

CAUSES OF SEVERE HYPOPHOSPHATEMIA

Acute renal failure: excessive P binders	Reye's syndrome
Chronic alcoholism and alcohol withdrawal	After major surgery
Dietary deficiency and PO_4^{3-} -binding antacids	Periodic paralysis
Hyperalimentation	Acute malaria
Neuroleptic malignant syndrome	Drug therapy
Recovery from diabetic ketoacidosis	Ifosfamide
Recovery from exhaustive exercise	Cisplatin
Kidney transplantation	Acetaminophen intoxication
Respiratory alkalosis	Cytokine infusions
Severe thermal burns	Tumor necrosis factor
Therapeutic hypothermia	Interleukin-2

FIGURE 7-13

Causes of severe hypophosphatemia. (From Popovtzer, *et al.* [6]; with permission.)

CAUSES OF HYPOPHOSPHATEMIA IN PATIENTS WITH ALCOHOLISM

Decreased net intestinal phosphate absorption	Increased urinary phosphate excretion	Acute movement of extracellular phosphate into the cells
Poor dietary intake of phosphate and vitamin D	Alcohol-induced reversible proximal tubular defect	Insulin release induced by intravenous solutions containing dextrose
Use of phosphate binders to treat recurring gastritis	Secondary hyperparathyroidism induced by vitamin D deficiency	Acute respiratory alkalosis caused by alcohol withdrawal, sepsis, or hepatic cirrhosis
Chronic diarrhea		Refeeding of the patient who is malnourished

FIGURE 7-15

Causes of hypophosphatemia in patients with alcoholism.

MAJOR CONSEQUENCES OF HYPOPHOSPHATEMIA

Decreased erythrocyte 2,3-diphosphoglycerate levels, which result in increased affinity of hemoglobin for oxygen and reduced oxygen release at the tissue level

Decreased intracellular adenosine triphosphate levels, which result in impairment of cell functions dependent on energy-rich phosphate compounds

CAUSES OF HYPOPHOSPHATEMIA IN PATIENTS WITH NONKETOTIC HYPERGLYCEMIA OR DIABETIC KETOACIDOSIS

Decreased net intestinal phosphate absorption	Increased urinary phosphate excretion	Acute movement of extracellular phosphate into the cells
Decreased phosphate intake	Glucosuria-induced osmotic diuresis	Insulin therapy
	Acidosis	

FIGURE 7-14

Causes of hypophosphatemia in patients with nonketotic hyperglycemia or diabetic ketoacidosis.

CAUSES OF HYPOPHOSPHATEMIA IN PATIENTS WITH RENAL TRANSPLANTATION

Increased urinary phosphate excretion
Persistent hyperparathyroidism (hyperplasia or adenoma)
Proximal tubular defect (possibly induced by glucocorticoids, cyclosporine, or both)

FIGURE 7-16

Causes of hypophosphatemia in patients with renal transplantation.

FIGURE 7-17

Major consequences of hypophosphatemia.

SIGNS AND SYMPTOMS OF HYPOPHOSPHATEMIA

Central nervous system dysfunction	Cardiac dysfunction	Pulmonary dysfunction	Skeletal and smooth muscle dysfunction	Hematologic dysfunction	Bone disease	Renal effects	Metabolic effects
Metabolic encephalopathy owing to tissue ischemia	Impaired myocardial contractility	Weakness of the diaphragm	Proximal myopathy	Erythrocytes	Increased bone resorption	Decreased glomerular filtration rate	Low parathyroid hormone levels
Irritability	Congestive heart failure	Respiratory failure	Dysphagia and ileus	Increased erythrocyte rigidity	Rickets and osteomalacia caused by decreased bone mineralization	Decreased tubular transport maximum for bicarbonate	Increased 1,25-dihydroxy-vitamin D ₃ levels
Paresthesias			Rhabdomyolysis	Hemolysis		Decreased renal gluconeogenesis	Increased creatinine phosphokinase levels
Confusion				Leukocytes		Decreased titratable acid excretion	Increased aldolase levels
Delirium				Impaired phagocytosis		Hypercalciuria	
Coma				Decreased granulocyte chemotaxis		Hypermagnesuria	
				Platelets			
				Defective clot retraction			
				Thrombocytopenia			

FIGURE 7-18

Signs and symptoms of hypophosphatemia. (Adapted from Hruska and Slatopolsky [2] and Hruska and Gupta [7].)



FIGURE 7-19

Pseudofractures (Looser's transformation zones) at the margins of the scapula in a patient with oncogenic osteomalacia. Similar to the genetic X-linked hypophosphatemic rickets, a circulating phosphaturic factor is believed to be released by the tumor, causing phosphate wasting and reduced calcitriol formation by the kidney. Note the radiolucent ribbonlike decalcification extending into bone at a right angle to its axillary margin. Pseudofractures are pathognomonic of osteomalacia with a low remodeling rate.

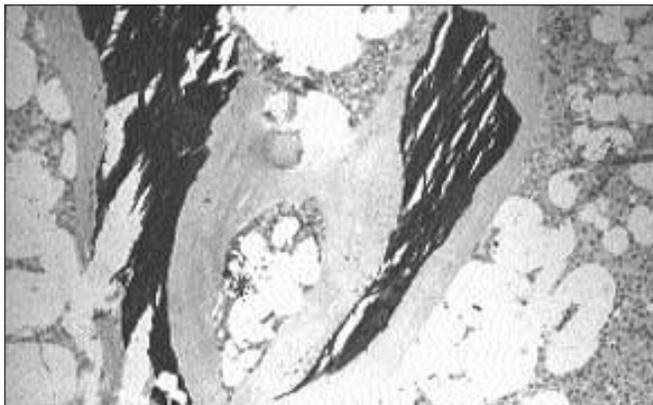
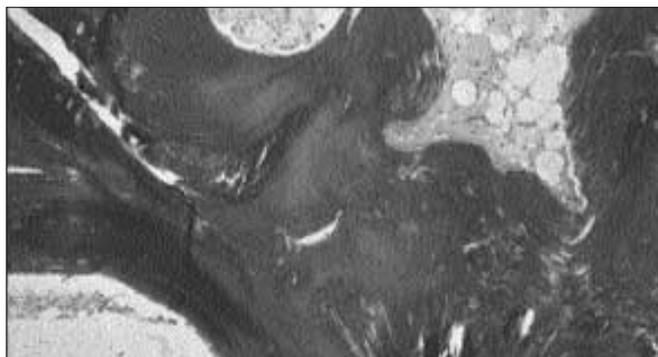


FIGURE 7-20 (see Color Plate)

Histologic appearance of trabecular bone from a patient with oncogenic osteomalacia. Undecalcified bone section with impaired mineralization and a wide osteoid (organic matrix) seam stained with von Kossa's stain is illustrated. Note the wide bands of osteoid around the mineralized bone. Absence of osteoblasts on the circumference of the trabecular bone portion indicates a low remodeling rate.

**FIGURE 7-21** (see Color Plate)

Microscopic appearance of bone section from a patient with vitamin D deficiency caused by malabsorption. The bone section was stained with Masson trichrome stain. Hypophosphatemia and hypocalcemia were present. Note the trabecular bone consisting of very wide osteoid areas (red) characteristic of osteomalacia.

USUAL DOSAGES FOR PHOSPHORUS REPLETION

Severe symptomatic hypophosphatemia (plasma phosphate concentration < 1 mg/dL)

10 mg/kg/d, intravenously, until the plasma phosphate concentration reaches 2 mg/dL

Phosphate depletion

2–4 g/d (64 to 128 mmol/d), orally, in 3 to 4 divided doses

Hypophosphatemic rickets

1–4 g/d (32 to 128 mmol/d), orally, in 3 to 4 divided doses

FIGURE 7-22

Usual dosages for phosphorus repletion.

PHOSPHATE PREPARATIONS FOR ORAL USE

Preparation	Phosphate, mg	Sodium, mEq	Potassium, mEq
K-Phos Neutral®, tablet (Beach Pharmaceuticals, Conestee, SC)	250	13	1.1
Neutra-Phos®, capsule or 75-mL solution (Baker Norton Pharmaceuticals, Miami, FL)	250	7.1	7.1
Neutra-Phos K®, capsule or 75-mL solution (Baker Norton Pharmaceuticals, Miami, FL)	250	0	14.2

FIGURE 7-23

Phosphate preparations for oral use.

PHOSPHATE PREPARATIONS FOR INTRAVENOUS USE

Phosphate preparation	Composition, mg/mL	Phosphate, mmol/mL	Sodium, mEq/mL	Potassium, mEq/mL
Potassium	236 mg K_2HPO_4 224 mg KH_2PO_4	3.0	0	4.4
Sodium	142 mg Na_2HPO_4 276 mg $NaH_2HPO_4 \cdot H_2O$	3.0	4.0	0
Neutral sodium	10.0 mg Na_2HPO_4 2.7 mg $NaH_2HPO_4 \cdot H_2O$	0.09	0.2	0
Neutral sodium, potassium	11.5 mg Na_2HPO_4 2.6 mg KH_2PO_4	1.10	0.2	0.02

FIGURE 7-24

Phosphate preparations for intravenous use. (From Popovtzer, *et al.* [6]; with permission.)

3 mmol/mL of phosphate corresponds to 93 mg of phosphorus.