Calcium and Parathyroid

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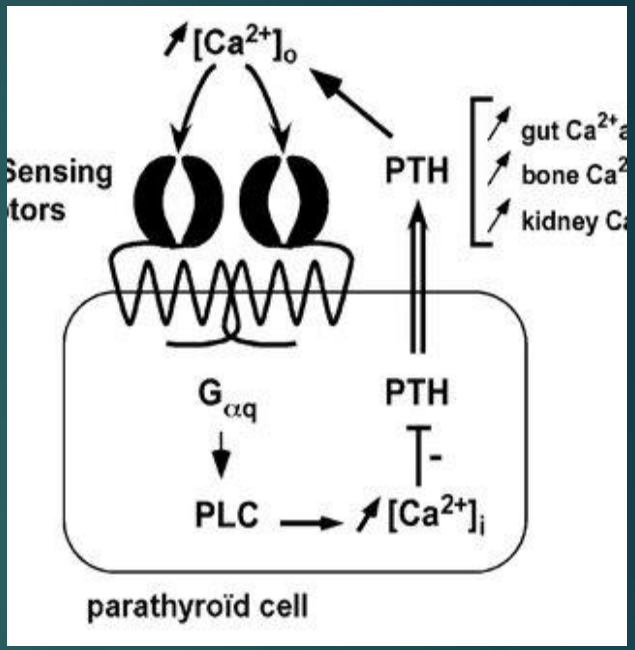
PTH regulation

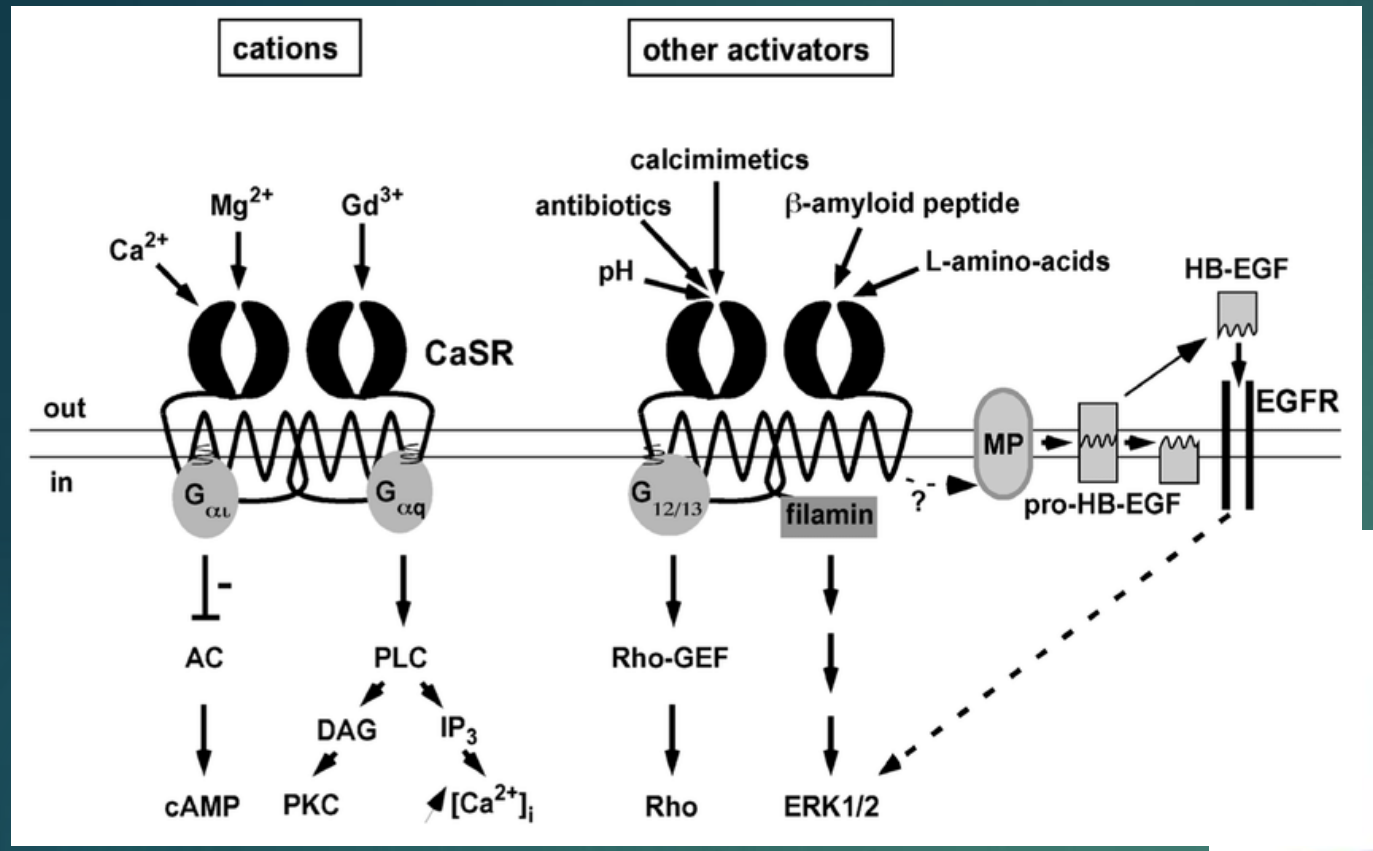
- The parathyroid gland senses the concentration of **extracellular ionized calcium** through a **cell-surface calcium-sensing receptor (CaSR**) for which calcium is an agonist
- CaSR:
  - **thyroid C** cells, which secrete CT in direct relationship to extracellular calcium
  - the **distal nephron** of the kidney, where calcium excretion is regulated
  - the **placenta**, where fetal-maternal calcium fluxes occur
  - the **brain** ?
  - **gastrointestinal** (GI) tract
  - **bone** cells

- Genetic and functional disorders of the CaSR have been described:
  - Activating defects cause hypocalcemia
  - Inactivating defects cause hypercalcemia

Secretory Regulation Of Parathyroid Hormone And The Calcium Sensor

- The major regulatory signal for PTH secretion is **ionized serum calcium**
- **Serum calcium inversely affects PTH secretion**
  - An increase in ionized calcium inhibits PTH secretion by increasing intracellular calcium through the release of calcium from intracellular stores and the influx of extracellular calcium through cell membranes and channels
- Serum calcium also inversely regulates transcription of the **PTH gene**
- Increased levels of 1,25-dihydroxyvitamin D inhibit **PTH gene transcription**




cations
other activators
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β-amyloid peptide
pH
L-amino-acids
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EGFR
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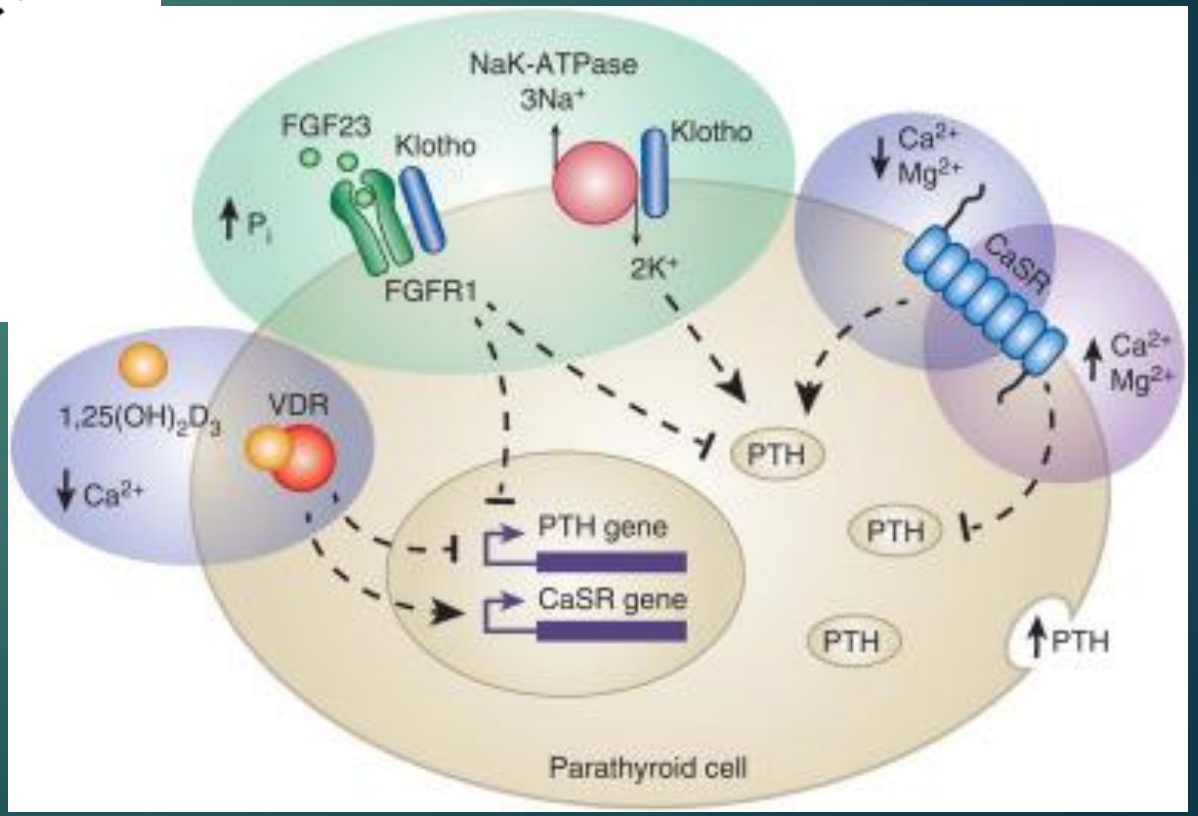
NaK-ATPase
3Na+
FGF23
Klotho
Klotho
Ca2+
Mg2+
Pi
CaSR
FGFR1
2K+
Ca2+
Mg2+
1,25(OH)2D3
VDR
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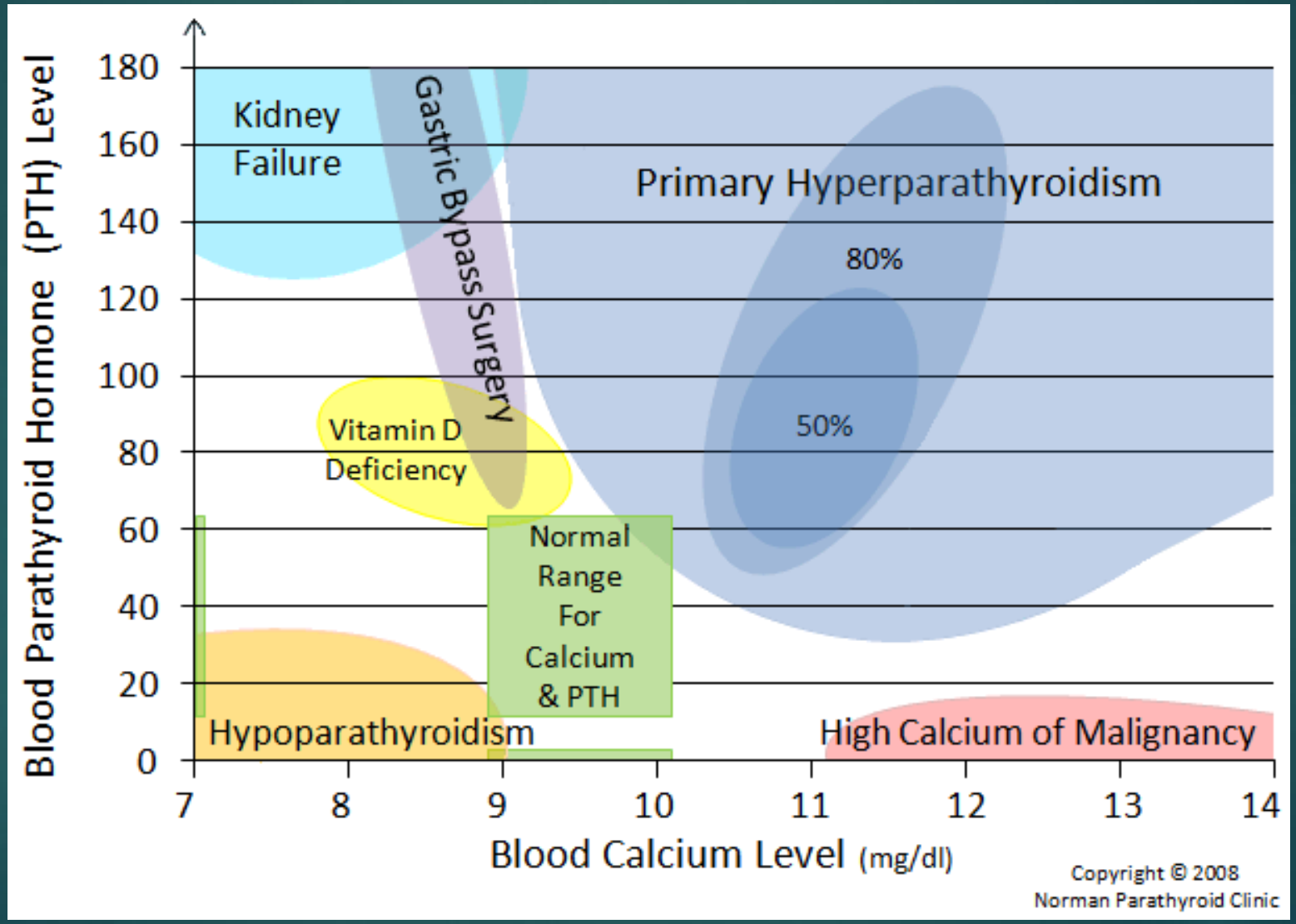
PTH
PTH gene
CaSR gene
PTH
PTH
PTH
Parathyroid cell

Secretory Regulation Of Parathyroid Hormone And The Calcium Sensor



PTH regulation

- **Intracellular magnesium may serve this secretory function in the parathyroids**
  - **Hypermagnesemia can inhibit PTH secretion**
  - **Hypomagnesemia can stimulate PTH secretion**
  - Prolonged depletion of magnesium will inhibit PTH biosynthesis and secretion
  - Hypomagnesemia also attenuates the biological effect of PTH by interfering with its signal transduction

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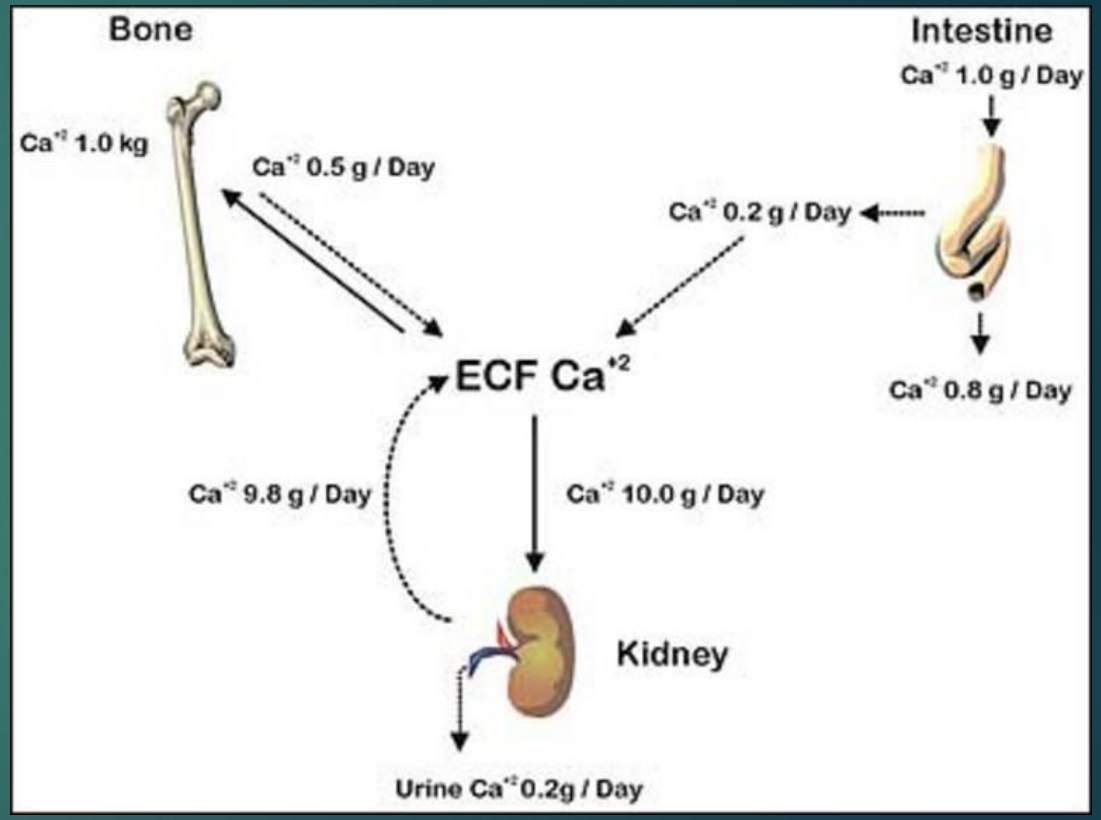
Why Mg levels

Biologic Effects Of Parathyroid Hormone

- PTH regulates serum **calcium and phosphorus** concentrations through receptors on **bone, intestine, and kidney**

- **Direct GI** effect of PTH on intestinal calcium or phosphate absorption **is weak**
- PTH stimulates **renal production of 1,25-D → absorption of Ca and phos**



Biologic Effects Of Parathyroid Hormone

- The **skeletal effects** of PTH are mediated through the **osteoblast**
  - Osteoblast cells express **PTH receptors**
  - Osteoblasts communicate with osteoclasts through the **RANK-OPG pathway**

- "**continuous**" High levels of PTH increase osteoclastic bone **resorption**
- Low levels, especially if delivered **episodically**, seem to increase osteoblastic **bone formation**

Biologic Effects Of Parathyroid Hormone

- PTH causes hypercalcemia and hypophosphatemia

- In the kidney, PTH:
  - increases the reabsorption of calcium, in the distal convoluted tubule
  - inhibits the reabsorption of phosphate in the renal proximal tubule

Biologic Effects Of Parathyroid Hormone

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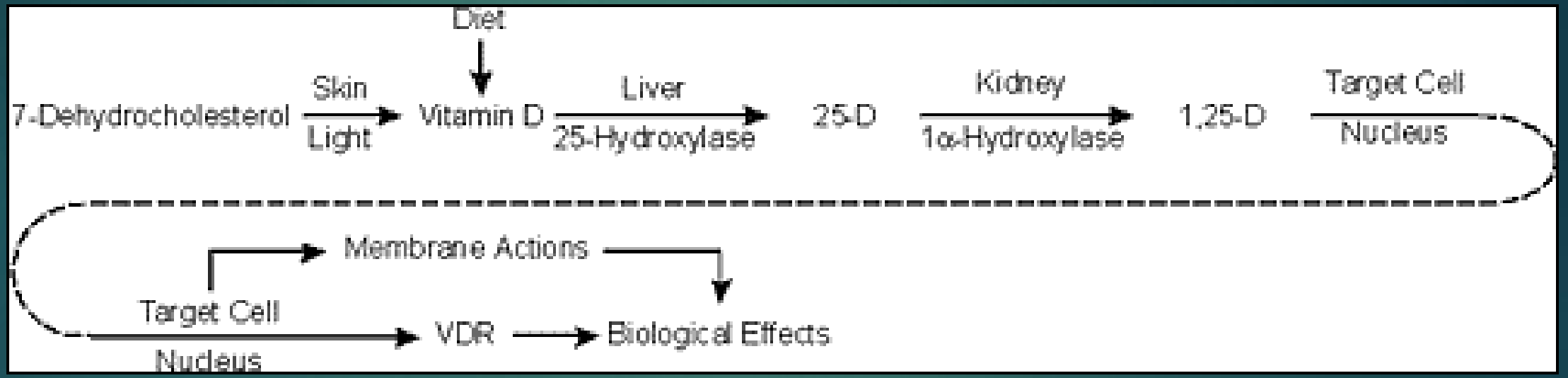
Why Phos levels

VITAMIN D

- Endogenous (vitamin D3)
  - Cholecalciferol (vitamin D3), is synthesized in the skin from the cholesterol under the influence of UV radiation
  - D3 is also available in oral supplements
- Exogenous (vitamin D2)
  - Ergocalciferol is produced by UV irradiation of the plant sterol ergosterol
  - Available through the diet

VITAMIN D

- **Metabolism and Activation**



Effects of 1,25-dihydroxy Vitamin D on Mineral Metabolism

- **Bone**
  - Promotes **mineralization of osteoid**
  - **Increases resorption at high doses**
- **Kidney**
  - Decreases calcium excretion
  - Decreases phosphorus excretion
- **GI Tract**
  - Increases calcium absorption
  - Increases phosphorus absorption
- **Blood**
  - **Increases calcium**
  - **Increases phosphorus**

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  - Increas
  -
- **Bloo**
  - **I** **alcium**
  - **Increases phosphorus**

Why Vit D levels

Total vs. Ionized Calcium

- Calcium in the blood is
  - bound to plasma proteins (~45%), notably albumin
  - bound to small anions such as phosphate and citrate (~10%)
  - free or ionized state (~45%) (metabolically active)

- Normal serum concentrations of total calcium range 8.5 and 10.6 mg/dL
- Ionized calcium between 4.65-5.30 mg/dL

- Corrected calcium (mg/dL) = measured total serum calcium (mg/dL) + [4.0- serum albumin (g/dL) X 0.8]

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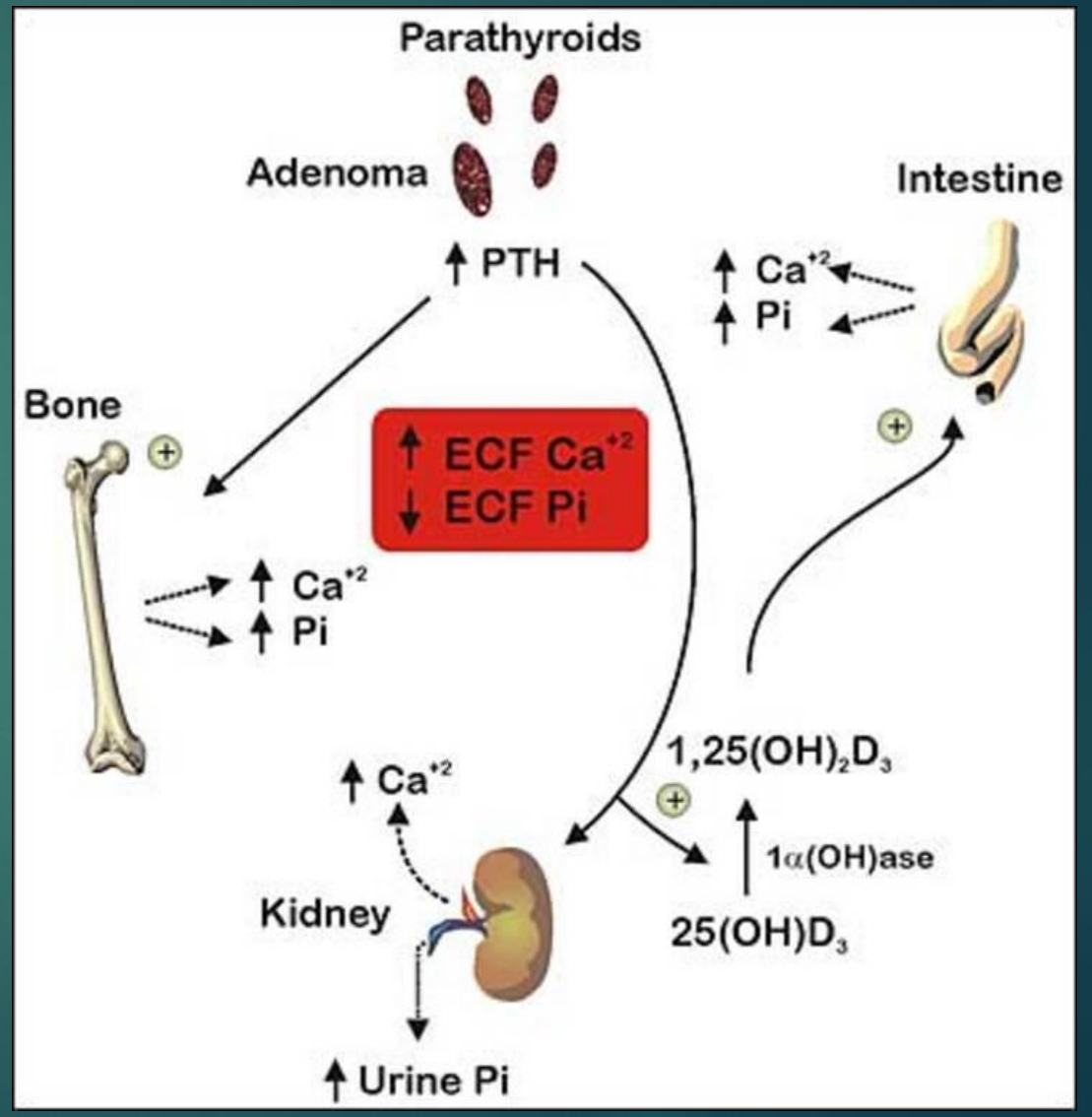
Why Albumin levels

Approach to Hypo-/Hypercalcemia

- Reduction in serum calcium → Stimulate PTH release →
  - increase bone resorption
  - Increase renal calcium reabsorption
  - stimulate renal conversion of 25-oh D3 to 1,25(OH)2D3 → intestinal calcium absorption

Approach to Hypo-/Hypercalcemia

- Decreased PTH and decreased 1,25(OH)2D3 should accompany hypercalcemia unless PTH or 1,25(OH)2D is causal



Hypercalcemic Disorders

- Medication-Induced
  - **Thiazides**
  - **Lithium**
  - **Vitamin D**
  - **Vitamin A**
  - **Milk-Alkali Syndrome**
  - **Estrogens “and Antiestrogens”**
  - **Theophylline**
  - **Aluminium Intoxication**

Hypercalcemic Disorders

- Medication-Induced
  - **Thiazides**
  - **Lithium**
  - **Vit**
  - **M**

Why dietary and medications/supplements are important

Hypercalcemic Disorders

- **Endocrine Disorders with Excess PTH Production**
  - Primary sporadic hyperparathyroidism
  - Familial hyperparathyroidism
  - Secondary hyperparathyroidism
  - Tertiary hyperparathyroidism
  - FHH
- **Endocrine Disorders without Excess PTH Production**
  - Hyperthyroidism, hypoadrenalism, pheochromocytoma, VIPoma,

Hypercalcemic Disorders

- **Malignancy-Associated Hypercalcemia**
  - with elevated PTHrP
  - with elevation of other systemic factors - increased 1,25(OH)2D3 in lymphomas, IL-6, hemolytic lesions

Hypercalcemic Disorders

- Inflammatory Disorders Causing Hypercalcemia
  - **Granulomatous Disorders**
  - **AIDS**
- Pediatric Syndromes
  - **Williams Syndrome**
  - **Idiopathic Infantile Hypercalcemia**
- **Immobilization**

History and Physical Examination

- Signs and symptoms are relevant to hypercalcemia
- Signs and symptoms are relevant to the causal disorder
- Hypercalcemic manifestations
  - Acute onset and severe vs. chronic and relatively mild

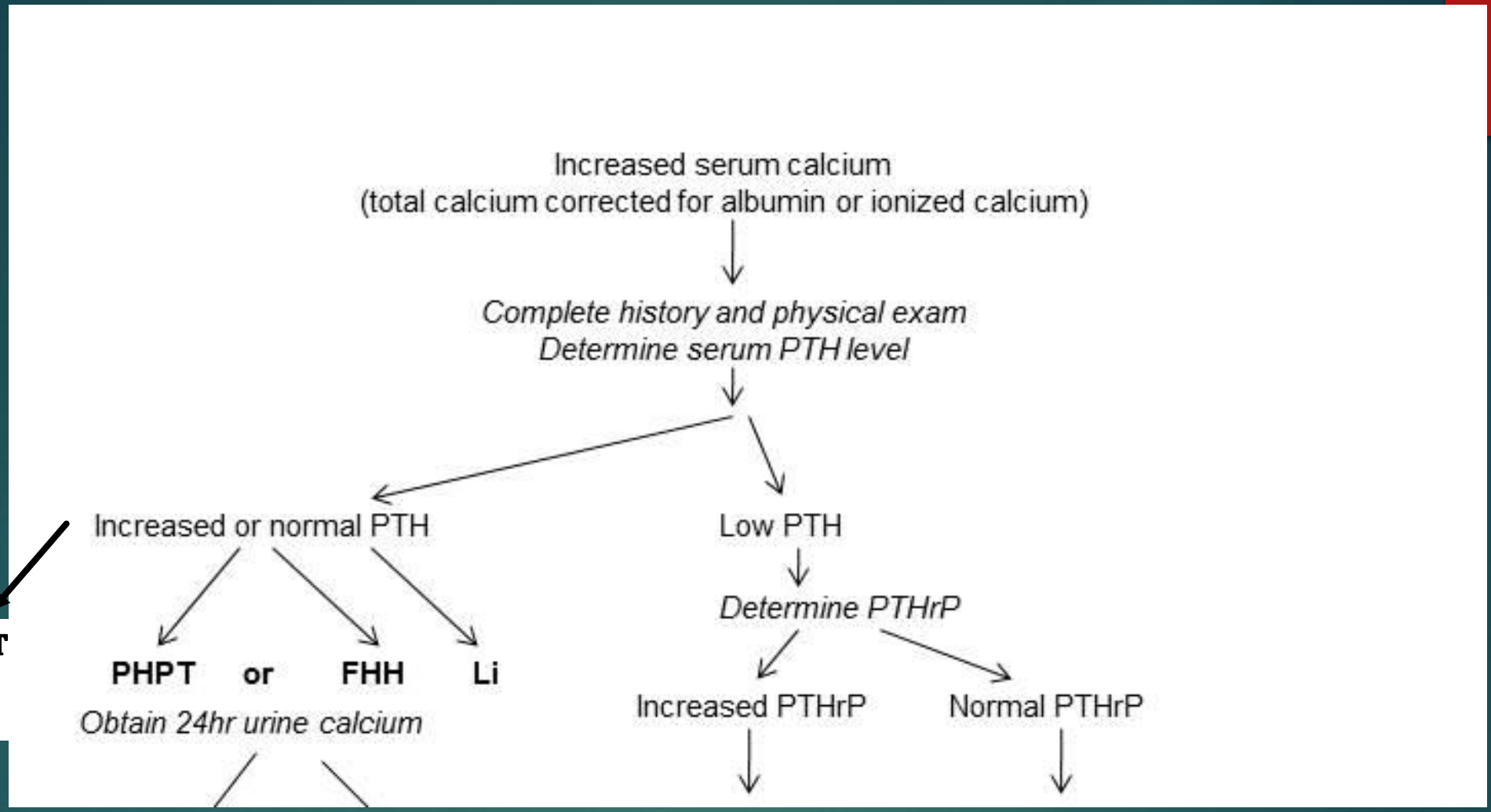
- Most patients are symptomatic when Ca >14 mg/dL
- In both acute and chronic cases the major manifestations affect **gastrointestinal, renal and neuromuscular function**

Manifestations of Hypercalcemia

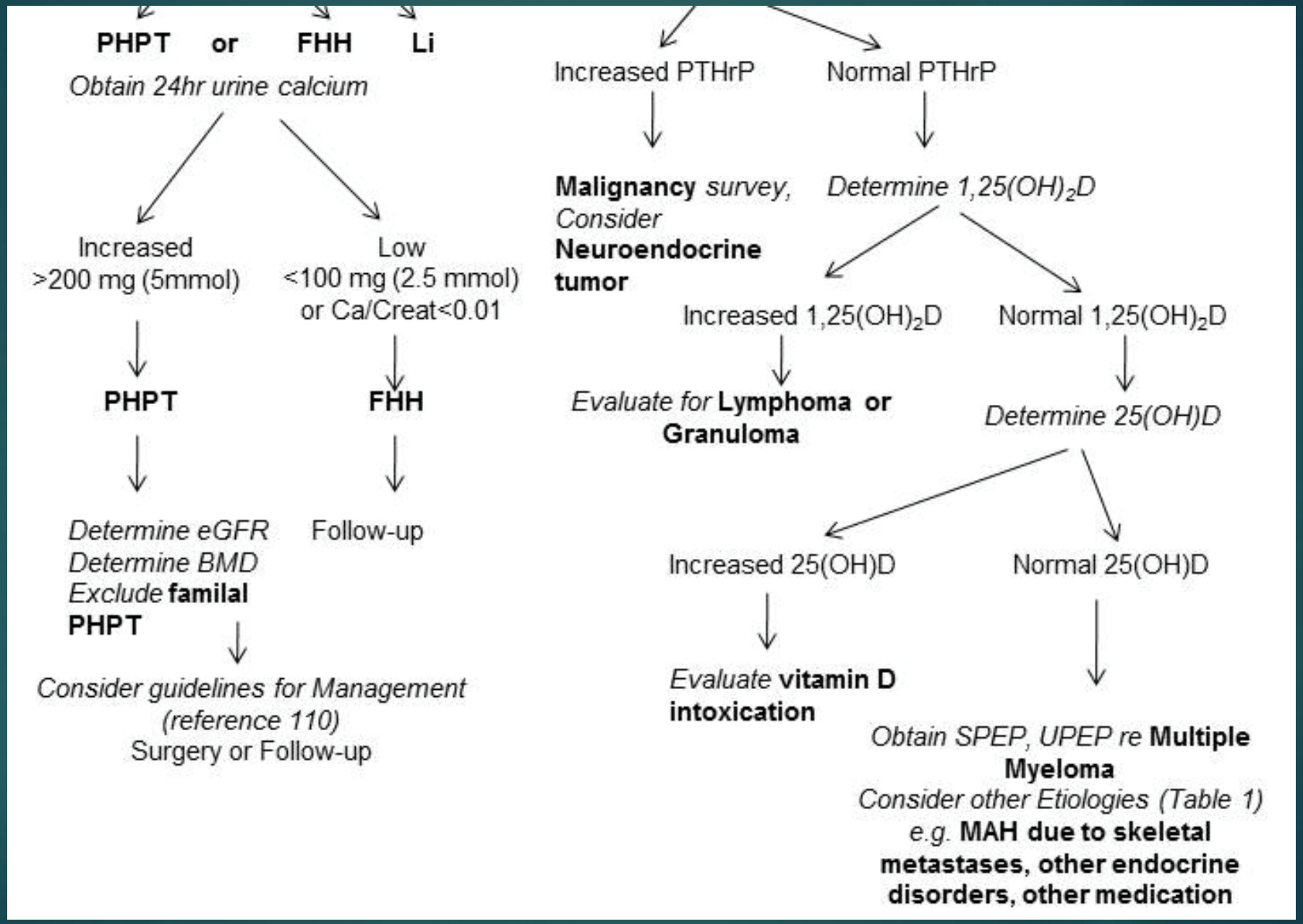
	Acute	Chronic
Gastrointestinal	Anorexia, nausea, vomiting	Dyspepsia, constipation, pancreatitis
Renal	Polyuria, polydipsia → dehydration	Nephrolithiasis, nephrocalcinosis
Neuromuscular	Depression, confusion, stupor, coma	Weakness
Cardiac	Bradycardia, first degree atrioventricular shortened QT interval Can be life-threatening	Hypertension, block, digitals sensitivity

Laboratory Examination

- Laboratory testing should be guided by the results of a **careful history and a detailed physical examination**
- Laboratory screening may include
  - Serum total Ca… ionized calcium
  - CMP (Serum creatinine and eGFR, Albumin, LFT, Lytes)
  - iPTH
  - Phosphorus
  - Mg
  - 25(OH)D … 1,25(OH)2DCBC
  - UA and 24 hour urine collection for calcium and creatinine



Secondary HPT Due to low Vit D or low eGFR


PHPT or FHH Li
Obtain 24hr urine calcium
Increased >200 mg (5mmol)
Low <100 mg (2.5 mmol) or Ca/Creat<0.01
PHPT
FHH
Determine eGFR
Determine BMD
Exclude familal PHPT
Follow-up
Consider guidelines for Management (reference 110)
Surgery or Follow-up
Increased PTHrP
Normal PTHrP
Malignancy survey, Consider Neuroendocrine tumor
Determine 1,25(OH)2D
Increased 1,25(OH)2D
Normal 1,25(OH)2D
Evaluate for Lymphoma or Granuloma
Determine 25(OH)D
Increased 25(OH)D
Normal 25(OH)D
Evaluate vitamin D intoxication
Obtain SPEP, UPEP re Multiple Myeloma
Consider other Etiologies (Table 1)
e.g. MAH due to skeletal metastases, other endocrine disorders, other medication

CLINICAL PRESENTATION OF HYPOCALCEMIA

- Hypocalcemia can present as an asymptomatic laboratory finding or as a severe, life-threatening condition

- Distinguishing acute from chronic hypocalcemia and asymptomatic from severely symptomatic hypocalcemia is critical for determining appropriate therapy

CLINICAL PRESENTATION OF HYPOCALCEMIA

- The hallmark of acute hypocalcemia is neuromuscular irritability
- **Neuromuscular irritability**
  - Chvostek's sign
  - Trousseau's sign:
  - **Paresthesias:** numbness and tingling in their fingertips, toes, and the perioral region
  - Tetany
  - Seizures (focal, petit mal, grand mal)
  - Muscle cramps
  - Muscle weakness
  - Laryngospasm
  - Bronchospasm

CLINICAL PRESENTATION OF HYPOCALCEMIA

- **Neurological signs and symptoms**
  - Extrapyramidal signs due **to calcification of basal ganglia** – chronic hypoCa
  - Calcification of cerebral cortex or cerebellum – chronic hypoCa
  - Personality disturbances
  - **Irritability**
  - **Impaired intellectual ability**
  - **Nonspecific EEG changes**
  - **Increased intracranial pressure**
  - Parkinsonism
  - Choreoathetosis
  - **Dystonic spasms**

CLINICAL PRESENTATION OF HYPOCALCEMIA

- **Cardiac**
  - **Prolonged QT** interval on EKG
  - Congestive heart failure
  - Cardiomyopathy

CLINICAL PRESENTATION OF HYPOCALCEMIA

- **Smooth muscle involvement**
  - Dysphagia
  - **Abdominal pain**
  - Biliary colic
  - Dyspnea
  - **Wheezing**

CLINICAL PRESENTATION OF HYPOCALCEMIA

- **Mental status**
  - **Confusion**
  - Disorientation
  - Psychosis
  - Fatigue
  - Anxiety
  - **Poor memory**
  - **Reduced concentration**

ETIOLOGY OF HYPOCALCEMIA

- Hypocalcemia can result from
  - Disorders of **vitamin D metabolism and action**
  - **Hypoparathyroidism**
  - **Resistance to PTH**

ETIOLOGY OF HYPOCALCEMIA

- **Inadequate vitamin D production and action**
  - Nutritional deficiency
  - Lack of sunlight exposure
  - Malabsorption
  - Post-gastric bypass surgery
  - End-stage liver disease and cirrhosis
  - Chronic kidney disease
  - Vitamin D-dependent rickets type 1 and type 2

ETIOLOGY OF HYPOCALCEMIA

- **Inadequate PTH production/Hypoparathyroidism**
  - **Functional hypoparathyroidism**
  - Magnesium depletion
  - Magnesium excess
  - **PTH resistance -** Pseudohypoparathyroidism
  - Post-thyroidectomy (cancer, Grave's disease, MNG.
  - Post-parathyroidectomy

ETIOLOGY OF HYPOCALCEMIA

- **Drugs**
  - Intravenous bisphosphonate therapy or Denosumab therapy – especially in patients with vitamin D insufficiency or deficiency
- Rapid transfusion of large volumes of citrate-containing blood
- Acute critical illness
- "Hungry bone syndrome"
- Osteoblastic metastases
- Acute pancreatitis
- Rhabdomyolysis

Acute Symptomatic Hypocalcemia

- Acute hypocalcemia can be life-threatening,
  - tetany, seizures, cardiac arrhythmias, laryngeal spasm, or AMS
- **Calcium gluconate is the preferred intravenous calcium** salt as calcium chloride often causes local irritation
- Calcium gluconate contains 90 mg of elemental calcium per 10 mL ampule, and usually 1 to 2 ampules (180 mg of elemental calcium) diluted in 50 to 100 mL of 5% dextrose is infused over 10 minutes
- This can be repeated until the patient's symptoms have cleared

Acute Symptomatic Hypocalcemia

- With persistent hypocalcemia → **calcium gluconate drip** over longer periods of time may be necessary.
- The goal should be to raise the serum ionized calcium concentration into the low normal range (~1.0 mM) and control the patient's symptoms.
- Drip rates **of 0.5-2.0 mg/kg/hour** are recommended
- As soon as possible, oral calcium supplementation should be initiated and, if warranted, therapy with vitamin D or its analogues.

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Thank you!

Acute Symptomatic Hypocalcemia

- Intravenous administration of calcium is not without problems
- Rapid administration could result in arrhythmias so intravenous administration should be carefully monitored. Local vein irritation can occur with solutions >200 mg/100 mL of elemental calcium. If local extravasation into soft tissues occurs, calcifications due to the precipitation of calcium phosphate crystals can occur (109).
- Calcium phosphate deposition can occur in any organ and is more likely to occur if the calcium-phosphate product exceeds 55. Calcium phosphate deposition in the lungs, kidney or other soft tissue may occur in patients receiving intravenous calcium especially in the presence of high serum phosphate levels.
- It is essential to measure serum magnesium in any patient who is hypocalcemic, as correction of hypomagnesemia must occur to overcome PTH resistance before serum calcium will return to normal

- The practicing physician can consider a simplified scheme when confronted with a patient with a disorder of calcium and skeletal metabolism – the serum or urinary calcium can be abnormally high or low and bone density can be increased or decreased.
- In practical terms, when the serum calcium is high, primary hyperparathyroidism and malignancy are at the top of the diagnostic list; when it is low, renal disease, hyoparathyroidism, malabsorption, and vitamin D deficiency should be considered
- Chronically abnormal phosphate levels in the non-acutely ill patient may be caused by renal failure, renal tubular defects, and abnormalities of FGF23 action.
- When bone density is decreased, it is usually due to osteoporosis or osteomalacia; when increased, osteopetrosis and other osteosclerotic disorders should be considered.
- These diagnostic categories can be properly assigned when one considers the interaction among the calcium regulating hormones that have been described in this chapter and orders the appropriate diagnostic tests. In most cases, the correct diagnosis is readily made.

- In this nephron region, PTH can, after binding to the PTHR, also stimulate CYP27B1, the 25(OH)D3-1a hydroxylase [1a(OH)ase], leading to increased synthesis of 1,25(OH)2D3 (30).

- Effect of PTH on increasing osteoclast stimulation is indirect, with PTH binding to the PTHR on pre-osteoblastic stromal cells (38) and other cells of the osteoblast lineage including osteocytes (39) and enhancing the production of the cytokine RANKL (receptor activator of NFkappaB ligand

- The renal production of 1,25(OH)2D3 is stimulated by hypocalcemia, hypophosphatemia and elevated PTH levels.

Figure 7. The Metabolic Activation of Vitamin D. Abbreviations: 25-D, 25-hydroxyvitamin

Approach to Hypercalcemia

- Hypercalcemia may be caused by:
- Endocrine Disorders with Excess PTH including primary sporadic and familial hyperparathyroidism, and tertiary hyperparathyroidism
- Endocrine Disorders Without Excess PTH including hyperthyroidism, pheochromocytoma, VIPoma, hypoadrenalism, and Jansen's Metaphyseal Chondrodysplasia
- Malignancy-Associated Hypercalcemia, which can be caused by elevated PTH-related protein (PTHrP), or other factors (e.g. increased 1,25(OH)2D3 in lymphomas)
- Inflammatory Disorders including Granulomatous Diseases, where excess 1,25(OH)2D3 production may be causal
- HIV/AIDS
- Pediatric Syndromes including Williams Syndrome and Idiopathic Infantile Hypercalcemia, where inappropriate levels of 1,25(OH)2D3 may occur due to a mutation in the 24-hydroxylase 25-hydroxyvitamin D gene
- Medication, including thiazide diuretics, lithium, vitamin D, vitamin A, estrogens and antiestrogens, and theophylline; and prolonged immobilization, particularly in states of high bone turnover
- Treatment should be aimed the underlying disorder, however, if serum calcium exceeds 12 to 14mg/dL (3 to 3.5mM), acute hydration and agents that inhibit bone resorption are required. Under selected conditions, calcimimetics, calciuresis, glucocorticoids, or dialysis may be needed.

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- ***Sporadic Primary Hyperparathyroidism***
- Sporadic primary hyperparathyroidism (PHPT) is generally (at least 85-90% of cases) associated with a single parathyroid adenoma which overproduces PTH. Although 10-15% of cases may be associated with multigland hyperplasia,
- To date, the only genes definitively implicated in sporadic benign PHPT are an oncogene that encodes a key regulator of the cell cycle and *MEN1*, a tumor suppressor gene, also implicated in familial multiple endocrine neoplasia type I

- The clinical manifestations of these disorders are caused by the overproduction of PTH and its effect on bone resorption and formation, on its capacity to stimulate renal 1,25(OH)2D3 production and on the resultant effect on ECF calcium which can modify the filtered renal load of calcium (Fig. 4). About 80% of cases of the most common form of PHPT i.e. benign sporadic PHPT present as mild or “asymptomatic” hyperparathyroidism in which hypercalemia is generally less than 1mg/dL (0.25 mM) above the upper limit of normal and may be normal intermittently (117) However significant increases in serum calcium may occur even after 13 years of follow up. Excess PTH production can produce significant bone loss. Classically this is manifested by discrete lesions including subperiosteal bone resorption of the distal phalanges, osteitis fibrosa cystica characterized by bone cysts and "brown tumors" (i.e. collections of osteoclasts intermixed with poorly mineralized woven bone), and ultimately fractures.
- resorption of cortical bone, reflecting the "catabolic bone activity" of PTH, with relative preservation of trabecular bone, reflecting its "anabolic activity" (123). Consequently the severity of bone disease in the West appears considerably diminished. Possibly as a consequence of less severe bone disease, hypercalcemia is also less marked, the filtered load of renal calcium is lower and the incidence of kidney stones and particularly of nephrocalcinosis has declined as well. Nevertheless hypercalciuria still occurs in 35-40% of patients with primary benign sporadic hyperparathyroidism and kidney stones occurs in 15-20% (124). About 25%of patients with mild (“asymptomatic”) sporadic PHPT have been reported to develop renal manifestations within 10 years, including renal concentrating defects or kidney stones. In the East, where relative or absolute vitamin D deficiency may limit the severity of hypercalcemia and therefore the filtered load of calcium, the incidence of nephrolithiasis (10-40%) does not appear to be as different as is the incidence of bone disease. The higher incidence in the West of benign sporadic PHPT in women and in an older age group (125) also appears to distinguish the presentation of this disorder in the West relative to the East

labs

- Surgical removal of the parathyroid adenoma currently remains the treatment of choice if the ECF calcium is greater than 1mg/dL (0.25mM) above normal, if there is evidence of bone disease [i.e. a BMD T-score of <−2.5 at the lumbar spine, total hip, femoral neck, or 33% radius (1/3 site) and/or a previous fracture fragility], if creatinine clearance (calculated) is reduced to <60 ml/min or if the patient is less than age 50. Surgery is also indicated in patients for whom medical surveillance is either not desired nor not possible (130). In addition, although hypercalciuria is only one of several risk factors affecting the development of kidney stones, some physicians still regard 24-hour urinary calcium excretion of greater than 400 mg as an indication for surgery.
- Imaging is not recommended to establish or confirm the diagnosis of PHPT, but has become routine for preoperative localization of the abnormal parathyroid tissue. The most commonly employed preoperative parathyroid imaging techniques are radionuclide imaging (i.e. sestamibi scanning) and ultrasound. Computed tomography, magnetic resonance imaging, and positron emission tomography scanning, arteriography, and selective venous sampling for PTH are usually reserved for patients who have not been cured by previous explorations or for whom other localization techniques are not informative or are discordant.

Laboratory Examination

- To establish the diagnosis of PHPT the most common cause of hypercalcemia in the clinic, documentation of at least two elevated corrected (or ionized) serum calcium levels with concomitant elevated (or at least normal) serum PTH levels is required (Figure1). Two site assays for PTH are currently the method of choice (232). If mild hyperparathyroidism is documented, then in addition to the level of urine calcium, bone densitometry, calculation of estimated GFR and a renal ultrasound or renal CT scan for evidence of nephrolithiasis may help determine the extent of the disease. For severe hyperparathyroidism, appropriate skeletal X-rays would be indicated to provide a baseline of disease extent before parathyroidectomy. Pre-operative localization of a parathyroid adenoma, generally by nuclear imaging (MIBI scans) or ultrasound has been helpful (233). Ultimately an experienced surgeon is the best guarantee for a successful neck exploration.
- The presence of a family history of hypercalcemia or of kidney stones should raise suspicion of MEN1 or MEN2a. If, in addition to HPT in the proband, one or more first-degree relatives are found have at least one of the three tumors characterizing MEN1 (parathyroid, pituitary, pancreas) or MEN2a (parathyroid, medullary thyroid carcinoma, pheochromocytoma) then it is highly likely that the disease is familial. Documentation of familial HPT should be transmitted to the surgeon so that multigland disease can be dealt with. The presence of ossifying fibromas of the mandible and maxilla, and renal lesions such as cysts and hamartomas in addition to HPT would suggest HPT-jaw tumor syndrome. In all patients with documented HPT, a 24 hour urine calcium and creatinine level should be obtained to exclude FHH. If the urine calcium to creatinine ratio is less than 0.01 and if testing serum and urine calcium in three relatives discloses hypercalcemia and relative hypocalciuria in other family members, then this diagnosis is likely and parathyroid surgery is to be avoided. If the urine calcium to creatinine ratio is greater than 0.01 then a BMD test should be performed and guidelines for treatment of primary HPTH should be considered (see below).

Laboratory Examination

- If hypercalcemia is associated with very low or suppressed serum PTH levels, then malignancy would be an important consideration, either in association with elevated serum PTHrP or in its absence, in which case it is generally as a result of the production of other cytokines. Hypercalcemia is however frequently a late manifestation of malignancy and the presentation of hypercalcemia is often acute and severe. When malignancy-associated hypercalcemia is suspected then an appropriate malignancy screen should be done including skeletal imaging to identify skeletal metastases. As well appropriate biochemical assessment such as a complete blood count, serum creatinine and serum and urine protein electrophoresis to exclude multiple myeloma would be appropriate. Detection of elevated serum 1,25(OH)2D levels may point toward the need for a search for lymphoma or for infectious or non-infectious granulomatous disease. Other testing (e.g. a TSH level) could be done for specific clinical disorders based on the findings on the history and physical examination. Although increased PTHrP may be associated with pheochromocytoma, serum PTH levels are suppressed in hypercalcemia in association with thyrotoxicosis, pheochromocytome, VIPoma and hypoadrenalism. Although these disorders may be suspected from clinical examination, detailed biochemical evaluation is required for confirmation

Management of Acute Hypercalcemia

1. Hydration
2. Inhibition of Bone Resorption
3. Calciuresis
4. Glucocorticoids (when indicated)
5. Dialysis (in renal failure)
6. Calcimimetics
7. Mobilization

- Ectodermal changes
- • Dry skin
- • Coarse hair
- • Brittle nails
- • Alopecia
- • Enamel hypoplasia
- • Shortened premolar roots
- • Thickened lamina dura
- • Delayed tooth eruption
- • Increased dental caries
- • Atopic eczema
- • Exfoliative dermatitis
- • Psoriasis
- • Impetigo herpetiformis

Postsurgical Hypoparathyroidism and Hypocalcemia

- One of the most common causes of hypocalcemia is inadvertent removal of, damage to, or inadvertent devascularization of the parathyroid glands during surgery for parathyroid or thyroid disease. This may be short-term, in which case it is parathyroid gland "stunning." If persistent (beyond 6 months), postoperative permanent hypoparathyroidism is the diagnosis. Other causes of postoperative hypocalcemia include the "hungry bone syndrome" with low serum calcium levels resulting from remineralization of the bone, as the stimulus for high bone turnover (e.g., high PTH or thyroid hormone levels) is removed are discussed below. There may be edema in the surgical field resulting in hypocalcemia due to the surgery itself, which may remit as the swelling subsides. The vascular supply to the remaining parathyroid glands may be compromised resulting in hypocalcemia. In chronic hyperparathyroidism, the dominant hyperactive parathyroid adenoma may have suppressed the remaining normal parathyroid glands. After removal of the adenoma, the remaining suppressed parathyroid glands will eventually regain their functional capacity, although this may take time.
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- post-operative hypocalcemia as either “hungry bone syndrome” (hypocalcemia and hypophosphatemia) or hypoparathyroidism (hypocalcemia and hyperphosphatemia