval [CI], 1.13-1.22)
- Each 1mL of blood drawn decreases hemoglobin by ~0.07 g/dL

(Paul Shaniuk is the greatest for contributing this slide)

JAMA Internal Medicine
Formerly *Archives of Internal Medicine*

References used (beyond notes in slides)

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