

Fluid and Electrolyte Disturbances Associated with Tube Feedings

Clinicians generally agree with the philosophy that “When the gut works, use it.” That is, if gastrointestinal function is present, enteral feedings should be favored over parenteral nutrition. Aside from being less expensive, enteral feedings are associated with better preservation of both immune function and intestinal function. Nevertheless, tube feedings are not without problems. Primarily, these problems arise because many tube-fed patients have preexisting fluid and electrolyte imbalances associated with their underlying illnesses. A multitude of enteral products are available; some are “disease specific” and others are “standard” (suitable for most patients). It is important to review some of the characteristics of enteral formulas to understand their potential impact on fluid and electrolyte balance.

FORMULA OSMOLALITY

Osmolality is an important characteristic of an enteral formula; it is primarily a function of the number and size of molecular and ionic particles in a given volume. **Table 12-1** shows the wide variance in osmolalities of some commercially available tube feeding formulas. Whereas some formulas approximate the osmolality of plasma (300 mOsm/kg) and, therefore, are deemed isotonic, others have considerably higher osmolalities and are referred to as “hypertonic.” Isotonic formulas are generally well tolerated; in contrast, hypertonic formulas can slow gastric emptying and cause nausea, vomiting, and distention. When hypertonic formulas are administered in the small bowel,

Table 12-1 Characteristics of Selected Enteral Formulas

Formula	Cal/mL	Osmolality	Content (mg) per 8 Ounces of Formula				
			Na	K	Ca	P	Mg
Glucerna 1.0	1.0	355	220	370	170	170	67
Glucerna 1.5	1.5	875	330	600	240	240	95
Jevity 1.0	1.0	300	220	375	215	180	72
Osmolite 1.0	1.0	300	220	370	180	180	72
Osmolite 1.5	1.5	525	330	425	240	240	95
Pulmocare	1.5	475	310	465	250	250	100
Two-Cal HN	2.0	725	345	580	250	250	100
Vital HN	2.0	500	170	420	200	200	80

Notes: All of the formulas are made by Abbott Laboratories, Abbott Park, Illinois. Formulations may have changed since this table was prepared; refer to the manufacturer’s literature.

they create an osmotic gradient that pulls water into the intestine. If the fluid is not adequately absorbed, cramping and diarrhea may result. For this reason, hypertonic formulas are introduced slowly until the body has time to adapt to them.

A formula's osmolality affects the renal solute load and thus the water requirements. Renal solute load can be defined as the sum of substances that must be excreted by the kidneys (such as urea, potassium, sodium, and chloride). A high renal solute load (created by nutrient use) requires a large water volume for excretion. If enough water is not provided, the patient will become dehydrated. Therefore, the renal solute load imposed by a formula should be considered in patients with impaired renal function and in those with increased losses of body fluids (such as from fever or diarrhea).

A number of liquid medications administered via feeding tubes are hyperosmolar and can cause osmotic diarrhea if given undiluted, especially into the small intestine. Among these products are acetaminophen, potassium chloride, and phosphosoda. For example, the osmolality of an acetaminophen solution can range between 3000 and 6000 mOsm/kg. The delivery of hyperosmolar preparations should be limited to the stomach; even then, the medications should be diluted before administration and water flushes given through the tube before and after delivery. This action not only dilutes the medication, but also enhances its absorption. Of course, it is important to keep any fluid restrictions in mind. At times, the parenteral route may be necessary for electrolyte supplements when they are not tolerated by the GI tract.

TYPES OF FORMULAS

Commercial sources supply standardized as well as specialized products targeted to patients with specific problems, such as renal, hepatic, and respiratory failure. Because numerous enteral formula products are available, it is important to read the literature supplied by manufacturers. Enteral formulas are classified as standard, elemental, or specialized, with multiple formulas available in each category.¹

Standard Formulas

A standard formula contains intact protein and is similar to an average diet for healthy individuals; it can be administered to patients with normal digestion. These formulas are available with and without added fiber. Unless there is evi-

dence to the contrary, a standard formula is the product of choice for the majority of tube-fed patients.²

Calorie-Dense Formulas

A calorie-dense formula usually contains 2.0 kilocalories per milliliter of fluid and is used in patients who require fluid restriction—for example, patients with congestive heart failure, syndrome of inappropriate antidiuretic hormone (SIADH), or renal failure. For instance, for a patient requiring 1800 kcal/day, the amount of water delivered in the formula could be reduced by 900 mL merely by converting from a 1.0 calorie per milliliter formula to a 2.0 calories per milliliter formula.³

Fiber-Containing Formulas

Fiber-containing formulas may be helpful in patients with diarrhea or constipation. The fiber added to the formula increases stool bulk and helps to regulate bowel transit time.⁴ Recall that the colon is the final site of water and electrolyte absorption and ultimately determines fecal composition. In patients who can tolerate high-residue formulas, use of a high-fiber formula is thought to increase the sodium and water absorptive ability of the colon, thereby minimizing fecal fluid loss. For example, in a study of a group of 20 critically ill patients randomized to either a soluble fiber formula or a fiber-free formula, the number of liquid stools was significantly lower in the fiber group.⁵ It has been recommended that this type of formula be considered in patients for whom tube feedings will be the sole source of nutrition for a long period of time, especially if intestinal disease is present.⁶

Elemental Formulas

An elemental formula contains hydrolyzed protein and simple sugars; further, it has a low fat content.⁷ This type of formula is administered to patients with severe malabsorption, such as may be seen with intestinal atrophy or loss of absorptive surface associated with profound malnutrition, critical illness, and acquired immune deficiency syndrome (AIDS).

Research reports focusing on the efficacy of elemental diets provide mixed findings. For example, several studies have indicated that peptide-based formulas are helpful in avoiding diarrhea in hypoalbuminemic, critically ill patients.^{8,9} In contrast, a larger prospective study did not demonstrate any advantage in a peptide-based formula over a standard, polymeric formula.¹⁰ Further, a meta-analysis of 10 trials involving a total of 334 patients found no significant

difference in the efficacy of elemental versus non-elemental formulas.¹¹ One group of investigators recommended that the use of elemental formulas be limited to specific conditions in which absorption has been definitely shown to be impaired.¹² Another group of investigators indicated that enteral feeding with elemental diets can lessen diarrhea in patients infected with human immunodeficiency virus (HIV).¹³ Elemental formulas are more expensive than standard formulas and have an unpleasant taste and odor.

Specialized Formulas

Formulas for Renal Disease

Compared to standard enteral formulas, formulas designed specifically for renal patients are calorically dense, are lower in protein, and have lower concentrations of potassium, magnesium, and phosphorus. Such a formulation is used because patients with renal failure have difficulty excreting urea (the end product of protein metabolism), electrolytes (especially potassium, phosphorus, and magnesium), and fluid. Thus an enteral formula for a renal failure patient not receiving dialysis should be calorically dense and restricted in protein and minerals. The renal enteral formula contains a high percentage of essential amino acids (allowing for protein synthesis with minimal production of urea). Patients with renal failure who are being tube fed require frequent monitoring of electrolyte values and fluid status. Standard enteral formulas are usually acceptable for patients with mild renal impairment or those who are on dialysis.¹⁴

Formulas for Chronic Obstructive Pulmonary Disease

Compared to standard formulas, enteral formulas for patients with chronic obstructive pulmonary disease (COPD) are lower in carbohydrate and higher in fat—a formulation intended to lower carbon dioxide production and, therefore, improve pulmonary status. Recall that metabolism of carbohydrate yields more carbon dioxide than does metabolism of fat. Lessening the formation of carbon dioxide reduces the workload on the lungs, which are responsible for eliminating carbon dioxide.

It has been pointed out that the amount of carbon dioxide generated is more a function of the number of calories delivered than of the formula's fat-to-carbohydrate ratio.¹⁵ For this reason, it is important to not overfeed pulmonary patients. Moreover, it is more difficult to wean a patient from a mechanical ventilator when excessive calories are delivered.

Formulas for Hepatic Disease

For patients with hepatic insufficiency who cannot tolerate the protein contained in standard enteral formulas, specialized products are available that are calorically dense and low in protein (to minimize ammonia production). Hepatic formulas contain increased amounts of branched chain amino acids and reduced amounts of aromatic amino acids.¹⁶ Theoretically, hepatic enteral formulas should reduce the neurological symptoms that occur with hepatic encephalopathy.¹⁷ These products are expensive, however, and their use is generally limited to patients with hepatic failure associated with encephalopathy.

Formulas for Diabetes

The carbohydrate content in standard enteral formulas may not be tolerated by patients with diabetes or stress-induced glucose intolerance. Thus use of a formula with complex carbohydrates (such as fructose) and fiber improves blood sugar control by delaying gastric emptying and reducing intestinal transit time.¹⁸ Trends toward better glycemic control with the use of specialized diabetic formulas have been reported in several small studies.^{19–21} However, it is unclear if the difference in glycemic control between specialized diabetic formulas and standard formulas is clinically significant. Given the current emphasis on tight blood glucose control via insulin drips in critically ill patients, special diabetic formulas may be used less often.

FLUID AND ELECTROLYTE DISTURBANCES ASSOCIATED WITH TUBE FEEDINGS

Tube-fed patients tend to have the fluid and electrolyte disturbances associated with their underlying disease and treatment conditions. Theoretically, then, it should be possible to observe all types of electrolyte disturbances in tube-fed patients. In addition, factors related to the enteral formula itself can produce disturbances if these products are used incorrectly. A combination of electrolyte imbalances is associated with refeeding syndrome, a potentially deadly complication.

Refeeding Syndrome

Definition

Refeeding syndrome (RFS) comprises a constellation of metabolic derangements that can occur when either parenteral or enteral nutrients are administered to a patient

who has been malnourished for a period ranging from days to weeks.²² Although parenteral nutrition has received more attention as a precipitator of RFS, enteral feedings are not without risk. For example, the sudden deaths of four malnourished children within 6 to 9 days of starting high-caloric enteral feedings have been reported.²³

The major electrolyte imbalances in RFS are hypophosphatemia, hypokalemia, and hypomagnesemia (discussed separately later in this chapter). These imbalances are associated with many of the symptoms of RFS (**Table 12-2**). Other problems associated with this syndrome include fluid and sodium retention, hyperglycemia, thiamine deficiency, and neurologic and hematologic complications, occurring within the first few days of feeding a starving patient.²⁴ While the pathophysiology of RFS is complex, it is primarily the result of an acute intracellular shift of electrolytes (phosphate, potassium, and magnesium), increased demand for phosphate during tissue anabolism, and formation of high-energy intracellular bonds.²⁵

Potentially life-threatening complications of RFS include cardiac arrhythmias, heart failure, respiratory failure, and hematologic derangements. (See Case Study 11-3.) **Table 12-3** summarizes selected risk factors associated with this syndrome.

Major Electrolyte Problems

Hypophosphatemia. As indicated previously, refeeding causes phosphates to shift into the cells during tissue synthesis; when this happens, the plasma phosphate level may drop precipitously. Hypophosphatemia tends to occur less often in enterally fed patients than in those who receive total parenteral nutrition (TPN), because enteral nutrition solutions usually contain adequate phosphate for patients with normal phosphate stores. However, this imbalance

remains a serious problem during aggressive enteral feeding of starving patients. Despite the phosphate content in enteral formulas, patients with protein-energy malnutrition can develop severe hypophosphatemia during enteral feedings; additive risk factors include chronic alcoholism and intestinal malabsorptive conditions.²⁶ For this reason, it is important to monitor serum phosphate levels daily for at least 1 week after commencement of feedings in malnourished patients.

Hypokalemia. Hypokalemia is a component of the refeeding syndrome. Adding to the problem are other causes of hypokalemia, including the use of potassium-losing diuretics and diarrhea. As shown in Table 12-1, the potassium content of tube feeding formulas varies. Hypokalemia can result if the potassium intake is chronically less than body requirements.

Hypomagnesemia. Hypomagnesemia is another component of RFS. As with the other primary cellular electrolytes (potassium and phosphorus), extracellular magnesium deficiency may result if inadequate amounts are present in the formula or added as supplements (either enterally or parenterally).

Sodium and Water Retention. For an unknown reason, the body retains fluid during RFS, causing the extracellular space to expand. This fluid retention increases cardiac workload, to the point that it may precipitate heart failure in patients with cardiovascular disease. The increased fluid retention, coupled with the adverse cardiac effects of hypophosphatemia, hypokalemia, and hypomagnesemia, places all patients with this syndrome at risk for adverse cardiac events.

Table 12-2 Selected Clinical Features of Refeeding Syndrome and Associated Imbalances

<i>Clinical Feature</i>	<i>Probable Associated Imbalances</i>
Paresthesias and muscle weakness	Hypokalemia, hypophosphatemia
Cardiac dysrhythmias	Hypokalemia, hypomagnesemia
Decreased cardiac muscle strength	Hypophosphatemia
Respiratory failure	Hypophosphatemia, hypokalemia
Congestive heart failure	Hypophosphatemia, salt and water retention
Rhabdomyolysis, muscle pain	Hypophosphatemia
Dysfunction of erythrocytes, leukocytes, and platelets	Hypophosphatemia
Slowed gastrointestinal motility	Hypokalemia

Table 12-3 Selected Risk Factors for Refeeding Syndrome*Patient Characteristics*

- Poor food intake for a period of more than 10 days
- Weight less than 70% of ideal body weight

Disease Conditions

- Anorexia nervosa
- Alcoholism
- Malignancy
- Intestinal malabsorption
- Recent major surgery

Thiamine Deficiency. Malnourished patients may also become deficient in thiamine (vitamin B₁), an important cofactor for carbohydrate metabolism. Wernicke's encephalopathy and lactic acidosis may develop if patients who are deficient in thiamine are refeed carbohydrates without prior adequate thiamine replacement.

Clinical Signs

Clinical signs of RFS may be nonspecific and difficult to recognize (see Table 12-2). Most prominent are the symptoms of hypophosphatemia, the primary electrolyte problem in RFS patients. Other signs may reflect those associated with deficits of potassium and magnesium (also prominent in RFS). Rhabdomyolysis may result from severe hypophosphatemia and hypokalemia, resulting in muscle pain and weakness. Weakness of the diaphragm associated with hypophosphatemia in conjunction with RFS may make it difficult to wean these patients from mechanical ventilation.²⁷ Cardiomyopathy is another possible complication, as are seizures, a disturbed mental state, and renal tubular impairment. Hematological effects associated with severe hypophosphatemia include thrombocytopenia, abnormal clotting process, and impaired leukocyte function.²⁸ Sodium and water retention may become manifest as edema associated with the rapid administration of carbohydrate to a starving patient. The most feared sequela is the potential for cardiac and respiratory arrest associated with RFS.

Prevention

Failure to detect and treat RFS can result in serious and even fatal consequences. Thus early recognition and interventions to prevent the syndrome is critical to protect patients from harm:

1. Recognize "at-risk" patients, such as those with chronic cachexia due to prolonged starvation or any patient who has been chronically deprived of adequate nutrition (see Table 12-3). For example, a patient whose weight is less than 70% of ideal is at greater risk than is a patient whose weight is near normal.²⁹ It is important to be aware that malnutrition is a major problem in hospitalized patients.
2. Advocate the testing of plasma electrolytes before initiating nutritional support in at-risk patients, either orally, enterally, or intravenously. Advocate replacing electrolyte deficits *before* starting feedings.
3. Begin nutritional repletion *slowly* and keep increases in calories modest during the first week.
4. Advocate daily assessments of serum sodium, potassium, magnesium, and phosphorus levels until the patient is stable.

Other Electrolyte Imbalances**Hyponatremia**

Hyponatremia is probably the most common imbalance seen in tube-fed patients. Contributing factors include water-retaining states (e.g., SIADH) and abnormal routes of sodium loss (primarily diarrhea or diuretic use). In the presence of excessive antidiuretic hormone (ADH) activity, large water supplements (by any route) can cause dilution of the serum sodium level, particularly when hypotonic or isotonic feedings are used. Although water boluses via the tube are usually charted, it is often difficult to determine the volume of flush solutions used to maintain tube patency and the volume of fluid in which medications are administered. The latter factor can be a significant source of fluid intake; thus the diluent fluid volume should be measured and recorded on the intake and output (I & O) record. Intravenous fluids also should be considered as a source of free water (such as in the use of D₅W as a diluent for intravenous medications).

Hypernatremia

Hypernatremia is less common today than it was in the past when high-protein, high-osmolality formulas (approximately 1000 mOsm/kg) were often used. Ingestion of large solute loads with too little water can result in dehydration (hypernatremia) and azotemia (uremia). Although formulas in use today typically have lower osmolalities, hypernatremia can still develop in patients who are given inadequate water supplements. Hypernatremia is most

prevalent in patients who are unable to make their thirst known (such as those who are unconscious, very young, aphasic, elderly, or debilitated). Elderly patients are notably more prone to developing hypernatremia because of their decreased renal concentrating ability, which makes it difficult for them to conserve needed water. The very young may also have difficulty in concentrating urine because of immature renal function. With decreased ability to concentrate urine, patients need more fluid to eliminate body wastes. If this fluid is not provided through the feeding tube or the IV route, it is taken from internal fluid reserves.

Hyperkalemia

If potassium supplements are given in addition to the enteral formula, hyperkalemia could result, particularly in high-risk patients (such as those with renal failure). Even standard formulas may contain more potassium than some patients can tolerate.

Hyperphosphatemia

Although hypophosphatemia is far more common, hyperphosphatemia has also been observed in tube-fed patients who have renal disease. This incidence reflects the parallel between electrolyte abnormalities and underlying disease states in tube-fed patients.

Hypermagnesemia

Patients with renal failure are at risk for hypermagnesemia if the amount of magnesium contained in the formula exceeds the ability of the kidneys to excrete magnesium. Use of magnesium-containing medications adds to the risk.

Fluid Volume Overload

It is possible to cause fluid volume overload when attempting to provide sufficient calories to a patient with renal, cardiac, or hepatic disease. For such patients, a formula supplying 2 kcal/mL is often selected (as opposed to one supplying only 1 kcal/mL). In addition, special low-sodium formulas are available for such patients. As noted in Table 12-1, some formulas contain considerably more sodium than others.

Edema can also occur when a high-carbohydrate formula is fed to a previously fasting patient.³⁰ This is because refeeding with carbohydrate causes an abrupt decrease in urinary sodium excretion in patients who have fasted for as little as 3 days. Fluid retention is most pronounced during the first few days of refeeding. Contributing to edema in

tube-fed patients may be the presence of hypoalbuminemia, which favors shifting of fluid from the vascular to the interstitial space.

Fluid Volume Deficit Associated with Hyperglycemia

Tube-fed patients are at risk for hyperglycemia because of the high carbohydrate content of some formulas and because of the relative insulin resistance commonly present in acute illness. Patients with mild to moderate hyperglycemia need extra fluid to replace increased urinary fluid losses until their disorder can be controlled by hypoglycemic agents. (When insulin is administered, it is important to remember its contributory effect on the shifting of potassium, phosphorus, and magnesium from the extracellular fluid into the cells.) Occasionally, tube feedings will cause severe hyperglycemia that may progress to a hyperosmolar reaction.

Zinc Deficiency

Although several trace element deficiencies may occur in patients receiving long-term enteral feedings as their only nutritional source, zinc deficiency has probably received the most attention. Zinc deficiency has been described in two patients who received tube feedings for 4 and 7 months, respectively.³¹ Both patients developed skin rashes around the groin and under the breasts and axilla; after supplementation with zinc sulfate, these rashes disappeared and the patients' serum zinc levels returned to normal.

Monitoring Metabolic Status

Routine Laboratory and Clinical Monitoring

Although clinical assessment is important, electrolyte disturbances are usually detected by laboratory analysis. Recommendations vary regarding the frequency of metabolic monitoring in tube-fed patients; however, it seems reasonable to measure serum sodium, potassium, glucose, blood urea nitrogen (BUN), and creatinine daily for the first week and once a week thereafter, and serum phosphorus, magnesium, and calcium at least twice weekly during the first week and once a week subsequently. As evidence of stabilization is gathered, the testing frequency can be gradually decreased. In many situations, the severity of illness dictates how frequently laboratory values are obtained. For example, it may be necessary to check all electrolytes daily in critically ill patients.

Fluid I & O should be monitored and recorded every 8 hours (or hourly in acute situations, such as when the patient experiences a hyperosmolar reaction). Body weight should be measured and recorded daily. In acute care settings, capillary blood glucose should be checked regularly until the patient is stable. If exogenous insulin is administered, capillary blood glucose should be measured every 4 hours. If blood glucose levels are markedly elevated, urine acetone levels should also be tested.

Hydration Status

Because tube-fed patients may develop either fluid volume deficit or fluid volume excess, with or without sodium imbalances, it is necessary to monitor the hydration status closely (Table 12-4). A perplexing problem for the nurse is determining how much free water is needed for each tube-

fed patient. The previous discussion identified several variables affecting this decision. Some key questions to consider include the following:

- Is there a need for fluid restriction due to SIADH or renal or cardiac disease?
- Is extra fluid required due to delivery of high-osmolality, high-protein feedings, or increased loss from other routes, such as diarrhea, fistula or wound drainage, hyperventilation, or fever?
- Is the patient receiving significant amounts of fluid through the IV route?
- How does the I & O record look?
- What is the serum sodium concentration?

All of these factors must be considered individually.

Table 12-4 Summary of Assessment of Hydration Status of Tube-Fed Patients

<i>Assessment</i>	<i>Description</i>
Fluid intake and output	<p>Record volume and type of all fluids given by mouth, tube, and IV; include water used to flush tube to maintain patency and to administer medications.</p> <p>Record all fluid losses, including those from the following sources:</p> <ul style="list-style-type: none"> • Urine • Liquid feces • Vomitus • Drainage from fistulas, wounds <p>Consider fluid losses associated with fever, perspiration, hyperventilation, and dry environmental conditions.</p>
Urine concentration	<ul style="list-style-type: none"> • In addition to volume of urine, record its color (ranging from dark amber to pale or colorless). • If necessary, measure urinary specific gravity with a urinometer or refractometer.
Body weight	<ul style="list-style-type: none"> • Measure body weight daily (using the same scales and the same clothing). • A slight increase in weight is anticipated in the anabolic patient; for example, a weight gain of 1 to 1.5 lb per week may be the result of increased nutrients. • Daily increases in weight may indicate fluid gain.
Edema	<ul style="list-style-type: none"> • Look for dependent edema in the feet and ankles of ambulatory patients and in the backs of bedfast patients. • Assess breath sounds for pulmonary edema.
Sensorium	<ul style="list-style-type: none"> • Assess for changes in sensorium (from baseline) after feedings are initiated. Sodium derangements (high or low) can affect responsiveness and level of consciousness.
Blood chemistries	<ul style="list-style-type: none"> • Examine serum sodium level: If high, it indicates a need for free water; if low, it indicates a need for water restriction. • Examine BUN/Cr ratio: If > 20:1, fluid volume deficit likely exists. • Look for elevated blood sugar level: If present, the patient is at increased risk for osmotic diuresis and fluid volume deficit.

Water Replacement Guidelines

Given these qualifiers, a rough guideline for the free water requirements of normal afebrile adults receiving tube feedings is 30 to 35 ml of water per kilogram of body weight per day. Another consideration in determining the amount of extra water to provide is the amount of water included in the formula itself. For example, most formulas that provide 1 calorie/mL contain 800 to 850 mL of water per liter of formula; more calorically dense formulas may contain only 600 mL per liter of formula. After determining how much water is provided by the enteral formula, it is necessary to calculate how much IV fluid is infused as well as how much water is given through the feeding tube with medications or as flushes to maintain tube patency. Subtracting what is given from what is needed provides the amount of extra water that should be provided.

Diarrhea

Diarrhea is a frequent complication in tube-fed patients.³² Although in some cases the cause of diarrhea is unknown, it can often be traced back to the enteral delivery of medications, such as antibiotics, potassium and phosphate supplements, and sorbitol-based drugs. Intestinal infections (e.g., *Clostridium difficile*) are also frequent causes of diarrhea. For example, a recent study of 20 patients started on nasogastric tube feedings found that 10 patients (50%) developed diarrhea and that these individuals had significantly higher concentrations of clostridia.³³ Yet another cause of diarrhea is the rapid delivery of a formula with a high osmolality.

If not corrected, diarrhea may necessitate the cessation of enteral nutritional support.³⁴ One way to minimize diarrhea is to prevent microbial contamination of the enteral formula and the delivery system. For example, a study of a large cohort of tube-fed patients found that the rate of diarrhea was significantly lower in those individuals for whom strict adherence to delivery-set washing-and-changing procedures was observed.³⁵ If diarrhea is due to enteral-delivered medications, it may be necessary to change the medications to the intravenous forms. Also, it may be necessary to select a different enteral formula, such as one without osmotically active, poorly absorbed short-chain carbohydrates.³⁶ Switching from a hyperosmolar formula to an isotonic formula may be sufficient to reduce diarrhea. Use of a fiber-containing formula is sometimes recommended to minimize diarrhea.³⁷

CASE STUDIES

Case Study 12-1

The condition of a 75-year-old woman admitted to the ICU with shortness of breath progressively worsened over a period of 1 week.³⁸ The patient's medical history included hypertension, interstitial lung disease, and alcohol abuse. She showed no clinical evidence of liver disease or of drinking in the week preceding her admission to the ICU. On physical examination, the patient was alert and fully oriented, but moderately malnourished. A chest x-ray showed pulmonary congestion. Rales were present. A diagnosis of congestive heart failure was made. The patient responded to diuretics, and serum electrolytes were found to be within normal range. After she was stabilized, enteral feedings were started and progressively advanced to 42 kcal/kg/day. On the third day of feedings, the patient's serum phosphorus level began to drop and she became drowsy. On the fourth day of feeding, she developed coma and respiratory failure and required intubation and mechanical ventilation. Her serum phosphorus level on day 5 was 0.5 mg/dL (normal range is 2.5 to 4.5 mg/dL). Despite subsequent correction of the hypophosphatemia, the patient did not regain consciousness and died on the eleventh hospital day. It was surmised that hypophosphatemia initiated the chain of events that ultimately led to her death.

Commentary. Central to the pathophysiology of refeeding syndrome is a block in the synthesis of adenosine triphosphate and 2,3-diphosphoglycerate, which ultimately leads to neurological and muscular dysfunction. Metabolic encephalopathy associated with hypophosphatemia can cause lethargy and coma; further, respiratory failure can be a consequence of severe hypophosphatemia. Like most malnourished patients, this patient had a normal serum phosphorus concentration on admission, even though her total body phosphorus content was likely diminished by chronic malnutrition. This deficit was unmasked by the initiation of enteral feedings when her body was called on to metabolize the nutrients (especially carbohydrates).

Case Study 12-2

A 22-year-old woman with a history of anorexia nervosa was admitted to the hospital for enteral feedings because she had sustained a large weight loss over the previous few months.³⁹ She was easily tired on exertion and complained of generalized weakness. Her admission body weight was 59

lb and she was 5 ft 1 in. tall. Lying flat, her blood pressure was 90/50 mm Hg; it dropped to 70/50 mm Hg when she sat upright. Her pulse rate was 50 beats/min. Because her serum phosphorus level was low (0.47 mmol/L; approximately 1.46 mg/dL), the patient was given oral phosphate 500 mg, twice daily. Tube feedings were started and advanced over several days to full strength at a rate of 100 mL/hr. Although she felt stronger, the patient became tachycardic on the fourth day. At that time, her serum phosphorus concentration was 0.18 mmol/L (roughly equivalent to 0.6 mg/dL). To counteract this imbalance, she was started on potassium phosphate supplements intravenously. On the sixth day, her serum phosphorus level had dropped to 0.16 mmol/L (0.5 mg/dL) and she developed symptoms of heart failure. Oxygen was started and the patient was given furosemide IV; her tube feedings were discontinued. In addition, her phosphate supplement was increased orally and IV. By the seventh day, her electrocardiogram was essentially normal and she no longer required oxygen. As she improved, the patient was restarted on enteral feedings and continued on oral phosphate supplements only. No further complications were noted.

Commentary. The cardiac decompensation noted in this patient during refeeding was likely caused by hypophosphatemia, and then enhanced by the cardiac changes associated with severe malnutrition. Fortunately, the changes were reversible. The authors of this case study emphasize the need to monitor serum electrolyte levels closely in anorectic patients during refeeding, especially during the first week. Further, they indicate a need to start feedings gradually, implementing graded increases in the caloric content of the feeds.

Case Study 12-3

A case was recently reported in which an obese 60-year-old man with carcinoma of the esophagus and dysphagia was admitted to the hospital for placement of a jejunostomy feeding tube via a mini-laparotomy.⁴⁰ Upon admission, his serum electrolyte levels were within normal range, although he had undergone an unintentional weight loss of approximately 40 lb within months prior to his admission. Initially, a solution of 10% dextrose was administered at a rate of 10 mL/hr via the feeding tube. At this time, the patient's serum K level decreased to 3.0 mEq/L (normal range, 3.5 to 5.0 mEq/L); further, his serum Mg level decreased to 1.6 mg/dL (normal range in the reporting laboratory, 1.8–2.7 mg/dL).

These deficiencies were treated with supplemental potassium and magnesium. A polymeric tube feeding formula was then started at a rate of 10 mL/hr. Over a period of 48 hours, the rate of the enteral formula was increased to 65 mL/hr. At this point, the patient complained of severe dyspnea and abdominal pain. Laboratory results showed a K level of 2.7 mEq/L, a Mg level of 1.5 mg/dL, and a serum phosphate level of 0.7 mg/dL (normal range, 2.5–4.5 mg/dL); recall that a concentration less than 1.0 mg/dL can be life-threatening. The patient was transferred to an ICU where he could be intubated and mechanically ventilated. Intravenous replacement of phosphorus and other electrolytes successfully normalized his serum electrolyte levels over the following 4 days. Jejunostomy feedings were started slowly again after 36 hours in the ICU and gradually advanced to a rate of 50 mL/hr. The patient was gradually weaned from the ventilator but later required a tracheostomy. He was transferred out of the ICU after 35 days; at that time, he was free of ventilatory support and was tolerating jejunostomy feedings.

Commentary. While refeeding syndrome is usually thought to occur in starving patients with a low body weight, this case demonstrates that it can occur even in obese patients who have lost a large percentage of their body weight over a short period of time. As noted in the case description, this patient had sustained a significant recent weight loss.

Case Study 12-4

A case was reported in which a 70-year-old woman was admitted to the hospital with shortness of breath and difficulty swallowing.⁴¹ Although she had lost weight recently, she did not know how much. The patient was tachycardic (pulse rate, 120/min) and had a respiratory rate of 26 breaths/min. On room air, her O₂ saturation was 75%. She complained of dry eyes and mouth. All of her blood work was normal except for a white blood cell count of 13,500. This patient was diagnosed with connective tissue disease leading to myositis and dysphagia.

Upon transfer to an intensive care unit, the patient was mechanically ventilated because of worsening respirations. A nasogastric tube was inserted and feedings were started, using a high-energy enteral formula. Twelve hours after the start of feedings, the patient suffered a cardiac arrest from which she was successfully resuscitated. In the following days, she remained drowsy and had severe muscle weakness; attempts to wean her from mechanical ventilation failed.

Upon consultation with a clinical nutrition team, the patient was diagnosed as having severe malnutrition complicated by refeeding syndrome. On day 1 of the ICU admission, the patient's serum phosphate level was below normal (1.3 mg/dL; normal range, 2.4–4.5mg/dL). Also, her serum magnesium, potassium, and calcium levels were slightly below normal. Following 3 days of repletion of these electrolytes, along with a change to an enteral formula with a reduced carbohydrate content, she was able to be weaned from ventilator. She was later allowed to return home on a normal diet with oral nutritional supplements.

Commentary. This patient fits the picture of a patient at increased risk for refeeding syndrome; that is, she had suffered a recent significant weight loss and was unable to eat due to dysphagia. Upon initiation of a high-energy formula, her serum phosphate, potassium, and magnesium levels dropped below normal. The respiratory weakness that prevented weaning from the ventilator did not subside until these imbalances were corrected and the enteral formula was changed to a low-carbohydrate formula. Recall that a high carbohydrate intake contributes to intracellular shifting of phosphate, potassium, and magnesium from the bloodstream.

Summary of Key Points

- Enteral feedings are commonly used to nourish patients in acute and chronic care facilities.
- A wide variety of formulas are available; their contents are listed on their labels.
- Many formulas provide 1 kcal/mL, while others provide 2 kcal/mL. The latter options are useful in patients who need fluid restriction.
- Hyponatremia is the most common electrolyte imbalance in tube-fed patients, especially those with high antidiuretic (ADH) levels. Contributing factors include excessive water administration during tube flushes and mixing with medications given via the tube.
- Hypophosphatemia, hypokalemia, and hypomagnesemia are imbalances associated with refeeding syndrome. This syndrome is a potential problem when malnourished patients receive aggressive enteral feedings.
- Feedings should be initiated slowly and advanced according to tolerance in malnourished patients to prevent refeeding syndrome.
- Plasma electrolytes should be closely monitored, especially when tube feedings are first initiated.
- Careful monitoring of intake and output is necessary to detect fluid volume imbalances associated with tube feedings.
- Frequent weighing of patients will help healthcare providers detect developing fluid volume imbalances.
- Hyperglycemia is possible with tube feedings, especially in patients with insulin resistance. Therefore, glucose monitoring is indicated during the early phase of feeding in acutely ill patients.
- Hyperosmolar medications should be diluted prior to administration via a feeding tube. The probability of diarrhea is decreased when the medication is administered into the stomach instead of the small bowel.

NOTES

1. Malone, A. M. (2005, June). Enteral formula selection: A review of selected product categories. *Nutrition Issues in Gastroenterology, Series #28. Practical Gastroenterology*, p. 44.
2. Malone, note 1.
3. Malone, note 1.
4. Alpers, D. H., Stenson, W. F., Taylor, B. E., & Bier, D. M. (2008). *Manual of nutritional therapeutics* (5th ed.). Philadelphia: Lippincott Williams & Wilkins, p. 341.
5. Rushdi, T. A., Pichard, C., & Khater, Y. H. (2004). Control of diarrhea by fiber-enriched diet in ICU patients on enteral nutrition: A prospective randomized controlled trial. *Clinical Nutrition*, 23, 1344–1352.
6. Alpers et al., note 4, p. 342.
7. Alpers et al., note 4, p. 342.
8. Brinson, R. R., Curtis, W. D., & Singh, M. (1987). Diarrhea in the intensive care unit: The role of hypoalbuminemia and the response to a chemically defined diet. *Journal of the American College of Nutrition*, 6, 517–523.
9. Brinson, R. R., & Kolts, B. E. (1988). Diarrhea associated with severe hypoalbuminemia: A comparison of a peptide-based chemically defined diet and standard enteral alimentation. *Critical Care Medicine*, 16, 130–132.
10. Mowatt-Larsen, C. A., Brown, R. O., Wojtsiak S. L., & Kudsk, K. A. (1992). Comparison of tolerance and nutritional outcome between a peptide and a standard enteral formula in critically ill, hypoalbuminemic patients. *Journal of Parenteral and Enteral Nutrition*, 16, 20–24.
11. Zachos, M., Tondeur, M., & Griffiths, A. M. (2007). Enteral nutrition therapy for induction of remission in Crohn's disease: Update of *Cochrane Database Systematic Review* (3)CD000542. *Cochrane Database of Systematic Reviews*, 1, CD000542.
12. Dietscher, J. E., Foulks, C. J., & Smith, R. W. (1998). Nutritional response of patients in intensive care unit to an elemental formula vs a standard enteral formula. *Journal of the American Dietetic Association*, 98, 335–336.
13. Salomon, S. B., Jung, J., Voss, T., Suguitan, A., Rowe, W. B., & Madsen, D. C. (1998). An elemental diet containing medium-chain triglycerides and enzymatically hydrolyzed protein can improve gastrointestinal tolerance in people infection with HIV. *Journal of the American Dietetic Association*, 98, 460–462.
14. Alpers et al., note 4, p. 343.

15. Alpers et al., note 4, p. 342.
16. Malone, note 1.
17. Malone, note 1.
18. Alpers et al., note 4, p. 343.
19. Craig, L. D., Nicholson, S., Silverstone, F. A., & Kennedy, R. D. (1998). Use of a reduced-carbohydrate, modified-fat enteral formula for improving metabolic control and clinical outcomes in long-term care residents with type 2 diabetes: Results of a pilot trial. *Nutrition*, 14, 529–534.
20. Leon-Sanz, M., Garcia-Luna, P. P., Sanz-Paris, A., Gomez-Candela, C., Casimiro, C., Chamorro, J., et al. (2005). Glycemic and lipid control in hospitalized type 2 diabetic patients: Evaluation of 2 enteral nutrition formulas (low carbohydrate-high monounsaturated fat vs high carbohydrate). *Journal of Parenteral and Enteral Nutrition*, 29, 21–29.
21. McCargar, L. J., Innis, S. M., Bowron, E., Leichter, J., Dawson, K., Toth, E., et al. (1998). Effect of enteral nutritional products differing in carbohydrate and fat on indices of carbohydrate and lipid metabolism in patients with NIDDM. *Molecular and Cellular Biology*, 188, 81–89.
22. Marinella, M. A. (2009). Refeeding syndrome: An important aspect of supportive oncology. *Journal of Supportive Oncology*, 7(1), 11–16.
23. Patrick, J. (1977). Death during recovery from severe malnutrition and its possible relationship to sodium pump activity in the leukocyte. *British Medical Journal*, 1, 1051–1054.
24. Stanga, Z., Brunner, A., Leuenberger, M., Grimble, R. F., Shenkin, A., Allison, S. P., et al. (2008). Nutrition in clinical practice—the refeeding syndrome: Illustrative cases and guidelines for prevention and treatment. *European Journal of Clinical Nutrition*, 62, 687–694.
25. Marinella, note 22.
26. Maier-Dobersberger, T., & Lochs, H. (1994). Enteral supplementation of phosphate does not prevent hypophosphatemia during refeeding of cachectic patients. *Journal of Parenteral and Enteral Nutrition*, 18, 182–184.
27. Patel, U., & Sriram, K. (2009). Acute respiratory failure due to refeeding syndrome and hypophosphatemia induced by hypocaloric enteral nutrition. *Nutrition*, 25(3), 364–367.
28. Patel & Sriram, note 27.
29. Alpers et al., note 4, p. 114.
30. Havala, T., & Shronts, E. (1990). Managing the complications associated with refeeding. *Nutrition in Clinical Practice*, 5, 23–29.
31. Jhangiani, S., Prince, L., Holmes, R., & Agardwal, N. (1986). Clinical zinc deficiency during long-term total enteral nutrition. *Journal of the American Geriatric Society*, 34, 385–388.
32. Thorson, M. A., Bliss, D. Z., & Savik, K. (2008). Re-examination of risk factors for non-*Clostridium difficile*-associated diarrhoea in hospitalized patients. *Journal of Advanced Nursing*, 62(3), 354–364.
33. Whelan, K., Judd, P. A., Tuohy, K. M., Gibson, G. R., Preedy, V. R., & Taylor, M. A. (2009). Fecal microbiota in patients receiving enteral feeding are highly variable and may be altered in those who develop diarrhea. *American Journal of Clinical Nutrition*, 89(1), 240–247.
34. Trabal, J., Leyes, P., Hervas, S., Herrera, M., & de Tallo Forga, M. (2008). Factors associated with nosocomial diarrhea in patients with enteral tube feeding. *Nutricion Hospitalaria*, 23(5), 500–504.
35. Luft, V. C., Beghetto, M. G., de Mello, E. D., & Polanczyk, C. A. (2008). Role of enteral nutrition in the incidence of diarrhea among hospitalized adult patients. *Nutrition*, 24(6), 528–535.
36. Barrett, J. S., Shepherd, S. J., & Gibson, P. R. (2009). Strategies to manage gastrointestinal symptoms complicating enteral feeding. *Journal of Parenteral and Enteral Nutrition*, 33(1), 21–26.
37. Alpers et al., note 4, p. 360.
38. Vaszar L. T., Culpepper-Morgan, J. A., & Winter, S. M. (1998). Refeeding syndrome induced by cautious enteral alimentation of a moderately malnourished patient. *Gastroenterologist*, 6, 79–81
39. Vaszar et al., note 38.
40. Patel & Sriram, note 27.
41. Gariballa, S. (2008). Refeeding syndrome: A potentially fatal condition but remains underdiagnosed and undertreated. *Nutrition*, 24(6), 604–606.

