

Electrolyte Replacement Therapy

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Lecture 6

- Identify when electrolyte replacement is needed and underlying cause
 - Potassium, Magnesium, Calcium, Phosphorous
- Understand different formulations, route, dosage and adverse effects of replacement
- Identify when goal replacement has been achieved
- Identify when maintenance therapy may be required

Hypokalemia

- Usually secondary to:
 - GI loss (vomiting, diarrhea)
 - Urinary losses (diuretics)

Also think about : co-existing electrolyte abnormality (hypomagnesemia), hyperaldosteronism, insulin therapy, alkalosis)

- Indications for replacement:
 - Evidence of potassium loss
 - Significant deficit in body potassium
 - Acute therapy in redistributive disorders (periodic paralysis, thyrotoxicosis)

- Symptoms: usually manifest when serum K <3.0
 - Muscle weakness (K <2.5), cramps
 - Respiratory muscle weakness
 - GI symptoms: anorexia, nausea, vomiting
 - Cardiac arrhythmias: atrial tachycardia, junctional tachycardia, AV block, ventricular tachycardia or fibrillation
 - sinus bradycardia, ST segment depression, decreased amplitude of T-wave, increased amplitude of U-wave.
 - If prolonged hypokalemia: functional changes in the kidney and **glucose intolerance**

Therapy

- Calculate potassium deficit (if normal distribution is present)
 - Acute: 0.27meq/L decrease in serum K⁺ for every 100meq reduction in total potassium stores
 - Chronic: 1meq/L decrease in serum K⁺ for every 200-400meq reduction in total potassium stores

Simplified:

$$\frac{\text{Goal K} - \text{Serum K}}{\text{serum Cr}} \times 100 = \text{total meq K required}$$

10meq of KCL will raise the serum K by ~.1meq/L

Formulations

- **Potassium Chloride : PREFERRED AGENT**
 - Most patients with hypokalemia and acidosis are also chloride depleted
 - Raises serum potassium at a faster rate
 - Available as liquid, slow release tablet or capsule, and IV
 - **Oral: 40meq tid-qid; IV 10meq/hr- 20meq/hr**
- **Potassium Bicarbonate/Citrate/Acetate:**
 - can be used in patients with hypokalemia and metabolic acidosis
- **Potassium Phosphate:**
 - Rarely used (Fanconi syndrome with phosphate wasting)

Ongoing Losses

- In general, use oral therapy
- KCL with normal or elevated serum bicarb
- Potassium citrate/acetate/bicarbonate in presence of acidosis (diarrhea)
- no need for continued supplementation with chronic renal potassium wasting (potassium sparing diuretic is more effective):
 - Chronic diuretic therapy
 - Primary aldosteronism

Adverse Effects

- Hyperkalemia
- Potassium is osmotically active- can increase tonicity of IV fluids
- Oral therapy- pills are large, can be difficult to swallow
- Peripheral IV therapy:
 - Pain
 - Phlebitis

Make sure to recheck serum potassium 2-4 hours later to assess response to therapy

Goal of Therapy

- Prevent life threatening complications
- Urgency of replacement depends on severity, rate of decline and co-morbid conditions
 - Elderly
 - underlying heart disease
 - on digoxin or anti-arrhythmic drugs

Example

- 72 year old female admitted for weakness and dehydration due to acute gastroenteritis. She is having up to 6 BM/day. Her serum K on admission is 2.5 meq and serum Cr is 2.0. EKG reveals u-waves.

1. How much potassium do you order?

$$\frac{4-2.5}{2} \times 100 = 75\text{meq}$$

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2. What formulation do you choose?

KCL; if bicarb is low then consider potassium bicarb or acetate

3. What route should the potassium be administered?

40meq (initial) oral and 40meq IV; (re-assess 2-4 hours later and give more orally if needed and tolerating po)

3. Serum potassium remains low, what else could be contributing?

Low magnesium, ongoing diarrhea

Hypomagnesemia

- Average daily intake: 360mg
- Presence of low magnesium (nearly 12% of hospitalized patients) suspected in following cases:
 - Chronic diarrhea
 - Hypocalcemia
 - Refractory hypokalemia
 - Ventricular arrhythmias
- Symptoms/Signs :
 - Tetany (seizures in children/neonates)
 - Hypokalemia
 - Hypoparathyroidism → hypocalcemia (<1.2mg/dL)
 - Vitamin D deficiency (due to low calcitriol)
 - EKG changes: widened QRS, peaked T-waves, → diminution, PR interval prolongation,
 - Ventricular arrhythmias (especially during ischemia or bypass)

Therapy

- **IV if symptomatic (magnesium sulfate)**
 - 1.5-1.9mg/dL → 2g magnesium sulfate IV
 - 1.2-1.4mg/dL → 4g
 - .8-1.1mg/dL → 6g
 - <.8mg/dL → 8g
 - **Low K/Ca w/ tetany/arrhythmia: 50meq (~6g) of IV Mg given slowly over 8-24 hrs**
- **Oral if asymptomatic:** each tablet contains 60-84mg, give 2-4 tabs/day in mild cases, 6-8 tabs for severe depletion
 - Slow Mag (magnesium chloride)
 - Mag-Tab SR (magnesium lactate)
 - Magnesium Oxide**
- **Avoid replacement in patients with reduced GFR**
- **Treat underlying disease** (diuretics, alcohol, uncontrolled diabetes)

Therapy

- Goal of therapy:

- maintain plasma magnesium concentration over 1.0mg/dL acutely in symptomatic patients
- In cardiac patients, maintain Mg >1.7 (usually goal 2.0mg/dL) to avoid arrhythmias
- Serum levels are poor reflection of actual body stores (mostly intracellular) so aim for high-normal serum level

- Adverse effects:

- Abrupt elevation of plasma Mg can remove the stimulus for Mg retention and lead to increased excretion
- Diarrhea
- Drug interactions
- Magnesium intoxication

Hypocalcemia

- **Clinical Manifestations:**
 - **Acute:** serum Ca <7.5mg/dL
 - Neurologic: tetany (from paresthesias to seizures and bronchospasm)
 - Cardiac: prolonged QT, hypotension, heart failure, arrhythmia
 - Papilledema
 - Psychiatric manifestations
 - **Chronic:**
 - EPS, dementia, cataracts, dry skin
- **Etiology:**
 - Vitamin D
 - PTH
 - Hypomagnesemia
 - Drugs

Therapy

- **Correct for albumin**
 - Ca lower by 0.8mg/dL for every 1g/dL reduction in serum albumin
 - or check ionized calcium
- **Level can be altered by acid/base disturbance**
- **Symptomatic or acute serum Ca <7.5mg/dL:**
 - **IV Calcium gluconate 1-2g(amp) over 10-20min** (temporary rise for 2-3 hrs, must be followed by slower infusion 50mL/hr if Ca remains low)
- **Asymptomatic and serum Ca >7.5mg/dL or chronic:**
 - **Oral therapy: calcium carbonate or citrate 1-2g/day (500mg bid-qid)**
- **Add Vitamin D in following cases:**
 - Hypoparathyroidism: **Vitamin D (Calcitriol .25-.5mcg bid)**
 - Vitamin D deficiency: 50,000IU/week for 6-8 weeks then 800-1000IU daily
 - Ergocalciferol (D3)
 - Cholecalciferol (D2)

Therapy

- Goals of therapy:

- Treat and prevent manifestations of hypocalcemia
- In hypoparathyroidism: to raise serum Ca to low-normal range (8.0-8.5mg/dL)

- Adverse Effects:

- Rapid infusion- bradycardia, hypotension
- Extravasation- tissue necrosis
- Hypercalcemia
- Hypercalciuria
- Constipation
- Hypophosphatemia
- Milk-alkali syndrome

Example

35 y/o male with hypoparathyroidism , presents with serum Ca of 6.2, albumin of 3.8, ionized Ca .77. Has some mild muscle cramps, otherwise asymptomatic.

1. How do you initially treat his hypocalcemia?
 - IV Calcium Gluconate 1g IV over 10-20min
2. Repeat serum Ca is 6.6, how do you proceed with treatment?
 - start Calcium gluconate 1mg/mL in D5W 50mL/hr infusion
2. After initial treatment, what maintenance regimen should you initiate?
 - Calcitriol (.5mcg bid, titrated up in this patient)
 - Calcium carbonate (1950mg po tid in this patient)

Hypophosphatemia

- **Due to:**
 - Redistribution
 - Decreased intestinal absorption (small bowel)
 - Increased urinary excretion

- **Common situations:**
 - Chronic alcoholism
 - IV hyperalimentation w/o phosphate supplementation
 - Refeeding syndrome
 - “Hungry Bone” syndrome
 - Respiratory alkalosis (hyperventilation)
 - Chronic ingestion of antacids (containing aluminum or Mg)
 - Hyperparathyroidism (primary or secondary)
 - Vitamin D deficiency
 - Fanconi syndrome (associated with multiple myeloma in adults)

Hypophosphatemia

- **Signs/Symptoms:** <2.0mg/dL, severe usually when serum PO₄ <1.0mg/dL

Acute:

- Metabolic encephalopathy- irritability, paresthesias → confusion, seizure, coma
- Respiratory failure due to weakened diaphragm
- Reduction in cardiac output leading to heart failure
- Proximal myopathy, dysphagia, ileus
- Elevated CPK, rhabdomyolysis
- Coagulopathy with thrombocytopenia

Chronic:

- Hypercalciuria
- Increased bone resorption: Osteomalacia, Ricketts

Treatment

- Usually aimed at treating the underlying cause (resolution of diarrhea, Vit D therapy, d/c antacid, etc.)
- If tx is needed, oral therapy is preferred
 - Asymptomatic, serum PO₄ <2.0mg/dL or symptomatic with serum PO₄ 1.0-1.9mg/dL
 - Available as tablet and powder/packets (sodium phosphate, potassium phosphate) 250-500mg tid-qid (w/ meals) over 24 hours
 - Decrease dose by one-half in patients with reduced GFR
 - Increase dose in severely obese patients
 - Recheck after 12 hours to determine if additional/continued supplementation is required

Treatment

- IV therapy if symptomatic and serum PO₄ <1.0mg/dL
 - sodium phosphate is preferred
 - Weight based
 - PO₄ >1.3mg/dL: .08-.24mmol/kg over 6 hours
 - PO₄ <1.3mg/dL: .25mmol-.05/kg over 8-12 hours
 - Increased dosage for critically ill patients in ICU
 - Frequent monitoring- recheck levels every 6 hours
 - Switch to oral when patient able or serum PO₄ >1.5mg/dL
- Goal of therapy: increase serum PO₄ to 2.0mg/dL
- Side effects of therapy:
 - Oral: Diarrhea, nausea, hyperkalemia (K-phos)
 - IV: Hyperphosphatemia → hypocalcemia, AKI, arrhythmia
- Maintenance therapy is not usually required

	Preferred Route	Preferred Formulation	Dosage	Response
Potassium	Oral	Potassium Chloride	10meq tabs	.1 increase serum K for 10meq given
Magnesium	Oral	Magnesium Oxide	2-4 tabs/day (420mg; 20meq/tab)	.5 increase for 2g (50meq) IV
	IV- arrhythmia	Magnesium Sulfate	2g IVP or slow infusion	
Calcium	IV- acute	Calcium Gluconate	1-2amp (rapid) 1mg/mL in D5W, 50mL/hr Infusion	.5mg/dL increase serum Ca for 1g given
	Oral- maintenance	Calcium Carbonate	1-2g/day	
Phosphate	Oral	Sodium Phosphate (neutra-phos)	1-2 packet tid-qid 1packet=250mg or 8mmol (weight based)	1.2mg/dL increase serum PO4