Calcium and Phosphorus Disorders: Student Handout

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Calcium and Phosphorus Disorders: A Student Guide

Learning Objectives

- Understand the calcium-phosphorus-PTH-vitamin D axis
- Recognize normal values and severity classifications
- Interpret PTH levels in calcium disorders
- Understand the kidney's central role in regulation
- Manage acute and chronic mineral disorders

Physiologic Overview

Normal Values

- **Calcium:** 8.5-10.5 mg/dL (ionized: 4.5-5.5 mg/dL)
- **Phosphate:** 2.5-4.5 mg/dL
- **PTH:** 10-65 pg/mL
- **1,25-vitamin D:** 25-65 pg/mL

The Regulatory Axis

Three hormones control calcium-phosphorus balance:

1. **PTH** (parathyroid hormone)
    - Released when calcium drops
    - Increases calcium, decreases phosphate
    - Acts on kidneys and bone
2. **Vitamin D** (1,25-dihydroxyvitamin D)
    - Active form made in kidneys
    - Increases intestinal calcium absorption
    - Increases phosphate absorption
    - Inhibited by PTH and FGF23
3. **FGF23** (fibroblast growth factor 23)
    - Released when phosphate rises
    - Promotes phosphate excretion
    - Inhibits vitamin D activation

Hypocalcemia (Calcium <8.5 mg/dL)

Causes

Low PTH: - Surgical removal (thyroidectomy, parathyroidectomy) - Autoimmune destruction - Infiltrative disease

High PTH (secondary hyperparathyroidism): - Vitamin D deficiency - Chronic kidney disease - Vitamin D-dependent rickets

PTH Resistance: - Chronic kidney disease (most common) - Pseudohypoparathyroidism (genetic)

Clinical Features

- Paresthesias (lips, fingers)
- Muscle cramps, tetany
- Chvostek sign (tap cheek ☐ twitch), Trousseau sign (BP cuff ☐ spasm)
- Seizures (severe)
- Cardiac: QT prolongation, arrhythmias

Management

Acute symptomatic: - IV calcium gluconate 10% 1-2 ampules in 50-100mL saline over 10-20 minutes - Monitor for overcorrection, extravasation risk - **Check magnesium** first—hypomagnesemia prevents calcium correction

Chronic: - Calcium supplements 1-3g daily + active vitamin D - Vitamin D deficiency: 50,000 IU weekly × 8 weeks, then maintenance - Hypomagnesemia replacement (magnesium citrate 400-800mg daily)

Hypercalcemia (Calcium >10.5 mg/dL)

Two Main Causes

PTH-mediated (30%): - Primary hyperparathyroidism (85% from adenoma) - Malignancy-related hyperparathyroidism

Non-PTH-mediated (70%): - Malignancy (PTHrP secretion, osteolytic lesions) - Vitamin D intoxication - Granulomatous disease (sarcoidosis, TB) - Thyroid toxicosis

Clinical Features

- Neuropsychiatric: confusion, lethargy, coma
- GI: nausea, anorexia, constipation
- Renal: polyuria, nephrolithiasis
- Cardiac: shortened QT, arrhythmias
- **"Stones, bones, groans, psychiatric overtones"**

Diagnostic Approach

1. **Check PTH first**

- High/normal PTH ☐ primary hyperparathyroidism or lithium
- Suppressed PTH ☐ check PTHrP, vitamin D levels

2. **PTHrP level** (if PTH suppressed)
   - Elevated ☐ malignancy
3. **Vitamin D level** (if PTH suppressed)
   - Elevated 1,25-D ☐ granulomatous disease
   - Elevated 25-D ☐ vitamin D intoxication

Management

Acute severe (>14 mg/dL or symptomatic): 1. **IV hydration:** 200-300 mL/hour normal saline (removes calcium in urine) 2. **Bisphosphonate:** - Zoledronic acid 4mg IV over 15 minutes (preferred) - Effect in 2-4 days, lasts 3-4 weeks 3. **Calcitonin:** 4-8 IU/kg every 6-12 hours (rapid but short-lived, for bridge) 4. **Dialysis:** For renal failure or unresponsive cases

Chronic (asymptomatic hyperparathyroidism): - Surgery (parathyroidectomy) = definitive treatment - Medical: bisphosphonates improve bone density; cinacalcet lowers calcium

Hyperphosphatemia (Phosphate >4.5 mg/dL)

Most Common Cause: Chronic Kidney Disease

In CKD: - Kidneys can't excrete phosphate - FGF23 rises (tries to compensate) - PTH rises (secondary hyperparathyroidism) - Calcium drops (phosphate binds calcium)

Clinical Consequences

- Vascular calcification (reduces lifespan)
- Secondary hyperparathyroidism
- Renal osteodystrophy (bone disease)
- Cardiac events

Management in CKD

Dietary restriction: - Target <800-1000 mg/day - Avoid: seeds, nuts, processed cheese, dairy (high phosphate density)

Phosphate binders (with meals): - **Calcium-based** (calcium acetate): cheap, but avoid if hypercalcemic - **Non-calcium-based:** sevelamer, lanthanum, iron-based (newer) - Bind dietary phosphate ☐ reduced absorption

Novel agents: - Tenapanor: blocks intestinal phosphate absorption (new) - Nicotinamide: reduces phosphate reabsorption

Hypophosphatemia (Phosphate <2.5 mg/dL)

Causes

Intracellular shift: - Refeeding syndrome (biggest acute risk) - Insulin administration - Alkalosis

Renal losses: - Diuretics, steroids - Primary hyperparathyroidism - FGF23-mediated (X-linked hypophosphatemia)

GI losses: - Malabsorption, diarrhea, short bowel - Phosphate binders overuse

Clinical Features

- Rhabdomyolysis (muscle breaks down)
- Hemolytic anemia (RBC dysfunction)
- Respiratory depression (weak respiratory muscles)
- Decreased WBC function (infection risk)

Management

Severe symptomatic (<1.0 mg/dL): - IV phosphate: 0.08-0.16 mmol/kg over 6 hours - Monitor for hypocalcemia (phosphate binds calcium) - Central line preferred (caustic)

Moderate (1.0-2.0): - Oral phosphate supplements: 250-500 mg TID-QID - Monitor calcium (may need to supplement)

Mild: - Dietary sources (meat, dairy, eggs) - Discontinue phosphate binders

Special Scenario: Refeeding Syndrome

What is it? Severe electrolyte shifts when malnourished patient receives nutrients

Phosphate specifically: - Cells take up phosphate for ATP synthesis - Serum phosphate DROPS precipitously - Can cause rhabdomyolysis, respiratory failure, death

Prevention: - Start nutrition slowly - Monitor phosphate, potassium, magnesium daily - Supplement phosphate, K, Mg pre-emptively

Practice Questions

Q1: A 65-year-old with recent thyroidectomy has ionized calcium 3.8 mg/dL and is tingling around lips. Magnesium is 1.2 (low). What's your priority?

Answer

The patient needs magnesium FIRST before calcium will work. Give magnesium 2-4g IV, then reassess. If calcium doesn't improve after magnesium correction, give IV calcium gluconate. Hypomagnesemia prevents PTH release and causes PTH resistance—you can't correct calcium until Mg^{2+} is normal.

Q2: A 58-year-old with lung cancer has calcium 13.2 and PTH is suppressed. What test distinguishes between PTHrP hypercalcemia and vitamin D intoxication?

Answer

Check PTHrP level (elevated in malignancy) and 1,25-vitamin D level (elevated in granulomatous disease or vitamin D intoxication). Lung cancer usually causes PTHrP-mediated hypercalcemia. Treatment: hydration, bisphosphonate, and treat underlying cancer.

Q3: A 42-year-old with CKD stage 4 has phosphate 5.8 and PTH 280 (high). He won't eat less dairy. What's your management?

Answer

He needs phosphate binders taken with meals. Calcium-based acetate can help, but non-calcium alternatives (sevelamer, lanthanum) are preferable given his rising PTH. Ensure adequate vitamin D (may need calcitriol). Dietary counseling on high-phosphate foods remains important—aim for <1000 mg/day.

Key Takeaways

- **Always check PTH** to distinguish primary from secondary hyperparathyroidism
- **Magnesium must be corrected** before calcium will normalize
- **CKD causes secondary hyperparathyroidism** via phosphate retention and vitamin D loss
- **Vitamin D deficiency is common** (>1 billion people affected)
- **Refeeding syndrome = severe hypophosphatemia risk** ☐ start nutrition slowly
- **Bisphosphonates take 2-4 days** to work (need calcitonin for bridge therapy)
- **PTHrP assay** distinguishes malignancy from primary hyperparathyroidism
- **Phosphate binders work best with meals** ☐ timing matters

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Study tip: Draw the "calcium-phosphorus seesaw"—when one goes up, the other tends down. Remember PTH and vitamin D both push calcium UP and phosphate DOWN.

See Also

Related Student Handouts

- Hypercalcemia Management
- CKD Complications
- CKD Nutrition and Dietary Management

Clinical Content (01-Clinical-Medicine/Nephrology)

- Electrolyte Disorders Hub
- CKD Hub - Full Clinical Reference
- Essential Renal Laboratory Tests

Butler-COM Resources

- Butler COM - Nephrology Deep Dive

Clinical Resources

- Clinical Review: Calcium Phosphate Review — Comprehensive clinical review with PubMed references

- Clinical Review: Phosphorus Management Clinical Report — Comprehensive clinical review with PubMed references