TABLE 73-3 CAUSES OF HYPERPHOSPHATEMIA

- Artifactual
  - Hemolysis
- Increased gastrointestinal intake
  - Rectal enemas
  - Oral Phospho-Soda purgatives
  - Gastrointestinal bleeding
- Intravenous phosphate loads
  - K-Phos
  - Blood transfusions
- Endogenous phosphate loads
  - Tumor lysis syndrome
  - Rhabdomyolysis (crush injury)
  - Hemolysis
- Reduced renal clearance
  - Chronic or acute renal failure
  - Hypoparathyroidism
  - Acromegaly
  - Tumoral calcinosis

collection of a fresh sample and immediate repeat determination of the serum phosphate level.

Increased Gastrointestinal Intake

Hyperphosphatemia may occur in patients receiving large oral phosphate loads. In a literature review, most cases of phosphate-induced hypocalcemia were caused by the administration of phosphate-containing purgatives as preparation for colonoscopy. Another underappreciated cause of this phenomenon is inadvertent perforation of the rectum during the administration of a rectal Phospho-Soda enema, with delivery of large amounts of phosphate directly into the peritoneal cavity, from which it is rapidly absorbed. Upper GI tract bleeding from ulcers of gastritis provides a large GI phosphate load and may be associated with hyperphosphatemia.

Intravenous Phosphate Loads

Large amounts of phosphate may be administered during treatment to replete potassium using potassium phosphate preparations. What appear to be trivial quantities of potassium preparation (e.g., 20 to 40 mEq of K-Phos) actually contain large amounts of phosphate and may lead to severe hyperphosphatemia and hypocalcemia (see Chapter 72). A second vehicle for delivering phosphate intravenously is transfusions of red blood cells, which ultimately hemolyze and release their copious phosphate stores.

Endogenous Phosphate Loads

Hyperphosphatemia may result from the destruction of large amounts of tissue in three situations. One is the tumor lysis syndrome, typified by a large Burkitt lymphoma responding promptly to chemotherapy with massive cell death. A second phenomenon is acute rhabdomyolysis releasing phosphate from skeletal muscle, and a third is severe hemolysis. In each case, a large phosphate load is delivered into the ECF. Combined with renal impairment common in these situations, this results in renal failure, severe hypocalcemia, seizures, and sometimes death.

Reduced Renal Clearance

Renal clearance of phosphate is the main mechanism for maintaining phosphate homeostasis. Acute and chronic disorders of the kidney lead to hyperphosphatemia. Because PTH prevents phosphate reabsorption in the proximal nephron, hypoparathyroidism is typically associated with high-normal to frankly elevated serum phosphorus values. A condition called *tumoral calcinosis*, in which the ability of the kidney to clear phosphate is specifically defective, leads to chronic hyperphosphatemia and accumulation of calcium-phosphate salts around large joints of the appendicular skeleton. Children, particularly adolescents, have higher serum phosphate concentrations than adults.

TABLE 73-4 CAUSES OF HYPOPHOSPHATEMIA

- Inadequate phosphate (PO_4) intake
  - Starvation
  - Malabsorption
  - PO_4-binding antacid use
  - Alcoholism
- Renal PO_4 losses
  - Primary, secondary, or tertiary hyperparathyroidism
  - Humoral hypercalcemia of malignancy (parathyroid hormone–related protein)
  - Diuretics, calcitonin
  - X-linked hypophosphatemic rickets
  - Autosomal dominant hypophosphatemic rickets
  - Oncogenic osteomalacia
  - Fanconi's syndrome
  - Alcoholism
- Excessive skeletal mineralization
  - Hungry bone syndrome after parathyroidectomy
  - Osteoblastic metastases
  - Healing osteomalacia, rickets
- PO_4 shift into extracellular fluid
  - Recovery from metabolic acidosis
  - Respiratory alkalosis
  - Starvation refeeding, intravenous glucose

HYPOPHOSPHATEMIA

Symptoms and Signs

Phosphate participates in a vast array of key cellular processes, including DNA synthesis and replication, energy generation and use, oxygen uptake and delivery by erythrocytes, and maintenance of the redox state of every cell in the body (see Chapter 72). The signs of phosphate depletion are nonspecific, diffuse, and often life-threatening. These signs may include respirator dependence, congestive heart failure, coma, hypotension, and generalized weakness and malaise. Because the signs and symptoms are nonspecific, they are frequently attributed to other causes and are left untreated. They typically occur in intensive care units (ICUs). In these settings, oral nutrition is nonexistent, intravenous phosphate repletion is inadequate, and diuretics and saline infusions accelerate renal phosphate losses. Appropriate therapy can produce startling results, with patients suddenly returning from being moribund to being ambulatory, extubated, and conversant.

Chronic hypophosphatemia leads to defects in skeletal mineralization, a phenomenon called *rickets* in children or *osteomalacia* in adults. These syndromes produce weakness, bone pain, bowing of the long bones, and fractures or pseudofractures (see Chapter 74).

Differential Diagnosis

Disorders can be divided into hypophosphatemia resulting from inadequate intake, from excessive renal losses, from excessive skeletal uptake, or from shifts of phosphate from the ECF into cells (Table 73-4). From a diagnostic standpoint, measuring the TmP (see Chapter 72) is important because it provides rapid determination of which type of hypophosphatemia the patient is confronting.

Inadequate Phosphate Intake

Disorders that involve inadequate phosphate intake are associated with a high TmP. Because essentially all foods are rich in