

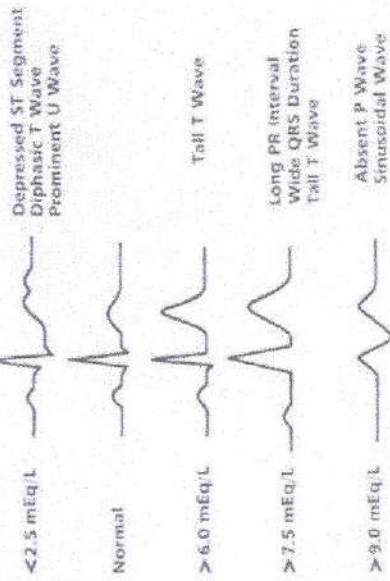
Hypokalemia: Treatment

- Mild to moderate: 3.0-3.4 mEq/L
- Severe: < 2.5-3.0 mEq/L
- Treatment
 - Treat underlying
 - Correct hypomagnesemia
 - การถ่ายน้ำเกลือที่บรรจุสารละลายโพแทสเซียม shift ของ K เข้าเซลล์

Hyperkalemia: Treatment

- Mild: 5.5 - 6.0 mEq/L
- Severe: > 7.0 mEq/L
- Treatment
 - ถ้า EKG เป็น hyperkalemia ให้รีบโทรแจ้งห้อง Lab ให้ treat านู

SERUM K



Treatment of symptomatic hyperkalemia

- Potassium removal
 - Kayexalate
 - Oral administration is 15-30 g in 50-100 mL of 20% sorbitol
 - Rectal administration is 50 g in 200 mL of 20% sorbitol
 - Dialysis
 - Shift potassium
 - Glucose 1 ampule of D₅₀ and regular insulin 5-10 units IV
 - Bicarbonate 1 ampule IV
 - Counteract cardiac effects
 - Calcium gluconate 5-10 mL of 10% solution
- D₅₀ = 50% dextrose.

Calcium Homeostasis

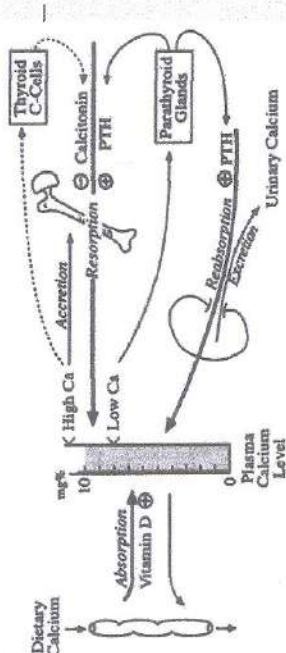
- ปกติในร่างกายมีประมาณ 1,000 gm
- อยู่ใน ECF compartment 1%, ส่วนใหญ่อยู่ใน bone
- มีทั้ง free form (ionized Ca^{2+}) และ bound form (+ albumin)
- ในภาวะ hypocalcemia ต้อง correct calcium ด้วย

$$Ca_{ionized} = Total [Ca^{2+}] (mg/L) \times [0.8 \times (1 - [Alb])]$$

Calcium Homeostasis

- Calcium เมื่อเข้าสู่ร่างกายโดยการรับประทาน จะถูกดูดซึมที่ลำไส้ โดยที่ vitamin D เป็นตัวกระตุ้นเพิ่มการดูดซึมในลำไส้
- Calcitonin เพิ่มการเก็บ calcium ไว้ที่ bone
- เมื่อมีภาวะ calcium ในเลือดต่ำ PTH จะถูกกระตุ้นให้หลั่งออกมา เกิด bone resorption ทำให้ระดับ calcium ในเลือดเพิ่มขึ้น
- Calcium ส่วนที่เหลือถูกขับออกทางไต

Calcium Homeostasis



Hyper- vs Hypocalcemia: Signs & Symptoms

System	Hypercalcemia	Hypocalcemia
GI	Anorexia, nausea, vomiting, abdominal pain	
Neuromuscular	Weakness, confusion, malaise, bone pain	Hyperreflexia, arrhythmias, heart failure, polyuria
Cardiovascular	Prolonged PR and QRS intervals	EKG prolonged QT interval, T wave inversion, Heart block, T wave flattening and widening, AV block
Renal	Polydipsia	

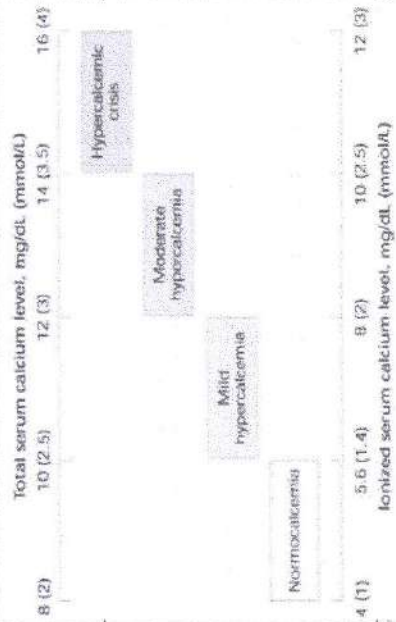
Hypocalcemia: Causes

- *Primary hypoparathyroidism*—*glandular aplasia, destruction or removal*
- *Hypomagnesemia, Hypermagnesemia*
- *Hypoalbuminemia*
- *Acute pancreatitis*
- *Vitamin D deficiency*
- *Rhabdomyolysis*
- *Pseudohypoparathyroidism*

Hypocalcemia: Treatment

- *IV calcium should only be given with close cardiac monitoring (EKG)* (ห้ามส่งไปสารที่มี bicarbonate/lactate มาก อยู่ เพราะจะกดหัวใจ)
- *Calcium can inhibit sinus node* → *bradycardia + arrest*
- *ถ้าเกิด extravasation อาจทำให้เกิด tissue necrosis/calcification*
- *Hypocalcemia with acidosis* → *give calcium before correcting acidosis* (ถ้าแก้ acidosis ก่อน calcium จะไม่ดี)
- *Chronic hypocalcemia* ถ้าไม่หายก็ *replace oral calcium + vitamin D* และ *F/U [Ca²⁺]*

Hypercalcemia



Hypercalcemia: Causes

- **Endocrine:**
 - *Hyperparathyroidism*
 - *MEN Type 1 (parathyroid adenoma, pituitary adenoma, pancreatic islet cell tumor)*
 - *Familial hypocalciuric hypercalcemia*
- **Malignancy:**
 - *Metastases*
 - *PTHrP (parathyroid related protein)*
 - *Breast cancer, lung cancer, bone cancer*

Hypercalcemia: Causes

- Granulomatous Disease:
 - Sarcoidosis
 - TB
- Miscellaneous:
 - Acute kidney failure
 - Milk-alkali syndrome
- Medications:
 - Lithium therapy
 - Thiazides (including Na, water absorption and ca concentrations)
 - Vitamin D

Hypercalcemia: Treatment

- Severe hypercalcemia: load IV fluid เพื่อลดความเข้มข้น
- ให้ furosemide ถ้าจำเป็น
- ให้ Calcitonin ร่วมกับทุก 12 ชั่วโมง
- ถ้าเกิดจาก Cancer ใช้ bisphosphonate
- ถ้าสูงมาก ๆ ให้ dialysis

Phosphate Hemostasis

- 80% of the total body phosphate is contained in bone
- High energy phosphate bound in ATP
- Essential element in phospholipid cell membranes, nucleic acid, phosphoproteins
- Phosphate is critical for activity for several important enzymes

Hypophosphatemia: Causes

- Mild: 2.5-3 mg/dL, Moderate: 1.0-2.5 mg/dL, severe: < 1 mg/dL

Transcellular shift	Refeeding syndrome Respiratory alkalosis Insulin administration
Renal losses	Diuretic therapy Osmotic diuresis Proximal renal tubular dysfunction
Insufficiency intestinal absorption	Malnutrition NG suction Phosphate binding antacid Vitamin D deficiency Malabsorption syndromes
Extrarenal catabolic cause	Burn Trauma Sepsis

Hypophosphatemia: Signs & symptoms

System	Clinical manifestation
Respiratory	Acute respiratory failure Ventilator dependent
Musculoskeletal	Muscle weakness Rhabdomyolysis Bone demineralization
Hematologic	Hemolysis Disorder of eryocyte morphology, toxic or chemical
Neurologic	Altered mental status Seizures Parosmia
Cardiovascular	Cardiomyopathy Decreased inotropy

Hypophosphatemia: Treatment

- Severe hypophosphatemia → IV phosphate replacement
- Moderate hypophosphatemia → oral phosphate

Hyperphosphatemia

- Serum $[PO_4^{3-}] > 4.5 \text{ mg/dL}$
- If $> 5 \text{ mg/dL}$ → clinical significant
- Clinical findings are signs and symptoms of HYPOCALCEMIA by
 - Calcium phosphate complex
 - Interfere with PTH-mediated bone resorption
 - Decrease vitamin D level

Hyperphosphatemia: Causes

Renal	Acute or chronic renal failure Increased renal absorption: Hypoparathyroidism Thyrotoxicosis
Cellular injury	Rhabdomyolysis Tumor lysis syndrome Hemolysis
Medication related	Abuse-phosphate containing laxatives Excessive phosphate administration Bisphosphonate therapy

Hyperphosphatemia: Treatment

- Limit phosphate intake
- Enhance urinary excretion
- Absence of ESRD → fluid and diuretic
- HD
- CKD → phosphate binding agents: Calcium, Aluminum, Renagel® (calcium free phosphate binder)

Magnesium Hemostasis

- ส่วนใหญ่อยู่ใน intracellular compartment
- 50% อยู่ในที่ bone, อีก 50% อยู่ใน soft tissue, muscle, liver
- ส่วนใหญ่ถูกดูดซึมที่ small bowel และถูก excrete ที่จอต

Hyper- and Hypomagnesemia: Signs & Symptoms

System	Hypermagnesemia	Hypomagnesemia
GI	Nausea, vomiting	
Neuromuscular	Weakness, tetragy, decreased reflex	Hyperactive reflex, Muscle tremors, tetany, Seizures
Cardiovascular	Hypotension, arrhythmia EKG: increased PR interval, widened QRS complex, elevate T wave	Arrhythmia EKG: prolong QT and PR interval, ST-segment depression, flattening or inversion of p waves, Torsades de pointes

Hypomagnesemia

- Defined as a $[Mg^{2+}] < 1.3 \text{ mEq/L}$
- Usually results from decreased absorption or increased loss of Mg from either the kidneys or intestines (diarrhea), alteration in thyroid hormone function and certain medications (e.g. pentamidine, diuretics, alcohol)
- Hypomagnesemia interferes with the effects of PTH, resulting in hypocalcemia and may also cause hypokalemia
- Symptoms: muscular tremors and fasciculations, ocular nystagmus, tetany, altered mental state, and cardiac arrhythmias e.g. torsades de pointes (multifocal ventricular tachycardia), ataxia, vertigo, seizures and dysphagia

Hypomagnesemia: Treatment

- Determined by its severity and patient's clinical status
- ~~Severe of symptomatic hypomagnesemia and Torsades de pointes is intermittent and not associated with arrest:~~
 - Give 1-2 gm of IV $MgSO_4$ over 5 to 60 minutes
- Torsades de pointes with cardiac arrest:
 - Give 1-2 gm of IV $MgSO_4$ over 5 to 20 minutes
- Seizures:
 - Give 2 gm IV $MgSO_4$ over 10 minutes
- Administration of calcium is usually appropriate because most patients with hypomagnesemia are also hypocalcemia

Hypermagnesemia

- Defined as a $[Mg^{2+}] > 2.2$ mEq/L (normal 1.3-2.2 mEq/L)
- Most common cause is renal failure.
- Neurologic symptoms are muscular weakness, paralysis, ataxia, drowsiness and confusion
- Moderate hypermagnesemia: vasodilation
- Severe hypermagnesemia: hypotension
- Extremely high serum $[Mg^{2+}]$: depressed level of consciousness, bradycardia, cardiac arrhythmias, hypoventilation and cardiorespiratory arrest

Hypermagnesemia: Treatment

- Treated with administration of calcium, which removes Mg from serum
- Eliminate sources of ongoing Mg intake
- Cardiorespiratory support may be needed until $[Mg^{2+}]$ are reduced
- Administration of 10% solution of $CaCl_2$ (5-10 mL (500-1000 mg) IV) will often correct lethal arrhythmias
- Dialysis is the treatment of choice for severe hypermagnesemia.

Hypermagnesemia: Treatment

- If renal function is normal and CV function adequate, IV saline diuresis (IV NSS and furosemide [1 mg/kg] can be used to increase renal excretion of Mg until diuresis can be performed
- Diuresis can also increase calcium excretion; the development of hypocalcemia will make signs and symptoms of hypermagnesemia worse