enteral feeding formulas ranges from 3% to 50% of energy. Parenteral fat is provided in separate containers as 20% and 30% emulsions that can be infused separately or mixed in the sterile pharmacy as an all-in-one or total nutrient admixture of amino acids, glucose, lipid, electrolytes, vitamins, and minerals. Although parenteral fat needs to make up only ~3% of the energy requirement in order to meet essential fatty acid requirements, when provided daily as an all-in-one mixture of carbohydrate, fat, and protein, the complete admixture has a fat content of 2–3 g/dL and provides 20–30% of the total energy requirement—an acceptable level that offers the advantage of ensuring emulsion stability. When given as a separate infusion, parenteral fat should not be provided at rates exceeding 0.11 g/kg of body mass or 100 g over 12 h—equivalent to 500 mL of 20% parenteral fat.

Medium-chain triglycerides containing saturated fatty acids with chain lengths of 6, 8, 10, or 12 carbons (>95% of which are C8 and C10) are included in a number of enteral feeding formulas because they are absorbed preferentially. Fish oil contains polyunsaturated fatty acids of the omega 3 family, which improve immune function and reduce the inflammatory response. At this time, fish oil injectable emulsions are available in the United States as an investigational new drug.

PN formulations provide carbohydrate as hydrous glucose (3.4 kcal/g). In enteral formulas, glucose is the carbohydrate source for so-called monomeric diets. These diets provide protein as amino acids and fat in minimal amounts (3%) to meet essential fatty acid requirements. Monomeric formulas are designed to optimize absorption in the seriously compromised gut. These formulas, like immune-enhancing diets, are expensive. In polymeric diets, the carbohydrate source is usually an osmotically less active polysaccharide, the protein is usually soy or casein protein, and fat is present at concentrations of 25–50%. Such formulas are usually well tolerated by patients with normal intestinal length, and some are acceptable for oral consumption.

PROTEIN OR AMINO ACID REQUIREMENTS

The daily protein recommendation for healthy adults is 0.8 g/kg, but body proteins are replenished faster with 1.5 g/kg in patients with PEM, and net protein catabolism is reduced in critically ill patients when 1.5–2.0 g/kg is provided. In patients who are not critically ill but who require SNS in the acute-care setting, at least 1 g of protein/kg is recommended, and larger amounts up to 1.5 g/kg are appropriate when volume, renal, and hepatic tolerances allow. The standard parenteral and enteral formulas contain protein of high biologic value and meet the requirements for the eight essential amino acids when nitrogen needs are met. Parenteral amino acid mixtures and elemental enteral mixtures consist of hydrated individual amino acids. Because of their hydrated status, elemental amino acid solutions deliver 17% less protein substrate than intact proteins. In protein-intolerant conditions such as renal and hepatic failure, modified amino acid formulas may be considered. In hepatic failure, higher branched-chain, amino acid–enriched formulas appear to improve outcomes. Conditionally essential amino acids like arginine and glutamine may also have some benefit in supplemental amounts.

Protein (nitrogen) balance provides a measure of the efficacy of parenteral or enteral SNS. This balance is calculated as protein intake/6.25 (because proteins are, on average, 16% nitrogen) minus the 24-h urine urea nitrogen plus 4 g of nitrogen (the latter reflecting other nitrogen losses). In critical illness, a mild negative nitrogen balance of 2–4 g/d is often achievable. A similarly mild positive nitrogen balance is observed in the nonstressed recuperating patient. Each gram of nitrogen lost or gained represents ~30 g of lean tissue.

MINERAL AND VITAMIN REQUIREMENTS

Parenteral electrolyte, vitamin, and trace mineral requirements are summarized in Tables 98e-3, 98e-4, and 98e-5, respectively. Electrolyte modifications are necessary with substantial gastrointestinal losses from nasogastric drainage or intestinal losses from fistulas, diarrhea, or ostomy outputs. Such losses also imply extra calcium, magnesium, and zinc losses. Zinc losses are high in secretory diarrhea. Secretory diarrhea contains ~12 mg of zinc/L, and patients with intestinal fistulas or chronic diarrhea require an average of ~12 mg of parenteral zinc/d (equivalent to 30 mg of oral elemental zinc) to maintain zinc balance. Excessive urinary potassium losses with amphotericin or magnesium losses with cisplatin or in renal failure necessitate adjustments in sodium, potassium, magnesium, phosphorus, and acid-base balance. Vitamin and trace element requirements are met by the daily provision of a complete parenteral vitamin supplement and trace elements via PN and by the provision of adequate amounts of enteral feeding formulas that contain these micronutrients.

Iron is a highly reactive catalyst of oxidative reactions and thus is not included in PN mixtures. The parenteral iron requirement is normally only ~1 mg/d. Iron deficiency occurs with considerable frequency in acutely ill hospitalized patients, especially those with PEM and gastrointestinal tract disease, and in patients subjected to frequent blood withdrawals. Iron deficiency is sometimes inadequately considered in hospitalized patients because there are commoner causes: the inflammation-mediated anemia of chronic disease (with an associated increase in serum ferritin, an acute-phase protein) and redistribution of the intravascular fluid volume during prolonged bed rest. Iron deficiency should be considered in every patient receiving SNS. A falling mean red cell volume, even if still in the low-normal range, together with an intermediate serum ferritin concentration is suggestive of iron deficiency. Intravenous iron infusions follow standard guidelines, always with a termination order and never as a standing order because of the risk of inadvertent iron overdosing. Major iron replacement during critical illness is of some concern because of the possibility that a substantial rise in the serum iron concentration may increase susceptibility to some bacterial infections.

TABLE 98e-3 USUAL DAILY ELECTROLYTE ADDITIONS TO PARENTERAL NUTRITION

Electrolyte	Parenteral Equivalent	Usual Intake
Sodium		1–2 meq/kg + replacement, but can be as low as 5–40 meq/d
Potassium		40–100 meq/d + replacement of unusual losses
Chloride		As needed for acid-base balance, but usually 2:1 to 1:1 with acetate
Acetate		As needed for acid-base balance
Calcium	10 meq	10–20 meq/d
Magnesium	10 meq	8–16 meq/d
Phosphorus	30 mmol	20–40 mmol

TABLE 98e-4 PARENTERAL MULTIVITAMIN REQUIREMENTS FOR ADULTS

Vitamin	Revised Values
Vitamin A	3300 IU
Thiamin (B_1)	6 mg
Riboflavin (B_2)	3.6 mg
Niacin (B_3)	40 mg
Folic acid	600 µg
Pantothenic acid	15 mg
Pyridoxine (B_6)	6 mg
Cyanocobalamin (B_{12})	5 µg
Biotin	60 µg
Ascorbic acid (C)	200 mg
Vitamin D	200 IU[a]
Vitamin E	10 IU
Vitamin K[b]	150 µg

[a]The current vitamin D requirement—a minimum of 600 IU/day—cannot be met with available injectable vitamin formulations. Calcitriol is not equivalent to vitamin D and is not a suitable replacement for it, since it is not a substrate for 25-hydroxyvitamin D biosynthesis. [b]A product is available without vitamin K. Vitamin K supplementation is recommended at 2–4 mg/week in patients not receiving oral anticoagulation therapy when the vitamin K–free product is used.