14

Overview of Parenteral Nutrition

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Objectives

Determine the appropriate indications for parenteral nutrition (PN).

Decide the best PN route based on the patient's nutrition, metabolic, and clinical status.

Initiate and manage PN therapy.

Describe the effects of PN on patient outcomes.

Test Your Knowledge Questions

1. What is the optimal nutrition support for a malnourished patient when enteral nutrition (EN) is not feasible for a prolonged period?

A. Central parenteral nutrition (CPN)
B. Nasogastric enteral tube feedings
C. Postpyloric enteral tube feedings
D. Peripheral parenteral nutrition (PPN)

2. In which patient condition or treatment could PN elicit an improved patient outcome?

A. Cancer chemotherapy
B. Preoperative care of surgery patients with upper gastrointestinal (GI) cancer
C. Allogeneic bone marrow transplantation
D. Critical illness

3. CPN is contraindicated in which of the following conditions?

A. Do not resuscitate (DNR) status
B. Peritonitis
C. Intestinal hemorrhage
D. High-output fistulas

4. PN should be discontinued when which of the following criteria are met?

A. A clear liquid diet is ordered.
B. Tube feeding is initiated at 10% of goal rate.
C. Solid food is well tolerated by mouth.
D. Advancement to a regular diet is poorly tolerated.

Test Your Knowledge Answers

1) The correct answer is A. The benefits of CPN are more closely associated with patients with malnutrition, although those benefits have not been consistently shown.1 Newer studies of the impact of PN on malnourished cancer patients' body composition (2010)2 and performance scores (2011)3 provide a perspective of PN on outcomes not currently considered in American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines (2009)4 that may expand the role of CPN in clinical practice.
2) The correct answer is B. A review of PN literature has reported improved outcomes in patients with upper GI tract malignancies when PN is initiated 7 days before surgery.5 An early report of a decrease in length of stay and infectious complications in allogeneic bone marrow transplant patients receiving PN has not been confirmed.6 A review of published data on the use of PN in cancer chemotherapy, in the perioperative period, and during critical illness reports no positive effect of PN on clinical outcomes and a significant increase in infectious complications in patients randomly assigned to PN therapy as compared with those receiving no nutrition support.5
3) The correct answer is A. Trujillo and colleagues7 abstracted indications for PN from the 1993 ASPEN guidelines as peritonitis, intestinal hemorrhage, intestinal obstruction, intractable vomiting, paralytic ileus, severe pancreatitis, stool output greater than 1 L/d, high-output fistulas, short bowel syndrome, and bone marrow recipients. PN therapy was contraindicated for patients who were classified as well nourished and had inadequate EN for less than 7 days; patients who had a DNR status and were deemed to warrant comfort measures only or were terminally ill; and those receiving adequate EN.
4) The correct answer is C. The goal of PN therapy is to maintain the nutrition status of the patient until some form of EN is tolerated. Critically ill patients whose therapy is withdrawn during the terminal stages of their disease process are the exception to this goal. In most other situations, GI function returns or appropriate enteral access is obtained, and PN is tapered as the amount of reliable enteral intake increases. PN support may be discontinued when patients can tolerate solid food by mouth, unless advanced age, debilitation, malignancy, or cultural food practices complicate the transition to oral intake. In those circumstances, a detailed transitional feeding plan should be established.8

Background

A successful infusion of hypertonic parenteral nutrients by Dudrick and colleagues9 in the late 1960s was a major advancement in providing nutrition to patients with a nonfunctioning GI tract. Although intravenous (IV) nutrition has been of interest since the 17th century,10,11 Dudrick et al were interested in "patients seriously depleted of protein and in whom it was known that operation would carry an increased risk of various complications, both infectious and non-infectious."11 Initially, challenges to providing PN therapy included selecting sources of safe IV nutrients and establishing adequate venous access for hypertonic nutrient administration. Venous access problems were resolved by subclavian vein catheterization use, which minimized thrombotic complications associated with peripheral PN infusions (see Chapter 16). Early PN formulations consisted of dextrose and protein hydrolysates of either casein or fibrin. Protein hydrolysates were replaced by newer, crystalline amino acids, which are better utilized and lack preformed ammonia. Lipid injectable emulsions (ILEs) were not available in the United States until the 1970s and were used primarily as a source of essential fatty acids. It was not until the 1980s that ILEs were routinely used as an energy source. This development coincided with approval by the US Food and Drug Administration for fat emulsions to be compounded in the same container as other IV nutrients. Such a formulation is commonly referred to as a 3-in-1 admixture or total nutrient admixture (TNA).

PN has been used in several clinical situations. When PN was first used, it was shown to provide a significant benefit to patients with GI fistulas who were unable to ingest nutrients by mouth.11 Home PN has become a lifeline for patients with short bowel syndrome, allowing them to resume a nearly normal lifestyle (see Chapter 30). New knowledge and technology have improved patient selection for PN, whereas individualized therapies and improved PN techniques have improved the safety of this therapy. The refinement of PN will continue to make it a useful therapy for patients with complex diseases whose GI tracts are nonfunctional.

The parenteral feeding formulation is a complex mixture containing up to 40 different chemical (nutrient) components that may cause problems with stability and compatibility (see Chapter 15). Serious harm and death have resulted from improperly compounded parenteral feeding formulations. Two deaths were attributed to the infusion of calcium phosphate precipitates, resulting from an improper admixture process.12 Other complications, such as venous catheter infections, hepatobiliary disease, and glucose disorders, have contributed to patient morbidity (see Chapters 16 and 17).13,14 The risks of complications can be minimized through careful patient selection and by having knowledgeable clinicians oversee the specialized nutrition support program. Nehme15 reports that patients whose PN was managed by an interdisciplinary team had significantly reduced metabolic, fluid, and electrolyte complications as compared with patients managed by individual clinicians. In Nehme's report, 8 of 11 patients with hyperglycemic, nonketotic dehydration and 2 of 7 patients with rebound hypoglycemia died in the group managed by individual clinicians, whereas no deaths occurred in the group managed by the interdisciplinary team. Interdisciplinary teams are also more likely to follow ASPEN guidelines regarding the use of PN.7

The benefit of PN in various conditions continues to be debated. Its use warrants a thorough evaluation of risks and benefits. The benefits can be difficult to determine because the patient's underlying disease process often affects measurable outcomes more than PN does.

Routes of Infusion

The components of a parenteral feeding formulation determine its osmolarity and infusion route. PN may be prepared for peripheral venous infusion or infusion through a central venous access device. PN may also be prepared as a TNA or a 2-in-1 solution. The latter contains all necessary IV macronutrients and micronutrients in the same container except ILE, which may be infused separately (see Chapter 15).

Parenteral feeding formulations are hypertonic to body fluids and, if administered inappropriately, may result in venous thrombosis, suppurative thrombophlebitis, or extravasation. Specifically, the osmolarity of a parenteral feeding formulation is primarily dependent on the dextrose, amino acid, and electrolyte content. Dextrose contributes approximately 5 mOsm/g; amino acids yield approximately 10 mOsm/g; and electrolytes provide approximately 1 mOsm per mEq of individual electrolyte additive. For example, the estimated osmolarity of a 1-liter total volume parenteral feeding formulation providing 150 g of dextrose, 50 g of amino acids, and 150 mEq of electrolyte additives is 1400 mOsm/L. Central venous administration is necessary for this PN feeding formulation because the maximum osmolarity tolerated by a peripheral vein is 900 mOsm/L.16

Central Parenteral Nutrition

CPN is often referred to as total parenteral nutrition because the entire nutrient needs of the patient may be delivered by this route. A complete, balanced formulation includes dextrose; amino acids; ILEs; electrolytes such as potassium, magnesium, and phosphorus; vitamins; and multiple trace elements, such as zinc, copper, manganese, chromium, and selenium. The glucose content (usually 150 to 600 g/d), along with amino acids and electrolytes, provides a hyperosmolar (1300 to 1800 mOsm/L) formulation that must be delivered into a large-diameter vein, such as the superior vena cava adjacent to the right atrium. The rate of blood flow in these large vessels rapidly dilutes the hypertonic parenteral feeding formulation to that of body fluids, minimizing the risk of complications associated with an IV infusion of hypertonic solutions. CPN provides complete nutrition in a reasonable fluid volume and may be concentrated to provide adequate energy and protein for those patients requiring fluid restriction. Because central venous access can be maintained for prolonged periods (weeks to years), CPN is preferred for use in patients who will require PN support for longer than 7 to 14 days, including those patients receiving care at home or other extended healthcare environments, such as assisted living or extended care facilities and nursing homes (see Chapters 36 and 38).

Peripheral Parenteral Nutrition

PPN is similar in composition to CPN, but it has lower concentrations of nutrient components to allow for peripheral venous administration. The dextrose dose in PPN is 150 to 300 g/d (5% to 10% of final concentration), and the amino acid content is 50 to 100 g/d (3% of final concentration). Large fluid volumes must be administered with PPN to provide energy and protein doses comparable to those of

CPN. PPN is usually an undesirable option for patients with fluid restriction because concentrating the solution to meet their fluid requirements frequently results in a hyperosmolar solution that is not suitable for peripheral administration. PPN may be used in patients to provide partial or total nutrition support when they are not able to ingest adequate energy orally or enterally, or when CPN is not feasible. However, this therapy is typically used for short periods (up to 2 weeks) because patients' tolerance is limited and because there are few suitable peripheral veins. PPN is generally not indicated in malnourished patients requiring longer periods of nutrition support.

Patients considered for PPN must meet 2 criteria: (1) they must have good peripheral venous access, and (2) they should be able to tolerate large volumes of fluid (2.5 to 3 L/d). They should require at least 5 days but no more than 2 weeks of partial or total PN. Contraindications to PPN are listed in Table 14-1.17 The use of PPN is controversial, with many believing that the risk of complications outweighs any potential benefit because candidates for this therapy have only minor, if any, nutrition deficits. When using PPN in critically ill patients, it is difficult to provide adequate doses of energy, protein, and micronutrients in a limited fluid volume. PPN formulations are hyperosmolar (600 to 900 mOsm/L) and may cause phlebitis and may require frequent peripheral IV site rotations (at least every 48 to 72 hours). ILE may be used to increase the energy density of the peripheral parenteral feeding formulation without increasing the osmolarity, and it has been reported to improve peripheral vein tolerance of PPN.17 The use of midline catheters is recommended in patients needing PPN for more than 6 days due to the catheters' length and lower probability of dislodging compared with other peripheral cannulas; however, midline catheters do not eliminate the risk of thrombophlebitis.18 Liu and colleagues recently found a favorable response when colorectal cancer patients at nutrition risk received a preoperative PPN formula that included multivitamins and trace elements and was infused at a volume of 1500 mL/d. Micronutrient inclusion resulted in lower C-reactive protein and higher albumin levels as well as a reduced anastomotic leak rate and shorter length of hospital stay.19

TABLE 14-1 Contraindications to Peripheral Parenteral Nutrition

- Significant malnutrition
- Severe metabolic stress
- Large nutrient or electrolyte needs (potassium is a strong vascular irritant)
- Fluid restriction
- Need for prolonged parenteral nutrition (>2 weeks)
- Renal or liver compromise

Source: Data are from reference 17.

Approaches to Parenteral Nutrition

As practice has evolved, new concepts and approaches to PN related to specific patient conditions have surfaced, including permissive underfeeding, hypocaloric feeding, and supplemental PN to avoid energy deficits. Permissive underfeeding is a concept relevant to critically ill patients who do not tolerate nutrition, especially PN, well. This approach is intended to minimize complications of PN delivery by providing only 80% of estimated energy requirements until the patient's condition improves.20

Hypocaloric feeding is used in both EN and PN therapy for obese patients to meet protein requirements but provide less energy than the estimated requirement.21 This approach is also designed to minimize the metabolic complications of PN while improving nitrogen balance. It is used for patients with a body mass index greater than 30, unless weight loss is not intended. It may be used in critically ill and other hospitalized patients. Very little data are available for long-term (greater than 30 days) use of this approach. (See Chapter 35 for more information on nutrition support and obesity.) Lastly, supplemental PN is an approach designed to minimize the energy deficit that accumulates during periods of no nutrition or undernutrition. It is used in those circumstances where EN is insufficient to meet energy needs.20,22

Indications for Parenteral Nutrition

General Guidelines

Malnutrition is associated with increased patient complications and mortality.23 Although PN has been shown to improve several markers of nutrition status, prospective, randomized trials have rarely shown PN to improve patient outcomes.5,24 However, many of these trials have been criticized for inadequate study designs, including inconsistent control for nutrition status, extent or type of underlying disease, or consistency in nutrient type and dose.24 PN has been shown to benefit patients with moderate-to-severe malnutrition who have no or inadequate oral or EN for prolonged periods. This finding is particularly relevant to the following populations: patients receiving perioperative support; patients with acute exacerbations of Crohn's disease, GI fistulas, or extreme short bowel syndrome; and critical care and cancer patients.5,25

PN is costly, and it may result in serious complications when used inappropriately.26 The costs of PN include not only the admixture but also expenses related to placing venous access, laboratory monitoring, and treatment of complications.26 As such, the use of PN is scrutinized by patients, providers, and payers.5 The therapy should only be used in those patients who will demonstrably benefit from it.27 Identifying these patients is not an easy task because the effects of the nutrition components of care may be confounded by the underlying disease process and its treatment. Specific guidelines for the implementation of PN have been developed by ASPEN,28 and Table 14-2 outlines criteria that may be used to determine the appropriate application of PN.29 These criteria can be easily adapted to a nutrition consultation form designed to educate the clinician requesting PN on the pertinent patient variables that identify a candidate for PN (Figure 14-1). By completing the nutrition consultation request section, the individual requesting PN addresses the previously mentioned criteria. Considerations include the patient's nutrition status, GI function, and the extent and severity of the underlying disease. See Practice Scenario 14-1 for a discussion of indications for PN.

TABLE 14-2 Indications for Parenteral Nutrition

Considerations for PN use:

- PN may be appropriate for patients who are unable to meet nutrition requirements with EN. These patients are already or have the potential of becoming malnourished.
- PPN may be used in selected patients to provide partial or total nutrition support for up to 2 weeks when those patients cannot ingest or absorb oral or enteral tube–delivered nutrients, or when CPN is not feasible.
- CPN support is necessary when PN is indicated for longer than 2 weeks, peripheral venous access is limited, nutrient needs are large, or fluid restriction is required, and the benefits of PN outweigh the risks.

Use CPN when:

- The patient has failed the EN trial with appropriate tube placement (postpyloric).
- EN is contraindicated or the GI tract has a severely diminished function because of the underlying disease or treatment. Specific applicable conditions are as follows:

– Paralytic ileus

– Mesenteric ischemia

– Small bowel obstruction

– GI fistula, except when enteral access may be placed posterior to the fistula or volume of output (less than 200 mL/d) supports a trial of EN

- The exact duration of starvation that can be tolerated without increased morbidity is unknown, as can occur in postoperative nutrition support. Expert opinion suggests that wound healing will be impaired if PN is not started within 5 to 10 days postoperatively for patients who cannot eat or tolerate enteral feeding.29
- The patient's clinical condition is considered in the decision to withhold or withdraw therapy. Conditions where nutrition support is poorly tolerated and should be withheld until the condition improves are severe hyperglycemia; azotemia; encephalopathy and hyperosmolality; and severe fluid and electrolyte disturbances.

CPN, central parenteral nutrition; EN, enteral nutrition; GI, gastrointestinal; PN, parenteral nutrition; PPN, peripheral parenteral nutrition.

Source: Data are from reference 29.

FIGURE 14-1 Nutrition Assessment and Recommendation Form

Clinical indications	Presumed oral intake will provide insufficient nutrition and/or is unsafe due to possible aspiration for a period greater than 4 weeks on nasogastric tube feeding? ☐ Yes ☐ No Life expectancy, specify: _____
Swallow evaluation	Was a video swallow study completed? ☐ Yes ☐ No If yes, when? _____ Were results abnormal? Specify: _____
Consistent with patient's wishes?	Is use of G-tube consistent with patient's preferences, as supported by patient's quality-of-life goals? ☐ Yes ☐ No
Preferences obtained	How have patient's preferences, goals, and values been obtained? Check all that apply: ☐ Discussed directly with patient ☐ Discussed with patient's surrogate (for patient lacking decision-making capacity) ☐ Documented in patient's advance directive and/or POLST form ☐ Surrogate committee formed to make decision on patient's behalf ☐ Other (specify): _____

Preferences documented	Are patient's preferences, goals and values formally documented in medical record or surrogate committee? ☐ Yes (date): _____ ☐ No
Stability of medical condition	Is patient's medical condition expected to remain stable to discharge? ☐ Yes ☐ No
Expected survival time	Is patient expected to survive for at least 30 days post G-tube placement? ☐ Yes ☐ No
Recommendation	Based on above answers is patient an appropriate candidate for G-tube? ☐ Yes ☐ No If no, recommend consults for discussion/decision-making with patient, family, caregiver, surrogate decision maker for feeding option needs by: ☐ Ethics ☐ Registered dietitian ☐ Physician ☐ Palliative care ☐ Pharmacist ☐ Speech-language pathologist

Sample/simulated form that may facilitate nutrition assessment by including key components required to diagnose malnutrition, determine the indications for enteral or parenteral nutrition, and establish a nutrition care plan that is documented for the patient. Alb, albumin; ARF, acute renal failure; Bicarb, bicarbonate; BUN, blood urea nitrogen; Ca, calcium; CBGs, complete blood gases; CHF, congestive heart failure; Chol, cholesterol; Cl, chloride; Corr Ca; corrected calcium; Crea, creatinine; CrCl, creatinine clearance; CRI, chronic renal insufficiency; DM1, type 1 diabetes; DM2, type 2 diabetes; ESRD-HD, end-stage renal disease on hemodialysis; GI, gastrointestinal; Gluc, glucose; H2 blocker, H-2 receptor antagonist; HCT, hematocrit; Hgb, hemoglobin; Hyper TG, hypertriglyceridemia; IBW, ideal body weight; ICa, ionized calcium; ICU, intensive care unit; IV, intravenous; K+, potassium; Mg, magnesium; Na, sodium; NG/OG, nasogastric/orogastric; NPO, nil per os; PAB, prealbumin; Phos, phosphorus; PICC, peripherally inserted central catheter; PLT, platelets; PMH, patient medical history; PO, per os; PPI, proton-pump inhibitor; SBO, small bowel obstruction; SSI, sliding-scale insulin; Trig, triglycerides; WBC, white blood cell count.

Practice Scenario 14-1

Question: When is parenteral nutrition (PN) indicated?

Scenario: A 47-year-old woman was admitted with recurring gastrointestinal (GI) problems. Her nutrition parameters were listed as follows:

1. Weight loss: 8.4 kg
2. Weight change: 11%
3. Period of weight change: 35 days
4. Intake history: <25% estimated nutrition needs
5. Prealbumin: 8 mg/dL

Abdominal scan findings demonstrated a bowel obstruction with pockets of fluid collections consistent with an intra-abdominal abscess.

Intervention: At surgery, the patient was found to have a complete bowel obstruction, multiple adhesions, recurrence of Crohn's disease, and a large suprapubic abscess. The surgical procedure consisted of an exploratory laparotomy, lysis of adhesions, small bowel resection to remove the disease-affected bowel, and drainage of the abdominal abscess. A nasogastric tube was placed, which drained 1500 to 2000 mL on postoperative Day 1.

Answer: The patient was at a high risk of developing postoperative complications such as wound dehiscence, wound infection, pneumonia, and renal failure. Because the problem with the GI tract was not expected to be resolved in 7 to 10 days, PN was indicated.25

Rationale: Whether PN is indicated is dependent on the severity of the patient's malnutrition, the length of time the patient will not be able to use the enteral route for nourishment, and the influence of the underlying clinical condition on the safety and efficacy of therapy. When a nutrition consult form (Figure 14-1) was completed, the patient met 2 criteria for severe malnutrition: (1) more than 10% weight loss over a 2- to 3-month period, and (2) inadequate oral intake for more than 7 days before her surgery. Because of the severity of malnutrition in this patient, some form of nutrition support was indicated. The problem with the GI tract precluded the use of EN and was not expected to be resolved within 7 to 10 days; therefore, PN was indicated.25

Gastrointestinal Function

Symptoms such as nausea, vomiting, diarrhea, and abdominal distention or cramps may preclude the use of the GI tract for prolonged periods. We do not know how long patients can endure inadequate oral nutrition and semi- or complete starvation before there is an impact on clinical outcomes. Generally, treatment toxicities in cancer patients that preclude an adequate oral intake for more than a week are an indication for PN.6 In critically ill patients at high nutrition risk or severely malnourished, PN is indicated if EN is not feasible.20 For critically ill patients with normal nutrition risk or no malnutrition, PN should be avoided for up to 7 days.20

For the severely malnourished patient, PN is indicated when an impairment of the GI tract occurs. PN is indicated in other conditions that preclude the use of the GI tract for more than 7 to 10 days.22 PN is often used when enteral tube feedings are unsuccessful as evidenced by GI intolerance or pulmonary aspiration. In some cases, enteral access is contraindicated or attempts at achieving enteral access may have failed. Finally, in certain conditions, the GI tract should not be used until the underlying problem is treated (Table 14-2).

Clinical Status

PN should only be initiated in patients who are hemodynamically stable and who can tolerate the fluid volume and protein, carbohydrate, and ILE doses necessary to provide adequate nutrient substrate. Table 14-3 lists examples of situations where the administration of PN warrants caution. Table 14-4 describes laboratory tests to use when assessing and monitoring patients receiving PN.8,30

TABLE 14-3 Clinical Conditions Warranting Cautious Use of Parenteral Nutrition

Condition	Suggested Criteria[a]
Hyperglycemia	Glucose >300 mg/dL
Azotemia	BUN >100 mg/dL
Hyperosmolality	Serum osmolality >350 mOsm/kg
Hypernatremia	Na >150 mEq/L
Hypokalemia	K <3 mEq/L
Hyperchloremic metabolic acidosis	Cl >115 mEq/L
Hypophosphatemia	Phosphorus <2 mg/dL
Hypochloremic metabolic alkalosis	Cl <85 mEq/L

BUN, blood urea nitrogen; Cl, chloride; K, potassium; Na, sodium.

[a]There is no published evidence to support the specific criteria noted in this column. These values are suggestions by the author and should be modified based on clinical judgment about the specific patient in question or the environment in which parenteral nutrition is being administered, such as intensive care unit, general medical ward, long-term care facility, or the home.

TABLE 14-4 Suggested Monitoring for Parenteral Nutrition

Parameter	Baseline	Initiation	Critically Ill Patients	Stable Patients
CBC with differential	Yes		Weekly	Weekly
INR, PT, PTT	Yes		Weekly	Weekly
Electrolytes: Na, K, Cl, CO_2, Mg, Ca, phosphorus, BUN, Cr	Yes	Daily × 3	Daily	1–2 × per week
Serum triglycerides	Yes	Day 1	Weekly	Weekly
Serum glucose	Yes	Daily × 3	Daily	1–2 × per week
Capillary glucose		As needed	≥3 × day until consistently <150 mg/dL	As needed
Weight	Yes	Daily	Daily	2–3 × per week
Intake and output	Yes	Daily	Daily	Daily unless fluid status is assessed by physical exam
ALT, AST, ALP, total bilirubin	Yes	Day 1	Weekly	Monthly
Nitrogen balance	As needed		As needed	As needed

ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; Ca, calcium; CBC, complete blood cell count; Cl, chloride; CO2, bicarbonate; Cr, serum creatinine; INR, international normalized ratio; K, potassium; Mg, magnesium; Na, sodium; PT, prothrombin time; PTT, partial thromboplastin time.

Source: Data are from references 8 and 30.

Specific Guidelines

Gastrointestinal Disorders

PN has not been shown to improve patient outcomes as the primary management of acute exacerbations of Crohn's disease or ulcerative colitis.5,31 A retrospective analysis of data for PN use in patients with small bowel fistulas suggests an improvement in mortality rates and spontaneous and surgical closures, except when the fistula arises from the bowel with active Crohn's disease.5 Data suggest that bowel rest is not necessary to achieve remission in Crohn's disease.31 (See Chapter 26 for more information on GI disorders.)

Pancreatitis

The role of PN in treating pancreatitis has evolved substantially since PN was first used. GI or bowel rest and PN no longer have a role in pancreatitis. Recent reviews highlight the importance of maintaining GI integrity with EN as a means to avoid complications from pancreatitis and improve outcomes from the disease.32 PN is unlikely to benefit patients with mild, acute, or chronic relapsing pancreatitis when the conditions last for less than 1 week.33 PN should be avoided unless EN is not feasible because of GI ileus, small bowel obstruction, or the inability to properly place an enteral feeding tube. Despite improvements in delivery and tolerance of EN in pancreatitis patients, 5% to 10% of patients will have GI

intolerance and require PN.34 When PN is needed, it is recommended that PN energy administration not exceed 25 to 35 kcal/kg/d and glucose be adequately controlled.33 It is also recommended to consider glutamine (0.3 g alanyl-glutamine [Ala-Gln] dipeptide per kg) to minimize the effect of being nil per os (nothing by mouth) on GI integrity.35 (See Chapter 28 for more information on pancreatitis.)

Perioperative Malnutrition

The stress of surgical procedures produces an abundance of proinflammatory cytokines, which increase metabolic rate and cause catabolism, resulting in a depletion of lean body mass and aberrations in glycemic control. Studies have shown that patients at the highest risk of adverse postsurgical outcomes are those with low visceral protein stores (specifically, albumin) at baseline.20 The ratio of prealbumin to C-reactive protein may predict diminishing inflammation and, therefore, a patient's return to normal anabolic metabolism facilitated by feeding (PN) and subsequent repletion.36 Well-designed and appropriately timed nutrition support in this population may help attenuate metabolic and oxidative stress and, as a result, improve postsurgical recovery. Early nutrition support in both the pre- and postoperative phases is associated with better patient outcomes. EN is the preferred form, mainly due to its protective effect on the GI mucosal barrier. Perioperative PN is reserved for patients with severe malnutrition at baseline, in whom the risk of surgery would outweigh any benefit because of the high risk of postoperative complications; maximal benefit is derived in severely malnourished patients who receive PN for more than 7 to 10 days.36 However, recent (2011) evidence has found that PN using contemporary doses of energy and protein has effects comparable to EN in malnourished cancer patients undergoing surgery.1 Therefore, PN in the perioperative patient may be useful in treating malnutrition when other nutrition options are not feasible. (See Chapters 24 and 33 for more information on surgery and cancer, respectively.)

Critical Illness

Critical illness is characterized by a catabolic state that is generally the result of systemic inflammatory response to infectious or traumatic insult. In this state, gut failure is common because of preferential blood supply to vital organs. Additionally, mesenteric ischemia resulting from hemodynamic compromise and the use of vasopressors is a potential problem in critical illness not usually seen in other conditions. These facts notwithstanding, the ASPEN/Society of Critical Care Medicine guidelines recommend the enteral route as the preferred means of nutrition support in this population, with the greatest benefit derived in patients started on enteral feedings within 24 to 48 hours of intensive care unit admission.20 The benefit of EN is largely due to (1) its positive impact on the immune barrier and decreasing the permeability of the GI tract to enteric organisms, which can contribute to the overall detrimental systemic inflammatory response, and (2) the low risk of mesenteric ischemia when introducing EN.20 Expert recommendations20 place PN as a last resort in this patient group; in patients whose baseline nutrition status was normal, it is reserved for those cases when EN cannot be initiated for more than 7 days. Critically ill patients requiring PN usually meet all the following criteria: (1) are malnourished at baseline; (2) will not reliably ingest or absorb significant amounts of EN for a period of greater than 7 to 10 days; and (3) have been adequately resuscitated from any hemodynamic compromise. PN is also indicated for patients who are hemodynamically stable and have a paralytic

ileus, acute GI bleeding, or complete bowel obstruction (see Chapters 23 and 24). Recent guidelines suggest a role for supplemental PN as described previously.20 These guidelines also provide methods to minimize the complications of PN, such as the use of hypocaloric feeding and maintaining target glucose of 140 or 150 to 180 mg/dL.20

Cancer

Routine PN use in patients receiving chemotherapy or radiation is associated with increased infectious complications and no improvement in clinical response, survival, or toxicity to chemotherapy.4 ASPEN guidelines for the provision of nutrition support in adult patients receiving anticancer therapy recommend a thorough assessment of the patient's nutrition status and the use of PN only in those who are malnourished and likely to be unable to ingest and absorb adequate nutrients for a period of 7 to 14 days.4 EN is preferred in cancer patients with functional GI tracts. EN is also preferred in patients undergoing a hematopoietic cell transplant because glycemic control is better during EN than PN.4 Data suggest favorable outcomes in both of these patient groups with the use of immune-enhancing EN.37 Until more specific data are available, indications for these patients are similar to those for other conditions (see Chapter 33). Recent research has found PN to have some beneficial results in cancer patients, which may lead to a broader use of PN in the future. As discussed previously, Klek et al found the effects of PN and EN in malnourished cancer patients undergoing surgery to be comparable.1 Pelzer and colleagues used bioelectrical impedance analysis to demonstrate improvements in body composition in pancreatic cancer patients who had lost weight while receiving EN.2

Home Parenteral Nutrition

In general, indications for home PN are the same as those for hospitalized patients, but careful consideration must be given to the capabilities of the patient and caregivers as well as the safety of the home environment for PN. For home PN candidates, the duration of PN is prolonged (more than 2 weeks), and hospitalization is no longer needed for medical reasons. However, federal (Medicare) and state (Medicaid) healthcare programs have developed criteria that must be met before home PN–associated costs are reimbursed. Medicare requires documentation that the patient's GI tract is nonfunctional ("artificial gut"), and this condition is permanent (at least 90 days of therapy is needed). The patient must also have documented evidence of inability to tolerate enteral feeding (malabsorption, obstruction).

Outcomes in home PN patients vary depending on the underlying disease causing their nonfunctional GI tract. Cancer patients have more frequent PN complications, which are more likely to result in readmission to the hospital.3,38 Also, the extent of the disease or its responsiveness to treatment is likely to influence the success of home PN in cancer patients with extensive disease. However, performance status (Karnofsky performance status score [KPF] greater than 50) has been associated with longer survival in incurable cancer patients receiving home PN.3 Improvements in quality of life, KPF, and nutrition status in advanced cancer patients have also been observed.39

Whether PN can be initiated in the home is controversial. Table 14-5 lists circumstances where the clinical risk warrants caution when considering the initiation of PN in the home. (See Chapter 38 for additional information on home nutrition support.)

TABLE 14-5 Conditions Warranting Caution When Initiating Parenteral Nutrition in the Home

Medical conditions:	*Electrolyte disorders:*
• Diabetes mellitus	• Hypernatremia
• Congestive heart failure	• Hypokalemia
• Pulmonary disease	• Hyperchloremic metabolic acidosis
• Severe malnutrition	• Hypophosphatemia
• Hyperemesis gravidarum	• Hypochloremic metabolic alkalosis

The Parenteral Nutrition System

Outcomes from PN are dependent on the system by which it is managed within the healthcare system. ASPEN guidelines provide practical advice for PN40 use as well as safe practices.41 As noted, successful use of PN depends on an adequate system to order, transcribe, prepare (compound), dispense, and administer.16 PN is a complex therapy requiring trained professionals to initiate and manage it.42,43 Outcomes are optimized when interdisciplinary care or nutrition support teams manage PN.44,45 Although the system is generally safe, PN is likely to cause patient harm when the system fails.46,47

Pace and colleagues48 used ASPEN guidelines to assess the overuse of PN, the underuse of EN, and the need to update hospital policies and procedures to reflect recent advances and changes in nutrition support practice. A performance model was used to revise policies and procedures and to educate staff. This process resulted in a 52% decrease in PN use during a 4-year period, an increase in appropriate PN use from 74% to 95%, and an elimination of PPN use.

In a tertiary care teaching hospital, PN use was evaluated in 209 patients managed by either individual medical or surgical services or a metabolic support service.3 Indications for PN were derived from ASPEN guidelines.28 PN therapy was considered preventable if the patient had a functional small bowel but there was no suitable enteral access. PN was contraindicated if the patients were classified as well nourished and had inadequate EN for fewer than 7 days; had DNR status and were deemed to warrant comfort measures only or were terminally ill; or were receiving adequate EN. Of the PN regimens initiated, 62% were indicated, 23% were preventable, and 15% were not indicated. Compliance to established guidelines was improved when patients were managed by the metabolic support service.3

PN should be reserved for use in patients who are unable to tolerate enteral nutrients for prolonged periods of time because of physical or physiological impediments. PN has been associated with complications and patient harm including infections related to the introduction of IV catheters and their manipulations49 or the administration of a viable growth medium;50 metabolic complications from overfeeding or refeeding; and problems caused by other errors during prescription, transcription, or preparation.16,51 In response to these errors, guidelines and expert recommendations have been developed to curb harm resulting from PN use.52 Although the overall error rates may have decreased

with the use of these recommendations, errors still occur and occasionally result in patient harm. In a prospective observational study, Sacks and colleagues47 found 74 errors in a cohort of 4730 prescriptions for PN (ie, an overall error rate of 1.56%). Of these errors, 67 (91%) were classified as nonharmful, whereas 6 (8%) resulted in temporary harm to a patient. Most errors occurred during the transcription and administration phase in this study. As suggested by the work of Sacks and colleagues, the incorporation of nutrition guidelines may help decrease error rates. In addition, the use of a multistep, double-check process that requires the verification of an electronically transcribed order against the actual written order may significantly decrease error rates.47

In addition to incorporating systematic procedures for electronically transcribing and compounding PN accurately, the use of multidisciplinary teams in the ordering phase has been shown to help ensure the appropriate use of PN.3 See Practice Scenarios 14-2 through 14-5 for discussions of proper initiation, advancement, monitoring, and discontinuation of PN.3,6,14,53 A 2011 study querying PN practices in statewide hospitals54 indicates that nutrition support teams and certified nutrition support clinicians can help reduce the inappropriate use of PN and, as a result, substantially lower costs. In this study, of the 278 PN cases reviewed by registered dietitians, PN was inappropriately prescribed in 32% of cases, resulting in 552 days and $138,000 in preventable hospital costs.54

Practice Scenario 14-2

Question: How should parenteral nutrition (PN) be initiated?

Scenario: PN is to be initiated in a 53-year-old man who has chronic disease–related malnutrition and a complete bowel obstruction. Nutrition-related and metabolic parameters in the patient are as follows:

- White blood cell (WBC) count: 9.6 × 109/L
- Sodium (Na): 135 mEq/L
- Potassium (K): 4.1 mEq/L
- Chloride (Cl): 103 mEq/L
- Bicarbonate (CO2): 24 mmol/L
- Blood urea nitrogen (BUN): 6 mg/dL
- Creatinine (Cr): 1.1 mg/dL
- Glucose: 234 mg/dL
- Magnesium (Mg): 1.8 mEq/L
- Calcium (Ca): 9.8 mg/dL
- Phosphorus: 1.5 mg/dL
- Prealbumin: 2 mg/dL
- Weight loss: 20 kg
- % weight loss: 14%
- Time of weight change: 45 days

Intervention: PN is initiated at a low rate (100 g dextrose per day) with a supplemental dose of phosphorus prior to the start of PN and an increased dose of phosphorus in PN.

Answer: A favorable clinical response to PN may be delayed by the patient's catabolic state. Glucose and phosphorus problems should be corrected before PN is initiated. Then, PN should be initiated slowly, beginning with a low energy dose.

Rationale: The metabolic response to stress or injury influences the efficiency by which nutrients are incorporated into the body (see Chapters 23 and 24). Also, tolerance to nutrition support is influenced by abnormalities in carbohydrate, protein, and fat metabolism that are characterized in the stressed patient as hyperglycemia, insulin resistance, uremia, encephalopathy, hyperosmolality, and hypertriglyceridemia. Severe deficits in electrolytes may be present and exacerbated by the initiation of a parenteral feeding formulation (see Chapter 7). In some conditions, caution in initiating PN is warranted (Table 14-3). The patient's laboratory data demonstrate elevated serum glucose and hypophosphatemia. Both conditions should be corrected before PN is initiated and should be addressed in the PN formula. Use of a nutrition consultation form (eg, Figure 14-1) not only assists with determining the appropriate indication for PN but also establishes a framework by which PN may be safely initiated. This patient is severely malnourished and, as such, at significant risk of developing refeeding syndrome.53 PN should be initiated slowly, beginning at a low energy dose. Electrolyte abnormalities should be corrected before initiating PN.

Practice Scenario 14-3

Question: When can parenteral nutrition (PN) be advanced to the goal infusion rate?

Scenario: PN is initiated in a 61-year-old woman who has a history of type 2 diabetes.

Intervention: PN is initiated at a low energy dose. The following morning, the patient's blood glucose concentration is in the range of 210 to 240 mg/dL. The patient's blood pressure and other vital signs are within acceptable parameters.

Answer: PN should be advanced only when the following criteria are met: stable blood pressure, pulse, and respiration rates; and normal serum phosphorus, potassium, and glucose concentrations. The best practice is to control the patient's blood glucose before advancing the rate of PN to its goal rate. A reasonable goal for blood glucose is 140 to 180 mg/dL.53

Rationale: Because PN contributes significantly to the fluid intake of the patient, patients with limited cardiac function may not tolerate the PN infusion. Therefore, patients should be assessed for signs and symptoms of congestive heart failure and pulmonary edema. In addition, vital signs such as blood pressure and pulse may be adversely affected by PN. It is prudent to not advance the parenteral feeding formulation rate until the following criteria are met: stable blood pressure, pulse, and respiration rates; and normal serum phosphorus, potassium, and glucose concentrations. Hyperglycemia is frequently encountered in patients receiving PN (see Chapter 17).14 The dextrose content of intravenous fluids and

medications may contribute to excessive glucose administration in patients receiving PN.14 The best practice is to control the patient's blood glucose before advancing the rate of PN to its goal rate.

Practice Scenario 14-4

Question: Once parenteral nutrition (PN) is infusing at its goal rate, what approach to monitoring should be taken?

Scenario: PN is advanced to the goal rate in a patient with normal renal function but a gastrointestinal fistula draining 800 mL/d. Laboratory values are normal after the acute replacement of potassium and magnesium and a correction of a metabolic acidosis.

Intervention: Follow-up laboratory tests are done on a daily/as-needed basis, and capillary blood glucose checks continue 4 times a day with sliding-scale insulin coverage.

Answer: Initially, fluid, electrolyte, and renal status should be monitored daily. Routine blood glucose monitoring should also be conducted daily. Metabolic parameters (triglycerides and liver function tests) should be obtained periodically. The effectiveness of PN may be further assessed by measuring serum visceral proteins on a weekly basis and determining nitrogen balance in patients with functioning kidneys and adequate urine output.

Rationale: Because PN may be a large source of fluid and electrolytes as well as other nutrients, serum levels of electrolytes, blood urea nitrogen, creatinine, and glucose should be assessed daily during the initial period of PN therapy. Patients receiving PN may be predisposed to fluid and electrolyte disturbances because of fluid losses from the gastrointestinal tract, drug therapy such as diuretics, or electrolyte losses during periods of semi- or complete starvation. Other parameters of fluid and electrolyte status to monitor are fluid intakes and outputs, as well as daily weights in combination with physical assessment for signs and symptoms of dehydration or edema.

Patients receiving PN often experience metabolic disturbances. In addition to serum electrolytes and blood glucose monitoring, the periodic assessment of serum triglycerides is necessary if lipid injectable emulsions are administered. Abnormal hepatic function has also been associated with PN. Hepatic function should be assessed before initiating PN and then weekly.53 See Table 14-4 for more on laboratory tests used in assessment and monitoring of PN.3

Practice Scenario 14-5

Question: When and how should parenteral nutrition (PN) therapy be discontinued?

Intervention: Following a surgical procedure for a bowel obstruction and the drainage of intra-abdominal abscess, PN is initiated in a 65-year-old woman. On postoperative Day 8, nasogastric tube output dramatically declines, the patient is noted to have bowel sounds, and she has a bowel movement. At this time, the nasogastric tube is removed and orogastric tube feedings are initiated.

Answer: PN may be discontinued when the patient can meet and tolerate an adequate percentage of their estimated energy and protein needs via the enteral route.

Rationale: The goal of PN therapy is to maintain the nutrition status of the patient until some form of enteral nutrition is tolerated. The exception is the critically ill patient in whom therapy is withdrawn during the terminal stages of the disease process. In most other situations, the problem with the gastrointestinal tract resolves or the appropriate enteral access is obtained. PN is tapered as the amount of reliable enteral intake increases. It may be discontinued when the patient can consume solid food or when he or she tolerates an adequate percentage of the estimated energy and protein needs.6 In this patient, enteral tube feedings are initiated 8 days after the operation and advanced to the goal infusion rate within 72 hours of initiation. PN therapy is decreased by 50% on postoperative Day 9 and discontinued on postoperative Day 10.

To prevent rebound hypoglycemia, PN may be tapered over 1 to 2 hours. If PN needs to be stopped emergently, a 10% dextrose in water solution should be infused at either the same rate as the PN or at a rate of at least 50 mL/h. When cyclic PN infusion is used in the home, some form of tapering is usually required during the last 2 hours of the cycle. Finally, PN may be rapidly discontinued if the patient is tolerating tube feeding in amounts adequate to maintain normal blood glucose levels.

A review by Taylor and colleagues also suggests that the incorporation of a dietitian in the care of critically ill patients leads to a higher quality assessment of these patients' nutrition needs.55 Dietitians are vital in thoroughly assessing patients' nutrition needs, including their fluid and electrolyte requirements, as well as suggesting the appropriate route and timing of nutrition provision. Additionally, research led by dietitians has provided insight into the achievement of optimal blood glucose control and the use of specialized nutrition. Dietitians and other qualified nutrition support clinicians help adjust patients' nutrition plans according to changes in physiological status.54

Conclusion

ASPEN guidelines are useful in identifying patients who are likely to benefit from PN. CPN provides adequate nutrients to maintain and replete the patient's nutrition stores. PPN may be useful for limited periods in maintaining nutrition status until the GI tract is functional. Recent evidence strongly supports EN to be the preferred mode of nutrition support in critical illness and pancreatitis because of its ability to maintain the integrity of the GI tract and properly support the systemic inflammatory response. PN should be reserved for those patients who are malnourished or at significant nutrition risk and have a contraindication to EN or in whom GI intolerance persists beyond 7 days. Current experience with PN in malnourished patients has demonstrated improvements in body composition with PN; PN outcomes comparable with those of EN when contemporary doses of energy and protein are used; improved quality, safety, and utilization when PN is managed by nutrition support teams; positive PN outcomes in long-term patients; improved PN performance measures; and better quality of life for some patients. Even though PN can cause several complications, these may be minimized when managed well by trained individuals, allowing for beneficial effects to be achieved.