Nephrology Fellow Clinical Compendium

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Disclaimer- This guide is intended as an overview with salient details only. In order to provide high quality patient care it is important to maintain close and appropriate supervision.

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Chapter 8: Electrolytes

By Sam Kant @kantsmd and ArunKumar Subbiah

Sodium

1 mmol NaCl = 8.5 mg
1 mmol Na = 23mg Na
1 gm salt tab = 17 meq NaCl

Osmolality 285-290 mOsm/kg = 2 Na + BUN/2.8 + glc/18 + ETOH/4.6

Electrolyte free water excretion = $V\ [1- \{(U_{Na} + U_K)/P_{Na}\}]$ where V = urine flow rate

- Free water restriction depends on **Urine/Plasma Electrolyte Ratio $(U_{Na} + U_K)/P_{Na}$:**
  Recommended water consumption (assuming 800 ml insensible water loss)
  - **> 1.0** 0 ml free water would be ideal but not practical so < 500 ml is the usual recommendation
  - **0.5-1.0** Up to 500 ml
  - **< 0.5** Up to 1 L

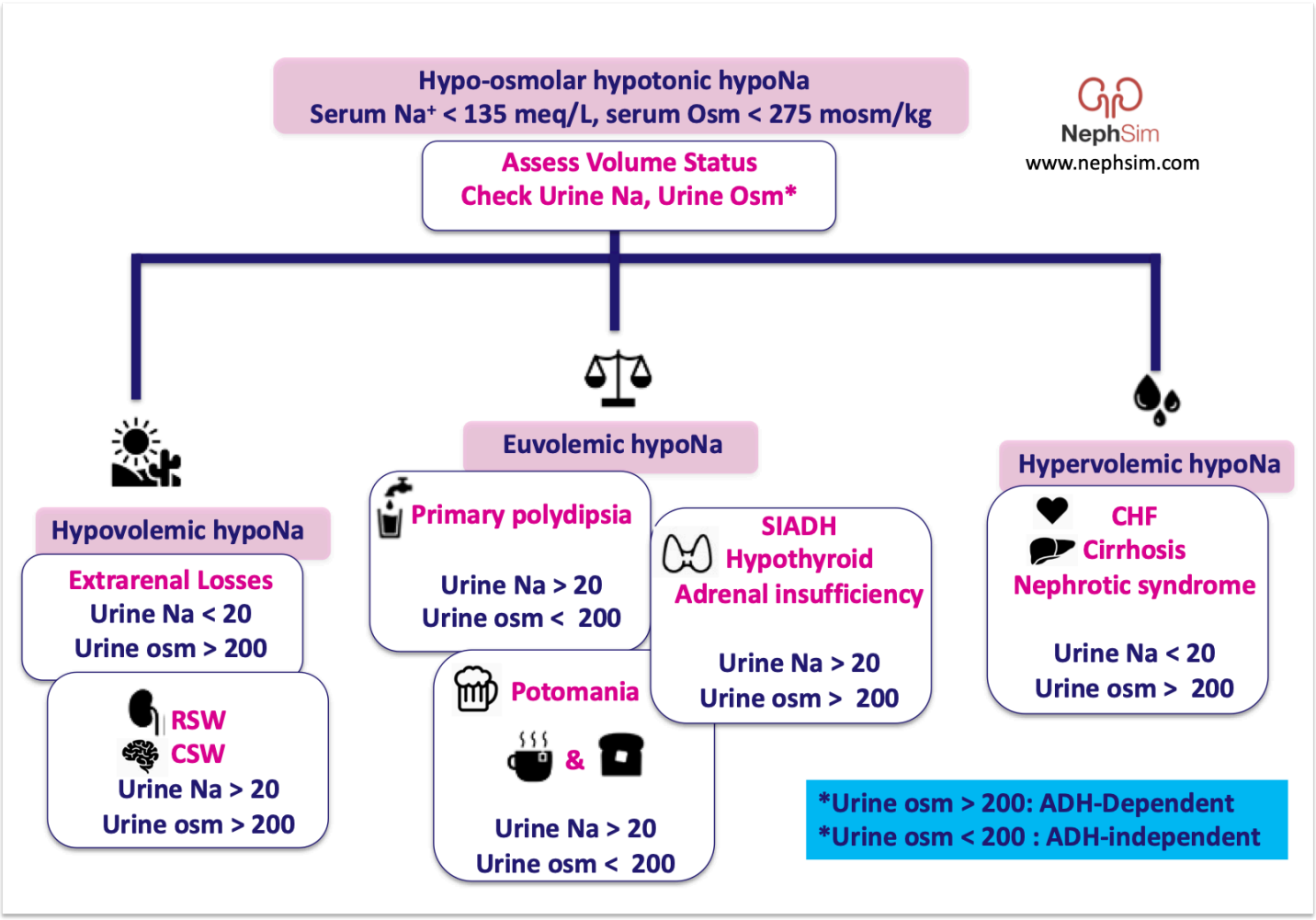
Na deficit in hyponatremia: TBW x (Na goal – Na current)

TBW calculated via Watson equation

513 meq Na in 3% saline

- If symptomatic > treat sodium for symptoms. Otherwise, max correction by 8 in 24 hours.
- If overcorrected (e.g. > 12 mmol/L in 24 hr or 18 mmol/L in 48 hr), use D5W or give desmopressin 1-2 ug SQ or IV doses at interval of 6-8 hrs.

Water deficit = %TBW x Wt (Current Na/Ideal Na – 1)



Compilation of guidelines on hyponatremia diagnosis and treatment

Tolvaptan

- Titrate to 30 mg once daily, after at least 24 hours, up to a maximum of 60 mg once daily, as needed to raise serum sodium.

DDAVP Clamp

This is a safe way of correcting serum sodium in patients at high risk for over correction.

- Should only be used in patients with severe hyponatremia with high risk of over correction (hypokalemia, tea and toast, volume depletion).
- ***Should not be used if they have volume overload or are symptomatic.***
- If overcorrection has *ALREADY* occurred this is termed reactive DDAVP and it is NOT a clamp.
- DDAVP Clamp is when this is done before correction has started

AJKD Paper Sood et al 2013 QI report of 25 patients

Table 3. DDAVP Clamp protocol. Not to be used in patients with volume overload or symptomatic hyponatremia.

DDAVP Clamp Protocol
Stop any maintenance fluids.
Start DDAVP 2 mcg IV q8h
Start 3% NaCl (1-1.5 ml/kg over 6 hours)
Fluid restrict patient to 1.2 liters per day
Monitor sodium every 2 hours initially. Once the sodium is rising predictably, decrease frequency to every 4-6 hours.
Adjust 3% NaCl infusion rate to achieve correction of less than 8 mmol/L per day. Try to avoid adjusting the rate more than every 6 hours. Look at the sodium trend rather than the latest value.
Continue 3% and DDAVP until the sodium is 125-130

DDAVP Clamp Protocol from Alsawah MY, Zaka A, **Topf JM**. (2021) Chapter 19: Sodium Homeostasis and Hyponatremia in the Intensive Care Unit. Handbook of Critical Care Nephrology. Editors: Koyner, Topf, Lerma.

CJASN Paper Rafat et al 2014 Observational study 20 patients

Table 4 Strategies for DDAVP Use

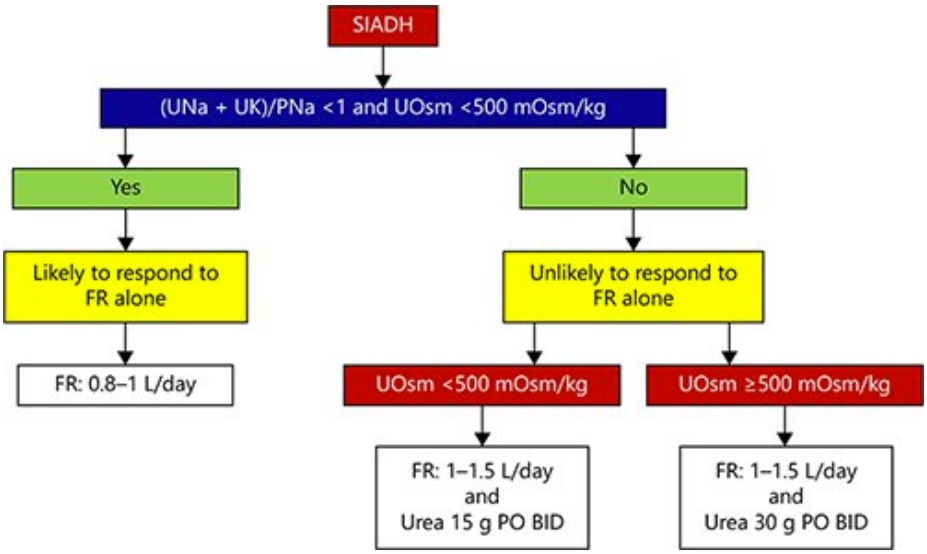
Strategy	Clinical or Biochemical Variables Prompting DDAVP Administration	Usual Co-interventions	Timing of First DDAVP Dose
Proactive	• Presenting serum sodium concentration (generally <120 mEq/L)	• Hypertonic saline infusion	• Early
Reactive	• Urine parameter change (high urine output or low urine osmolality) and/or: • Sodium parameter change (high rate of change or absolute change)	• ±Hypotonic fluids to stabilize/re-lower serum sodium concentration	• Mid
Rescue	• Sodium change (absolute change exceeding correction limit) and/or: • Neurologic symptoms of imminent osmotic demyelination syndrome	• Hypotonic fluids to stabilize/re-lower serum sodium concentration	• Late

DDAVP = desmopressin.

From MacMillan et al 2015

Urea

Oral urea is administered at a dose of 0.25–0.5 g/kg/day with usual doses of 15, 30, and 60 g/day.



From Rondon-Berrios 2020

Dosing

- Typical in-patient dosing ranges between 15-60 g/day BID
- Typical out-patient dosing ranges between 15-30g/day BID but doses of 60g/day BID are sometimes used.

Ure-Na

- lemon lime flavor
- 15 g pouches

UreaAide

- 15 g packets
- 1 lb Bag with dosing scoop
- natural mint flavor or unflavored

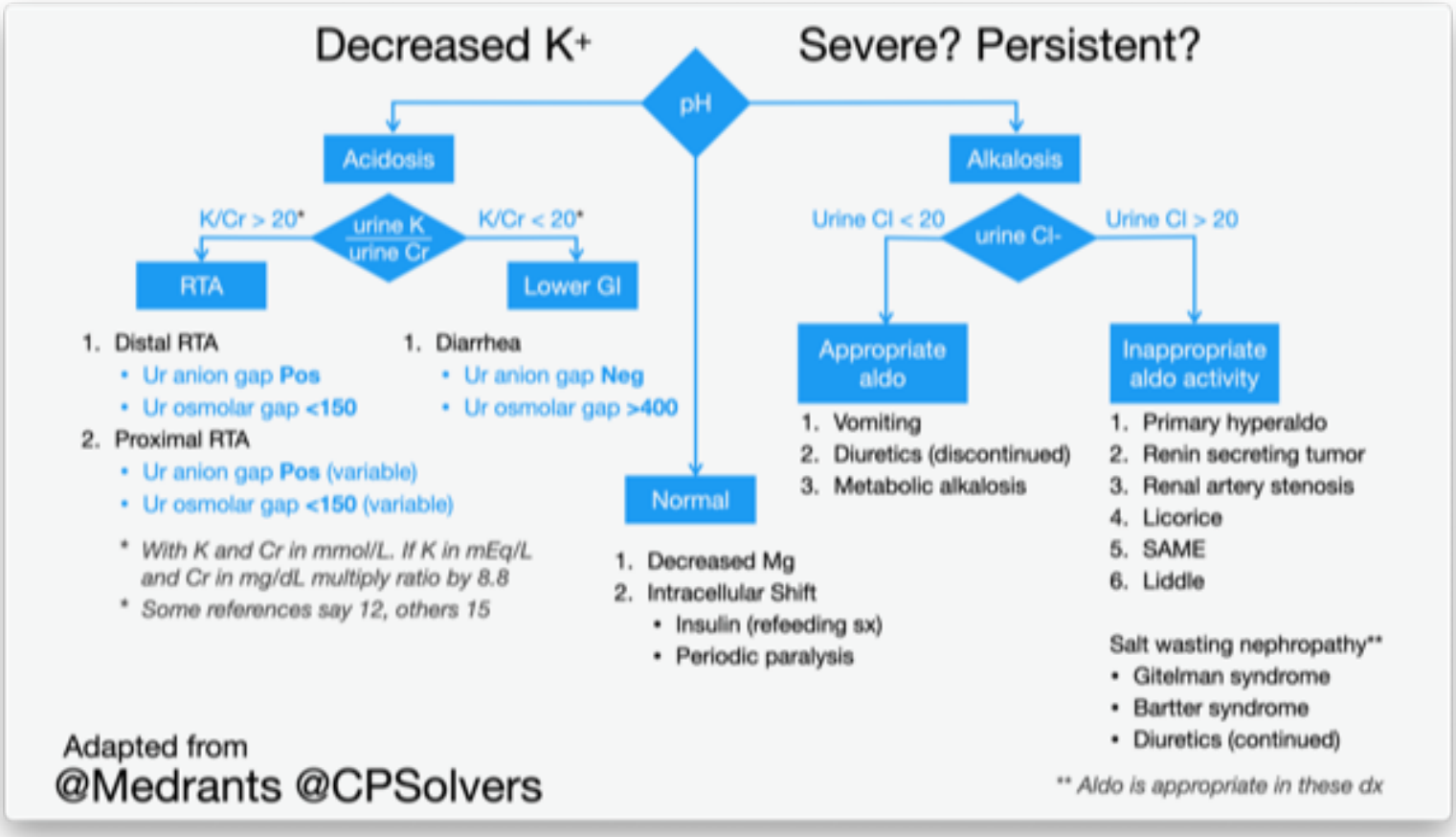
Potassium

Potassium: physiology and pathology homeostasis

Hypokalemia

Average serum potassium decreases by 0.3 mEq/L for each 100 mEq reduction in total body potassium stores. Hypokalemia can happen due to total body depletion and/or intra/extra cellular shifts.

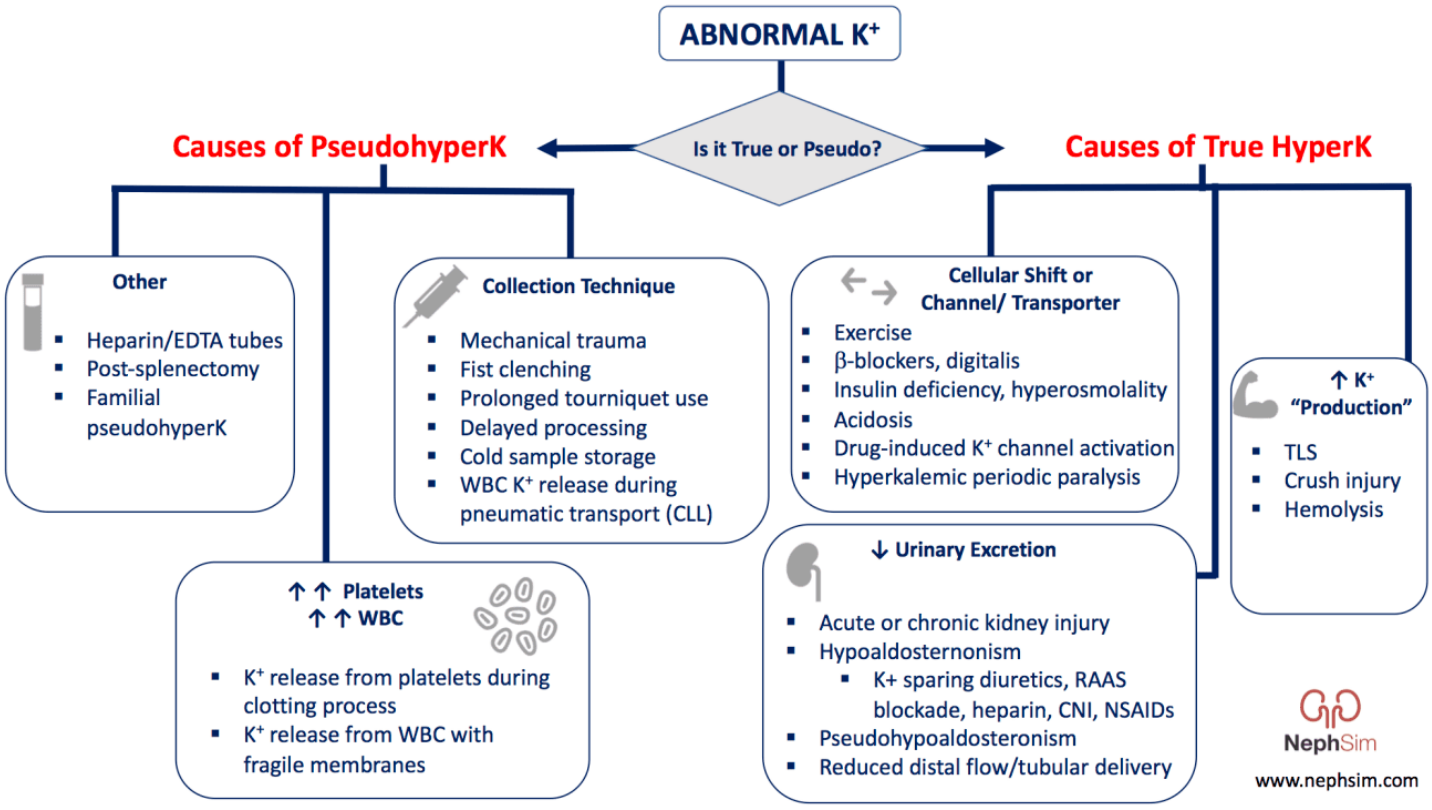
- Can administer via oral/enteral route when GI function is intact; the patient has mild ($K^+ > 3$ mEq/L) to moderate (K^+ 2.5 to 3 mEq/L) asymptomatic hypokalemia with normal kidney function.
- The recommended maximum rate of IV potassium replacement in most patients should not be more than 10 to 20 mEq of KCl per hour



from Joel Topf

Hyperkalemia

Check a nice review here: Hyperkalemia



Work up

- Assess kidney function
- is the patient urinating?
- Should treatment be IVF with Lasix?
- EKG
- Calcium gluconate or calcium chloride, 10% solution, 10 mL IV over 10 minutes can help antagonize the membrane effects of hyperkalemia on the myocardial conduction system. This effect lasts for 30 to 60 minutes.
- Nebulized albuterol 10 mg- can last 2 to 6 hours and must be followed by strategies to definitively remove potassium from the body.
- Regular insulin 10 units IV with 50% dextrose 50 mL. Dextrose is not needed if the plasma glucose is above 250 mg/dL. Always recheck the blood glucose after giving insulin.
- Pursue kidney replacement therapy when hyperkalemia is refractory to medical therapy, preferred method for rapid correction of potassium is intermittent hemodialysis.
- Oral potassium binders:
    - Patiromer (onset of action: 7 hours) dose- 8.4 to 25.2 g/day
    - Sodium zirconium cyclosilicate (onset of action:1 hour) dose- 5 to 10g/day

Hyperkalemia review

Risk of low K baths or rapid drop in K is arrhythmias so use caution with 2 and 1 K baths, do not use 0 K baths unless discussed prior with attending (review)

Review of Regulation of Potassium Homeostasis

Calcium

- For every 1 g/dL decrease of serum albumin less than 4.0 g/dL, add 0.8 mg/dL to total serum calcium
- Calcium chloride (1 gram contains 13.2 mEq or 272 mg elemental calcium): Only give in central line
- Calcium gluconate (1 gram contains 4.7 mEq or 94 mg elemental calcium) – can be given through peripheral line.
- Initially, intravenous calcium (1 to 2 g of calcium gluconate, in 50 mL of D5W) can be infused over 10 to 20 minutes for severe symptoms. The calcium should not be given more rapidly, because of the risk of serious cardiac dysfunction. This dose will raise the serum calcium concentration for only 2-3 hours; it should be followed by a slow infusion of calcium in patients with persistent hypocalcemi**a**
- 1 AMPULE Calcium Chloride = 3 AMPULES of calcium gluconate

Corrected Ca (mg/dL)	**Ionized Ca** (mmol/L)	**Infusion** (avoid in hyperphosphatemia - unless pt symptomatic)
8-8.5 (Mild, asymptomatic)	1-1.1	Oral replacement preferred 1 gm Ca gluconate IV over 60 min
7-8 (Moderate)	0.85-1.0	1-2 gm Ca gluconate IV over 60 min
< 7 (Severe)	< 0.85	3 gm Ca gluconate over 120 min and recheck lab 2 hours after. If tetany, give bolus of 1 gm in 10 min Consider calcium drip

Oral Agents:

Oral Calcium Pills	**Elemental Calcium content per pill**	**Pill Size**
Calcium carbonate	250 mg	650 mg
Calcium gluconate	90 mg	1000 mg

Calcium citrate	200 mg	950 mg
Calcium lactate	60 mg	300 mg

Treatment of CKD-MBD targeted at lowering high serum phosphate and maintaining serum calcium (KDIGO CKD-MBD 2017 Clinical Practice Guidelines)

CKD G3a–G5D

- treatment of CKD-MBD should be based on serial assessments of phosphate, calcium, and PTH levels, considered together (Not Graded).
- suggest lowering elevated phosphate levels toward the normal range (2C).
- suggest avoiding hypercalcemia (2C).
- decisions about phosphate-lowering treatment should be based on progressively or persistently elevated serum phosphate (Not Graded).
- suggest restricting the dose of calcium-based phosphate binders (2B).
- suggest limiting dietary phosphate intake in the treatment of hyperphosphatemia alone or in combination with other treatments (2D).
- reasonable to consider phosphate source (e.g., animal, vegetable, additives) in making dietary recommendations (Not Graded).

ESKD on Dialysis

- suggest using a dialysate calcium concentration between 1.25 and 1.50 mmol/l (2.5 and 3.0 mEq/l) (2C)

Treatment of abnormal PTH levels in CKD-MBD

CKD G3a–G5 not on dialysis

- the optimal PTH level is not known.
- suggest that patients with levels of intact PTH progressively rising or persistently above the upper normal limit for the assay be evaluated for modifiable factors, including hyperphosphatemia, hypocalcemia, high phosphate intake, and ***vitamin D deficiency*** (2C).
- ***suggest that calcitriol and vitamin D analogs not be routinely used*** (2C).
- ***reserve the use of calcitriol and vitamin D analogs for patients with CKD G4–G5 with severe and progressive hyperparathyroidism*** (Not Graded).

ESKD on Dialysis

- for those requiring PTH-lowering therapy, we suggest calcimimetics, calcitriol, or vitamin D analogs, or a combination of calcimimetics with calcitriol or vitamin D analogs.

Suggested Vitamin D repletion protocol (NKF KDOQI): Dose for six months duration.

- Severe: 25-Vit D < 5 ng/ml: Replete 50,000 Unit once weekly for 12 wks, then monthly

- Moderate 5-15 ng/ml: 50,000 unit weekly for 4 weeks then monthly
- Mild 16-30 ng/ml: 50,000 unit monthly

Generic Name	Biology	Trade Name	PO Dose	IV Dose	PTH	Ca2+	Phos	Comments	Cost *GoodRx /30 capsules
Cholecalciferol	Vitamin D3	Generic	600 to 800 units once daily (15-20 µg)	none	↓	↑↑	↑↑		$10
Ergocalciferol	Vitamin D2	Calcidol	600 to 800 units once daily (15-20 µg)	none	↓	↑↑	↑↑		$10
Calcitriol	1,25-dihydroxyvitamin D3	Vectical and Rocaltrol	0.25 - 1 µg once daily	0.5 - 4 µg per dialysis session	↓↓	↑↑	↑		$10
Alfacalcidol	1,25-dihydroxyvitamin D3	Generic	0.5 µg - 1 µg daily	1 µg - 4 µg per dialysis	↓↓	↑↑	↑↑		$20
Paricalcitol	Synthetic vitamin D2 analogue, 19-nor-1, 25(OH)2D2	Zemplar	1 µg daily 2 µg QOD	0.04- 0.1 µg/kg (4-10 µg for 100 kg person) µg-IV per dialysis session Conversion-hecterol x2	↓↓↓	Minimal ↑	Minimal ↑	Does not induce Vit D receptor in gut, thus less Phos and Calcium absorption	$40 $400 per 25 ml of 5 mcg/ml
Doxercalciferol	synthetic vitamin D2 analogue that undergoes metabolic activation *in vivo* to form 1alpha,25-dihydroxyvitamin D2	Hecterol	1 µg - 3.5 µg daily	4 µg IV per dialysis session max is 20 µg per session Conversion-Zemplar/2	↓↓↓	↑↑	↑↑		$100 $400 per 100 ml of 2 mcg/ml

Management post parathyroidectomy (Dr. Sidney Kobrin's protocol: University of Pennsylvania)

Preoperative

- If the serum calcium is < 11, consider administering 2-3 micrograms of calcijex (calcitriol) with HD or administer 1 microgram of oral calciltriol (rocaltrol) daily for 3-5 days prior to surgery.
- Stop sensipar (cinacalcet).

Postoperative

- Check the serum calcium every 8 hours for the first 2 post-op days
- Keep intravenous calcium on standby
- Administered promptly if the patient develops tetany, latent tetany (Positive Chvostek or Trouseau sign) OR a serum calcium less than 7.5 mg/dl.
- Ask pharmacy to add 10 ampules of calcium gluconate to 1L of D5W. This will make a concentration of 940 mg of calcium/1L of fluid.
- Start calcium infusion at a rate of 1.0 ml/Kg (use ideal body wt) per hour, monitor and titrate. Patients typically require 0.5 to 1.5 mg/kg of elemental calcium per hour. Ensure patient does not get volume overloaded.

- As soon as the patient can swallow, administer oral calcium (calcium carbonate at a dose of 1 gram of *elemental calcium (which is about 2 gm calcium carbonate)* 3 times per day between meals.
- Also, administer oral rocaltrol at a dose of 2 micrograms twice daily. NOTE: patients on hemodialysis patients should also receive at least 2 micrograms of calcijex at each dialysis treatment while the calcium level is < 10.5.
- Increase the rocaltrol and calcium by 25% each day if the serum calcium is below 8.5.
- Decrease the oral calcium and rocaltrol by 25% if the serum calcium is > 10.3.
- For patients on hemodialysis who have persistent hypocalcemia, consider using a higher calcium dialysate. For patients on PD patients, consider using a high calcium dialysate and/or adding 1-3 ampules of calcium gluconate to each exchange.

Calcium Infusion: If using central line:

- If total Ca < 8.5 give 5 amps of CaCl + 250 cc D5W at 8 cc/hr
- If Ca 7.5-8 give 5 amps of CaCl + 250 cc D5W at 16 cc/hr
- If Ca < 7.5 give 5 amps of CaCl + 250 cc D5W at 20 cc/hr

Magnesium

PO replacement is preferred in asymptomatic patients able to tolerate

- Magnesium oxide 400 mg to 800 mg TID
- Slow Mg: less Diarrhea, however, less Mg too.
- Oral dose: 20-50 percent absorbed
- Cathartic dose: 80-160 mEq/day

IV replacement is with 1 g MgSO4 in 100 cc IV solution given over 60 minutes

- 1.5-1.9 mg/dL 1 gram MgSO4 IV over 60 minutes
- 1.2-1.4 mg/dL 2 grams MgSO4 IV over 120 minutes
- 0.8-1.1 mg/dL 3 grams MgSO4 IV over 120 minutes; and 4 hours after replacement, check serum Mg level

Preparations

Product	Amount needed to get 40 meq/day
Mg Oxide 400 mg	2 tablets
Mg Gluconate 500 mg	17 tablets

Mg Chloride(slow-Mag) 535 mg	7.5 tablets
Mg Hydroxide-1200 mg/15ml 500 mg/15ml	15 ml

Phosphate

Phosphorus vs Phosphate

Comparison Table

Characteristics	Phosphorus	Phosphate
Definition	A multi-valent nonmetal chemical element of the VA group.	A chemical derivative of the phosphoric acid, containing the phosphate ion (PO^{3-}_4).
Molar mass	30.97 g/mol	94.97 g/mol
Chemical formula	The symbol of phosphorus is P.	The chemical formula of the phosphate ion is PO_4.
Structure	Phosphorus forms several simple substances, the most widely distributed are white phosphorus, consisting of P_4 molecules, and red phosphorus, which has a crystal atomic lattice.	The phosphate ion is a polyatomic ion with a tetrahedral arrangement of the atoms. It consists of one phosphorus atom, located in the center and surrounded by four oxygen atoms.
Oxidation degree	–3, +3 or +5	–3
Forms/Types	· White phosphorus; · Red phosphorus, etc.	· Orthophosphates; · Pyrophosphates; · Tripolyphosphates; · Polyphosphates

DB Difference Between.net

From difference between

Intravenous repletion:

Phos (mg/dl)	Treatment

< 1.0	30 mmol Na Phos IV over 6 hrs
1-1.5	15 mmol Na Phos IV over 4-6 hrs
1.5-2	Oral Neutra-Phos 1-2 packet q8 hrs 1 cup skim milk q8 hrs 15 mmol Na Phos IV over 4-6 hrs

Give slow infusion to prevent phlebitis

Consider potassium phosphate if patient's potassium low.

Oral Dosage:

- K-Phos Neutral 250 mg Tablet: 1 Tablet TID
- Neutral Phos: Mix one Package in 75 ml TID
- Neutral Phos K: Mix one Package in 75 ml TID

Phosphate Preparation	Phosphorus Content	K content per pill	Na content per pill
K-phos Neutral	250 mg = 8 mmol	1.1 mEq	13.1 mEq
Neutra-Phos	250 mg	7.1 mEq	7.1 mEq
Neutra-Phos K	250 mg	14.2 mEq	0

Review of Calcium, Phosphate, and Magnesium Homeostasis:

EKG changes associated with electrolyte imbalances