Chapter 59: Nutrition Assessment and Support

INTRODUCTION

- Malnutrition is a consequence of nutrient imbalance resulting from inadequate intake, absorption, or utilization of protein and energy. Undernutrition can result in changes in subcellular, cellular, or organ function that increase the individual's risks of morbidity and mortality.
- For information on overnutrition or obesity, see Chapter 58.
- Nutrition screening provides a systematic way to identify individuals in any care environment with preexisting malnutrition or those at risk for malnutrition for whom a detailed nutrition assessment is warranted.
- Nutrition assessment is the first step in developing a nutrition care plan. Goals of nutrition assessment are to identify the presence of factors associated with an increased risk of developing undernutrition and complications, estimate nutrition needs, and establish baseline parameters for assessing the outcome of therapy.
- This assessment should include a comprehensive medical, surgical, and dietary history and a nutrition-focused physical exam (NFPE) including anthropometrics and laboratory measurements.
- The NFPE uses a system-based approach to assess for abnormal nutrition-related clinical and physical findings in each region of the body.

NUTRITION ASSESSMENT

Anthropometric Measurements

- Anthropometric measurements are physical measurements of the size, weight, and proportions of the human body used to compare an individual with normative population standards. Common measurements are weight, stature, head circumference (for children younger than 3 years of age) and waist circumference. Measurements of limb size (eg, skinfold thickness and mid-arm muscle and wrist circumferences), along with bioelectrical impedance analysis (BIA), may be useful in selected individuals.
- Interpretation of actual body weight (ABW) should consider ideal weight (IBW) for height, usual body weight (UBW), fluid status, and age. Change over time can be calculated as the percentage of UBW. Unintentional weight loss, especially rapid weight loss (5% of UBW in 1 month or 10% of UBW in 6 months), increases risk of nutrition-related poor clinical outcomes in adults.
- The best indicator of adequate nutrition in children is appropriate growth. Weight, stature, head circumference (until 3 years), and body mass index (BMI) (after 2 years) should be plotted on the appropriate growth curve. Average weight gain for newborns is 10–20 g/kg/day (24–35 g/day for term infants and 10–25 g/day for preterm infants depending on gestational age).
- BMI is another index of weight-for-height. Interpretation of BMI should include consideration of gender, frame size, race/ethnicity, and age. BMI values greater than 25 kg/m^2 are indicative of overweight, and values less than 18.5 kg/m^2 are indicative of undernutrition. BMI is calculated as follows:

Body weight (kg)/[height (m)]^2 **or** [Body weight (lb) × 703]/[height (in.)]^2

- Measurements of skinfold thickness estimate subcutaneous fat, mid-arm muscle circumference estimates skeletal muscle mass, and waist circumference estimates abdominal (visceral) fat content.

- BIA is a simple, noninvasive, and relatively inexpensive way to assess LBM, total body water (TBW), and water distribution. It is based on differences between fat tissue and lean tissue's resistance to conductivity. Hydration status should be considered in interpretation of BIA results.

Biochemical and Immune Function Studies

- LBM can be assessed by measuring serum visceral proteins (**Table 59-1**). They are of greatest value for assessing uncomplicated starvation and recovery, and less useful for assessing status during acute stress. Interpret visceral proteins relative to overall clinical status because they are affected by many factors other than nutrition.
- Nutrition affects immune status both directly and indirectly. Total lymphocyte count and delayed cutaneous hypersensitivity reactions are immune function tests useful in nutrition assessment, but their lack of specificity limits their usefulness as nutrition status markers.
- Delayed cutaneous hypersensitivity is commonly assessed using antigens to which the patient was likely previously sensitized. The recall antigens used most frequently are mumps and *Candida albicans*. Anergy is associated with severe malnutrition; immune response can be restored with nutrition repletion.

Specific Nutrient Deficiencies

- Biochemical assessment of trace element, vitamin, and essential fatty acid deficiencies should be based on the nutrient's function, but few practical methods are available. Therefore, most assays measure serum concentrations of the individual nutrient.
- Clinical syndromes are associated with deficiencies of the following trace elements: zinc, copper, manganese, selenium, chromium, iodine, fluoride, molybdenum, and iron.
- Single vitamin deficiencies are uncommon; multiple vitamin deficiencies more commonly occur with malnutrition. For information on iron deficiency and other anemias, see Chapter 33.
- Essential fatty acid deficiency is rare but can occur with prolonged lipid-free parenteral nutrition (PN), very low-fat enteral formulations or diets, severe fat malabsorption, or severe malnutrition. The body can synthesize all fatty acids except for linoleic and α-linolenic acid.
- Carnitine can be synthesized from lysine and methionine, but hepatic synthesis is decreased in premature infants. Low carnitine levels can occur in premature infants receiving PN or carnitine-free diets.

Assessment of Nutrient Requirements

- Assessment of nutrient requirements must be made in the context of patient-specific factors (eg, age, gender, size, disease state, clinical condition, nutrition status, and physical activity).
- Adults should consume 45%–65% of total calories from carbohydrates, 20%–35% from fat, and 10%–35% from protein. Recommendations are similar for children, except that infants should consume 40%–50% of total calories from fat.

Energy Requirements

- Energy requirements of individuals can be estimated using validated predictive equations or directly measured, depending on factors including severity of illness and resources available. The simplest method is to use population estimates of calories required per kilogram of body weight.
- Healthy adults with normal nutrition status and minimal illness severity require an estimated 20–25 kcal ABW/kg/day (84–105 kJ ABW/kg/day). Daily energy requirements for children are approximately 150% of basal metabolic rate with additional calories to support activity and growth. Consult references for equations used to estimate energy expenditure in adults and children.
- Energy requirements for all ages increase with fever, sepsis, major surgery, trauma, burns, long-term growth failure, and chronic conditions (eg, bronchopulmonary dysplasia, congenital heart disease, and cystic fibrosis).

Protein, Fluid, and Micronutrient Requirements

Protein

- Protein requirements are based on age, gender, nutrition status, disease state, and clinical condition. The usual recommended daily protein allowances are 0.8 g/kg for adults, 1.5 g/kg for adults over 60 years of age, 1.5–2 g/kg for patients with metabolic stress (eg, infection, trauma, and surgery), and 2.5–3 g/kg for patients with burns.

Fluid

- Daily adult fluid requirements are approximately 30–40 mL/kg.
- Fluid requirements for children and preterm infants who weigh less than 10 kg are at least 100 mL/kg/day. An additional 50 mL/kg should be provided for each kilogram of body weight between 11 and 20 kg, and 20 mL/kg for each kilogram greater than 20 kg.
- Factors that may result in increased fluid requirements include but are not limited to gastrointestinal (GI) losses, fever, sweating, and increased metabolism, whereas kidney or heart failure and hypoalbuminemia with starvation are examples of factors that may result in decreased fluid requirements.
- Assess fluid status by monitoring urine output and specific gravity, serum electrolytes, and weight changes. An hourly urine output of at least 1 mL/kg for children and 40–50 mL for adults is needed to ensure tissue perfusion.

Micronutrients

- Requirements for micronutrients (ie, electrolytes, minerals, trace elements, and vitamins) vary with age, sex, route of ingestion, and underlying clinical conditions.
- Sodium, potassium, magnesium, and phosphorus requirements are typically decreased in patients with kidney failure, whereas calcium requirements are increased (see Chapters 74 and 75).

TABLE 59-1

Serum Proteins Used for Assessment of Lean Body Mass

Serum Protein	Half-Life (Days)	Function	Factors Resulting in Increased Values	Factors Resulting in Decreased Values
Albumin	18–20	Maintains plasma oncotic pressure; transports small molecules	Dehydration, anabolic steroids, insulin, infection	Fluid overload; edema; kidney dysfunction; nephrotic syndrome; poor dietary intake; impaired digestion; burns; heart failure; cirrhosis; thyroid, adrenal, or pituitary hormones; trauma; sepsis
Transferrin	8–9	Binds Fe in plasma; transports Fe to bone	Fe deficiency, pregnancy, hypoxia, chronic blood loss, estrogens	Chronic infection, cirrhosis, burns, enteropathies, nephrotic syndrome, cortisone, testosterone
Prealbumin (transthyretin)	2–3	Binds T_3 and, to a lesser extent, T_4; retinol-binding protein carrier	Impaired kidney function	Cirrhosis, hepatitis, stress, surgery, inflammation, hyperthyroidism, cystic fibrosis, burns, zinc deficiency

Fe, iron; T_3, triiodothyronine; T_4, thyroxine.

Drug–Nutrient Interactions

- Concomitant drug therapy can alter serum concentrations of vitamins (**Table 59-2**), minerals, and electrolytes.
- Some drug delivery vehicles contain nutrients. For example, the vehicle for propofol is 10% lipid emulsion, and most IV therapies include dextrose or sodium.

TABLE 59-2

Drug and Nutrient Interactions

Drug	Effect
Angiotensin-converting enzyme inhibitors	Increased urinary zinc losses
Angiotensin receptor blockers	Increased urinary zinc losses
Antacids	Thiamine deficiency
Antibiotics	Vitamin K deficiency
Aspirin	Folic acid deficiency; increased vitamin C excretion
Cathartics	Increased requirements for vitamins D, C, and B_6

Cholestyramine	Vitamins A, D, E, and K and β-carotene malabsorption
Colestipol	Vitamins A, D, E, and K and β-carotene malabsorption
Corticosteroids	Decreased vitamins A, D, and C
Diuretics (loop)	Thiamine deficiency
Diuretics (thiazides)	Increased urinary zinc losses
Efavirenz	Vitamin D deficiency caused by increased metabolism of 25(OH)D and $1,25(OH)_2D$
$Histamine_2$ antagonists	Vitamin B_{12} malabsorption (reduced acid results in impaired release of B_{12} from food)
Isoniazid	Vitamin B_6 and niacin deficiency
Isotretinoin	Vitamin A increases toxicity
Mercaptopurine	Niacin deficiency
Methotrexate	Folic acid inhibits effect
Orlistat	Vitamins A, D, E, and K malabsorption caused by fat malabsorption
Pentamidine	Folic acid deficiency
Phenobarbital	Increased vitamin D metabolism
Phenytoin	Increased vitamin D metabolism; decreased folic acid concentrations
Primidone	Folic acid deficiency
Protease inhibitors	Vitamin D deficiency (impaired renal hydroxylation)
Proton pump inhibitors	Decreased iron and vitamin B_{12} absorption (reduced acid results in impaired release of B_{12} from food)
Sulfasalazine	Folic acid malabsorption
Trimethoprim	Folic acid depletion
Warfarin	Vitamin K inhibits effect; vitamins A, C, and E may increase effect
Valproic acid	Zinc
Zidovudine	Folic acid and B_{12} deficiencies increase myelosuppression

NUTRITION SUPPORT

- The primary objective of nutrition support therapy is to promote positive clinical outcomes of an illness and improve quality of life.

Enteral Nutrition

- Enteral nutrition (EN) delivers nutrients by tube or mouth into the GI tract; we will focus on delivery through a feeding tube. The goal of EN is to provide calories, macronutrients, and micronutrients to those who are unable to achieve these requirements from an oral diet.
- EN is indicated for the patient who cannot or will not eat enough to meet nutritional requirements and who has a functioning GI tract and a method of enteral access. Potential indications include neoplastic disease, organ dysfunction, hypermetabolic states, GI disease, and neurologic impairment.
- Distal mechanical intestinal obstruction, bowel ischemia, and necrotizing enterocolitis are contraindications to EN. Contraindications to tube placement include active peritonitis and uncorrectable coagulopathy. Conditions that challenge the success of EN include severe diarrhea, protracted vomiting, enteric fistulas, severe GI hemorrhage, hemodynamic instability, and intestinal dysmotility.
- EN has replaced PN as the preferred method for the feeding of critically ill patients requiring specialized nutrition support. Advantages of EN over PN include maintaining GI tract structure and function; fewer metabolic, infectious, and technical complications; and lower costs.
- The timing of initiation of EN in the critically ill patients is of clinical significance. Initiation within 24–48 hours of admission to an intensive care unit appears to attenuate the stress response and reduce infectious complications and mortality. If patients are only mildly to moderately stressed and well nourished, EN initiation can be delayed until oral intake is inadequate for 5–7 days.

Access

- EN can be administered through four routes, which have different indications, tube placement options, advantages, and disadvantages (**Table 59-3**). The choice depends on the anticipated duration of use and the feeding site (ie, stomach vs. small bowel).
- The stomach is generally the least expensive and least labor-intensive access site; however, patients who have impaired gastric emptying are at risk for aspiration and pneumonia.
- Long-term access with gastrostomy and jejunostomy tubes should be considered when EN is anticipated for more than 4–6 weeks.

TABLE 59-3

Options and Considerations in the Selection of Enteral Access

Access	EN Duration/Patient Characteristics	Tube Placement Options	Advantages	Disadvantages
Nasogastric or orogastric	Short term Intact gag reflex Normal gastric emptying	Manually at bedside	Ease of placement Allows for all methods of administration Inexpensive Multiple commercially available tubes and sizes	Potential tube displacement Potential increased aspiration risk
Nasojejunal	Short term Impaired gastric motility or emptying High risk of GER or aspiration	Manually at bedside Fluoroscopically Endoscopically	Potential reduced aspiration risk Allows for early postinjury or postoperative feeding Multiple commercially available tubes and sizes	Manual transpyloric passage requires greater skill Potential tube displacement or clogging Bolus or intermittent feeding not tolerated
Gastrostomy	Long term Normal gastric emptying	Surgically Endoscopically Radiologically Laparoscopically	Allows for all methods of administration Low-profile buttons available Large-bore tubes less likely to clog Multiple commercially available tubes and sizes	Attendant risks associated with each type of procedure Potential increased aspiration risk Risk of stoma site complications
Jejunostomy	Long term Impaired gastric motility or gastric emptying High risk of GER or aspiration	Surgically Endoscopically Radiologically Laparoscopically	Allows for early postinjury or postoperative feeding Potential reduced aspiration risk Multiple commercially available tubes and sizes Low-profile buttons available	Attendant risks associated with each type of procedure Bolus or intermittent feeding not tolerated Risk of stoma site complications

EN, enteral nutrition; GER, gastroesophageal reflux.

Administration Methods

- EN can be administered by continuous, cyclic, bolus, and intermittent methods. The choice depends on the location of the feeding tube tip, patient's clinical condition, intestinal function, and tolerance to tube feeding.
- Continuous EN is preferred for initiating therapy and has the advantage of being well tolerated. Disadvantages include cost and inconvenience associated with pump and administration sets.
- Cyclic EN has the advantage of allowing breaks from the infusion system, thereby increasing mobility, especially if EN is administered nocturnally.
- Bolus EN is most commonly used in patients in the home or long-term care setting who have a gastrostomy. Advantages include short administration time (eg, 5–10 minutes) and minimal equipment (eg, a syringe). Bolus EN has the potential disadvantages of causing cramping, nausea, vomiting, aspiration, and diarrhea.

- Intermittent EN is similar to bolus EN except that the feeding is administered over 20–60 minutes, which improves tolerability but requires more equipment (eg, reservoir bag and infusion pump). Like bolus EN, intermittent EN mimics normal eating patterns.
- Protocols outlining initiation and advancement criteria are a useful strategy to optimize achievement of nutrient goals based on GI tolerance. Clinical signs of intolerance include abdominal distention or cramping, high gastric residual volumes, aspiration, and diarrhea.
- Continuous EN feedings are typically started in adults at 20–50 mL/hr and advanced by 10–25 mL/hr every 4–8 hours until the goal is achieved. Intermittent EN feedings are started at 120 mL every 4 hours and advanced by 30–60 mL every 8–12 hours.

Formulations

- Historically, EN formulations were created to provide essential nutrients, including macronutrients (eg, carbohydrates, fats, and proteins) and micronutrients (eg, electrolytes, trace elements, vitamins, and water).
- Over time, formulations have been enhanced to improve tolerance and meet specific patient needs. For example, immunonutrients or pharmaconutrients are added to modify the disease process or improve clinical outcome; however, these health claims are not regulated by the FDA.
- The molecular form of the protein source determines the amount of digestion required for absorption within the small bowel. The carbohydrate component usually provides the major source of calories; polymeric entities are preferred over elemental sugars. Vegetable oils rich in polyunsaturated fatty acids are the most common sources of fat in EN formulations.
- Soluble and insoluble fiber has been added to several EN formulations. Potential benefits of soluble fiber include trophic effects on colonic mucosa, promotion of sodium and water absorption, and regulation of bowel function.
- Osmolality is a function of the size and quantity of ionic and molecular particles primarily related to protein, carbohydrate, electrolyte, and mineral content. The osmolality of EN formulations for adults ranges from 280 to 875 mOsm/kg (mmol/kg). Osmolality is commonly thought to affect GI tolerability, but there is a lack of supporting evidence.

Classification of Enteral Feeding Formulations

- EN formulations are classified by their composition and intended patient population (**Table 59-4**). Formularies should focus on clinically significant characteristics of available products, avoid duplicate formulations, and include only specialty formulations with evidence-based indications.

TABLE 59-4

Adult Enteral Feeding Formulation Classification System

Category	Features	Indications
Standard polymeric	Isotonic 1–1.2 kcal/mL (4.2–5 kJ/mL) NPC:N 125:1–150:1 May contain fiber	Designed to meet the needs of the majority of patients Patients with functional GI tract Not suitable for oral use
High protein	NPC:N <125:1 May contain fiber	Patients with protein requirements >1.5 g/kg/day, such as trauma patients and those with burns, pressure sores, or wounds Patients receiving propofol
High caloric density	1.5–2 kcal/mL (6.3–8.4 kJ/mL) Lower electrolyte content per calorie Hypertonic	Patients requiring fluid and/or electrolyte restriction, such as kidney insufficiency
Elemental	High proportion of free amino acids Low in fat	Patients who require low fat Use has generally been replaced by peptide-based formulations
Peptide-based	Contains dipeptides and tripeptides Contains MCTs	Indications/benefits not clearly established Trial may be warranted in patients who do not tolerate intact protein due to malabsorption
Disease specific		
Kidney	Caloric dense Protein content varies Low-electrolyte content	Alternative to high-caloric density formulations, but generally more expensive
Liver	Increased branched-chain and decreased aromatic amino acids	Patients with hepatic encephalopathy
Lung	High fat, low carbohydrate Anti-inflammatory lipid profile and antioxidants	Patients with ARDS and severe ALI
Diabetes mellitus	High fat, low carbohydrate	Alternative to standard, fiber-containing formulation in patients with uncontrolled hyperglycemia
Immune-modulating	Supplemented with glutamine, arginine, nucleotides, and/or omega-3 fatty acids	Patients undergoing major elective GI surgery, trauma, burns, head and neck cancer, and critically ill patients on mechanical ventilation Use with caution in patients with sepsis Select nutrients may be beneficial or harmful in subgroups of critically ill patients
Oral supplement	Sweetened for taste Hypertonic	Patients who require supplementation to an oral diet

ALI, acute lung injury; ARDS, acute respiratory distress syndrome; MCT, medium-chain triglyceride; NPC:N, nonprotein calorie-to-nitrogen ratio.

Complications and Monitoring

- Monitor patients for metabolic, GI, and mechanical complications of EN (**Table 59-5**).
- Metabolic complications associated with EN are similar to those of PN, but the incidence is lower.
- GI complications include nausea, vomiting, abdominal distention, cramping, aspiration, diarrhea, and constipation. Gastric residual volume is thought to increase the risk of vomiting and aspiration.
- Mechanical complications include tube occlusion or malposition and inadvertent nasopulmonary intubation. Techniques for clearing occluded tubes include pancreatic enzymes in sodium bicarbonate and using a declogging device. Techniques for maintaining patency include flushing with at least 15–30 mL of water before and after medication administration and intermittent feedings and at least every 8 hours during continuous feeding.

TABLE 59-5

Suggested Monitoring for Adult Patients on Enteral Nutrition

Parameter	During Initiation of EN Therapy	During Stable EN Therapy
Vital signs	Every 4–6 hours	As needed with suspected change (ie, fever)
Clinical assessment		
Weight	Daily	Weekly
Total intake/Output	Daily	As needed with suspected change in intake/output
Tube-feeding intake	Daily	Daily
Enterostomy tube site assessment	Daily	Daily
GI tolerance		
Stool frequency/Volume	Daily	Daily
Abdomen assessment	Daily	Daily
Nausea or vomiting	Daily	Daily
Gastric residual volumes	Every 4–8 hours (varies)	As needed when delayed gastric emptying suspected
Tube placement	Prior to starting, then ongoing	Ongoing
Laboratory		
Electrolytes, blood urea nitrogen/serum creatinine, glucose	Daily until stable, then 2–3 times/week	Every 1–3 months
Calcium, magnesium, phosphorus	Daily until stable, then 2–3 times/week	Every 1–3 months
Liver function tests	Weekly	Every 1–3 months
Trace elements, vitamins	If deficiency/toxicity suspected	If deficiency/toxicity suspected

EN, enteral nutrition.

Drug Delivery Via Feeding Tube

- Administering drugs via tube feeding is a common practice. If the drug is a solid that can be crushed (eg, *not* a sublingual, sustained-release, or enteric-coated formulation) or is a capsule, mix with 15–30 mL of water or other appropriate solvent and administer. Otherwise, a liquid dosage preparation should be used. Administer multiple medications separately, each followed by flushing the tube with 5–15 mL of water.

- Mixing of liquid medications with EN formulations can cause physical incompatibilities that inhibit drug absorption and clog small-bore feeding tubes. Incompatibility is more common with formulations containing intact (vs. hydrolyzed) protein and medications formulated as acidic syrups. Mixing of liquid medications and EN formulations should be avoided whenever possible.
- The most significant drug–nutrient interactions result in reduced bioavailability and suboptimal pharmacologic effect (**Table 59-6**). Continuous feeding requires interruption for drug administration, and medications should be spaced between bolus feedings.

TABLE 59-6

Select Medications with Special Considerations for Enteral Feeding Tube Administration

Drug	Interaction	Comments
Phenytoin	Reduced bioavailability in the presence of tube feedings Possible phenytoin binding to calcium caseinates or protein hydrolysates in enteral feeding	To minimize interaction, holding tube feedings 1–2 hours before and after phenytoin has been suggested Adjust tube-feeding rate to account for time held for phenytoin administration Monitor phenytoin serum concentration and clinical response closely Consider switching to IV phenytoin or an alternative-treatment option if unable to reach therapeutic serum concentration
Fluoroquinolones Tetracyclines	Potential for reduced bioavailability because of complexation of drug with divalent and trivalent cations found in enteral feeding	Consider holding tube feeding 1 hour before and after administration Avoid jejunal administration of ciprofloxacin Monitor clinical response
Warfarin	Decreased absorption of warfarin because of enteral feeding; therapeutic effect antagonized by vitamin K in enteral formulations	Adjust warfarin dose based on INR Anticipate need to increase warfarin dose when enteral feedings are started and decrease dose when enteral feedings are stopped Consider holding tube feeding 1 hour before and after administration
Omeprazole Lansoprazole	Administration via feeding tube complicated by acid-labile medication within delayed-release, base-labile granules	Granules become sticky when moistened with water and may occlude small-bore tubes Granules should be mixed with acidic liquid when given via a gastric feeding tube An oral liquid suspension can be extemporaneously prepared for administration via a feeding tube

INR, International normalized ratio.

Parenteral Nutrition

- PN provides macro- and micronutrients by central or peripheral venous access to meet specific nutritional requirements of the patient.
- PN should be considered when a patient cannot meet nutritional requirements enterally for an extended time period.

Components of Parenteral Nutrition

- Macronutrients (ie, water, protein, dextrose, and lipid) are used for energy (dextrose and lipid) and as structural substrates (protein and lipid).
- Protein is provided as crystalline amino acids (CAAs). When oxidized, 1 g of protein yields 4 calories (~17 J). Including the caloric contribution from protein in calorie calculations is controversial; therefore, PN calories can be calculated as either total or nonprotein calories.
- Standard CAA products contain a balanced profile of essential, semi-essential, and nonessential L-amino acids and are designed for patients with "normal" organ function and nutritional requirements. Standard CAA products differ in protein concentration, total nitrogen, and electrolyte content but have similar effects on protein markers.
- The primary energy source in PN solutions is carbohydrate, usually as dextrose monohydrate, which is available in concentrations ranging from 5% to 70%. When oxidized, 1 g of hydrated dextrose provides 3.4 kcal (14.2 kJ).
- Commercially available intravenous lipid emulsions (IVLE) provide calories and essential fatty acids. These products differ in triglyceride source, fatty acid content, and essential fatty acid concentration.
- When oxidized, 1 g of fat yields 9 kcal (38 kJ). Because of the caloric contribution from egg phospholipid and glycerol, caloric content of IVLE is 1.1 kcal/mL (4.6 kJ/mL) for the 10%, 2 kcal/mL (8.4 kJ/mL) for the 20%, and 3 kcal/mL (12.6 kJ/mL) for the 30% emulsions.
- Essential fatty acid deficiency can be prevented by giving IVLE, 0.5–1 g/kg/day for neonates and infants and 100 g/wk for adults.
- IVLE 10% and 20% products can be administered by a central or peripheral vein, added directly to PN solution as a total nutrient admixture (TNA) or three-in-one system (lipids, protein, glucose, and additives), or co-infused with a CAA and dextrose solution, commonly referred to as a two-in-one solution. IVLE 30% is approved only for TNA preparation.
- Micronutrients (ie, vitamins, trace elements, and electrolytes) support metabolic activities for cellular homeostasis such as enzyme reactions, fluid balance, and regulation of electrophysiologic processes.
- Multivitamin products have been formulated to comply with guidelines for adults, children, and infants. These products contain 13 essential vitamins, including vitamin K.
- Requirements for trace elements depend on the patient's age and clinical condition.
- Chromium, copper, manganese, selenium, and zinc are considered essential and available as single- or multiple-entity products for addition to PN solutions.
- Sodium, potassium, calcium, magnesium, phosphorus, chloride, and acetate are necessary components of PN for maintenance of numerous cellular functions.
- Electrolyte requirements depend on the patient's age, disease state, organ function, previous and current drug therapy, nutrition status, and extrarenal losses.

Specifics of Parenteral Nutrition

- The patient's clinical condition determines whether PN is administered through a peripheral or central vein.
- Peripheral parenteral nutrition (PPN) candidates do not have large nutritional requirements, are not fluid restricted, and are expected to regain GI tract function within 10–14 days. Solutions for PPN have lower final concentrations of amino acid (3%–5%), dextrose (5%–10%), and micronutrients as compared with central parenteral nutrition (CPN).
- Primary advantages of PPN include a lower risk of infectious and technical complications.
- CPN is useful in patients who require PN for more than 7–14 days and who have large nutrient requirements, poor peripheral venous access, or fluctuating fluid requirements.
- CPN solutions are highly concentrated hypertonic solutions that must be administered through a large central vein. The choice of venous access

site depends on factors including patient age and anatomy. Peripherally inserted central catheters (PICCs) are often used for both short- and long-term central venous access in acute or home care settings.

- Disadvantages include risks associated with catheter insertion, use, and care. Central venous access has a greater potential for infection.
- PN regimens for adults can be ordered on traditional paper order forms or by using standardized electronic order forms. Standardized order forms are popular because they help educate practitioners and foster cost-efficient nutrition support by minimizing errors in ordering, compounding, and administering.
- Pediatric PN regimens typically require an individualized approach because practice guidelines often recommend nutrient intake based on weight. Labeling should reflect “amount per kilogram per day.”

EVALUATION OF THERAPEUTIC OUTCOMES

- Assessing the outcome of EN includes monitoring objective measures of body composition, protein and energy balance, and subjective outcome for physiologic muscle function and wound healing.
- Measures of disease-related morbidity include length of hospital stay, infectious complications, and patient’s sense of well-being. Ultimately, the successful use of EN avoids the need for PN.
- Outcomes with PN are determined through routine assessment of the clinical condition of the patient, with a focus on nutritional and metabolic effects of the PN regimen.
- Biochemical and clinical parameters should be monitored routinely in patients receiving PN (**Figure 59-1**).

FIGURE 59-1

Monitoring strategy for patients receiving parenteral nutrition (PN).

(ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; CBC, complete blood cell count; INR, international normalized ratio; PN, parenteral nutrition; PT, prothrombin time; SCr, serum creatinine)

image

See Chapter 158, Assessment of Nutrition Status and Nutrition Requirements, authored by Katherine Hammond Chessman and Vanessa J. Kumpf; Chapter 159, Parenteral Nutrition, authored by Todd W. Mattox and Catherine M. Crill; and Chapter 160, Enteral Nutrition, authored by Vanessa J. Kumpf and Diana W. Mulherin, for a more detailed discussion of this topic.