Parenteral Nutrition - Pediatric/Neonatal - Inpatient/Ambulatory Clinical Practice Guideline

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CPG Contact for Content:
Name: Susan Stone, PharmD, BCNSP, CNSC, Clinical Nutrition Support
Phone Number: (608) 263-1290
Email Address: SStone@uwhealth.org

CPG Contact for Changes:
Name: Philip Trapskin, PharmD, BCPS, Drug Policy Manager
Phone Number: (608) 265-0341
Email Address: PTrapskin@uwhealth.org

Guideline Author(s):
Susan Stone, PharmD, BCNSP, CNSC; Pharmacy
Andrea Magee, MS, RD, CNSC, CD Clinical Nutrition
Laura Bodine, MS, RD, CNSC, CD; Clinical Nutrition
Rachel Parks, MS, RD, CNSC; Clinical Nutrition
Gretchen Manthei, PharmD, BCNSP; Pharmacy
Caitlin Curtis, PharmD, BCNSP; Pharmacy
Monica Bogenschutz, PharmD, BCPS; Pharmacy

Coordinating Team Members:
Amanda Condon, PharmD, Pharmacy
Carin Bouchard, PharmD, BCPS; Drug Policy Program

Review Individuals/Bodies:
Peter Nichol, MD, PhD - Pediatric Surgery
Luther Sigurdsson, MD - Pediatric Gastroenterology
Jamie Limjoco, MD - Medical Director of the NICU
Sabrina Butteris, MD; Pediatrics, Hospitalists
Christian Capitini, MD; Pediatrics, Hematology
Scott Hagen, MD; Pediatrics, PICU
Mary Schroth, MD; Pediatrics, Pulmonary
Monica Bogenschutz, PharmD, BCPS
Gretchen Manthei, PharmD, BCNSP
Susan Kleppin, RPh, FASHP, Chartwell

Committee Approvals/Dates:
UW Health Nutrition Committee (02/2016)
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Executive Summary

Guideline Overview

This guideline describes the optimal use of parenteral nutrition in neonatal and pediatric patients.

Key Revisions (2016 Periodic Review)

1. Expansion of pediatric malnutrition definition
2. Added recommendations for when to start parenteral nutrition cycling in neonates
3. Update of references and grading

Key Practice Recommendations

1. Consider parenteral nutrition if all attempts at enteral nutrition or oral feeding are unsuccessful
2. Indications:
    a. Patients unable to meet needs through oral or enteral nutrition support
    b. Lack of enteral access
    c. Gut failure or absence
    d. Chylous ascites or chylothorax if chylous output remains elevated despite use of high medium chain triglyceride/low long chain triglyceride feeding
    e. Patients on high-dose inotropes or with clinically significant hemodynamic instability
3. Nutritional requirements
    a. Energy
    b. Protein
    c. Carbohydrate
    d. Intravenous Fat Emulsion (ILE)
    e. Fluid
    f. Electrolytes
    g. Trace Elements
    h. Vitamins
4. Routine addition of insulin to parenteral nutrition is discouraged
5. Percutaneous catheters advanced to the superior vena cava are preferred for central parenteral nutrition
6. Administration of parenteral nutrition should follow safe practices related to maintenance of tubing, limiting hang time for ILE, and use of filters to prevent infusion of intrinsic or extrinsic contaminants
7. Complications of parenteral nutrition include
    a. Glycogen storage as fat
    b. Hepatic steatosis
    c. Increased carbon dioxide production
    d. Cholestasis
    e. Metabolic Bone Disease
8. Monitoring should include the following, depending on duration of parenteral nutrition
    a. Anthropometrics
    b. Blood chemistries including magnesium and phosphate
    c. Triglycerides
    d. Point-of-care glucoses every two to six hours for certain patients
    e. C-reactive protein
    f. AST and ALT, alkaline phosphatase, and bilirubin
    g. Carnitine
    h. Vitamins A, B-6, B-12, D, and E

   i. Trace elements
   j. Iron studies
   k. Essential fatty acid profile
9. Cyclic parenteral nutrition should be considered in patients on or anticipated to be on long-term parenteral nutrition, patients who are on home parenteral nutrition, patients with cholestasis to prevent worsening hepatic dysfunction, and patients who are ready to transition to oral intake
10. Patients should be evaluated daily for ability to begin oral feedings or enteral nutrition
11. Most patients should have parenteral nutrition rates gradually weaned to off to prevent hypoglycemia
12. Home parenteral nutrition may be indicated for patients who are stable enough for discharge but cannot receive sufficient energy and protein enterally or orally to meet their needs
13. Physical traits and limitations of parenteral nutrition include 3-in-1 stability and medications added in or Y-sited

INTERIM REVISION 2021

Recommendations for filter use have been revised (see Section 6.3). 1.2-micron filters are now recommended for all parenteral nutrition with intravenous lipid emulsion or for intravenous lipid emulsion alone.[1] A 0.2-micron filter should be used for aqueous parenteral nutrition solutions without intravenous lipid emulsion.

INTERIM REVISION 2022

For recommendations on use of parenteral nutrition in a child with spinal muscular atrophy or other neuromuscular degenerative diseases, refer to the Pediatric Neuromuscular Disease (NMD) Management guideline**.**

Companion Documents

1. Nutrition Support – Developing, ordering and monitoring a Nutrition Support Care Plan - Adult/Pediatric/Neonatal

Scope

Disease/Condition(s): Initiation, advancement, and monitoring of parenteral nutrition as well as supplementation for the neonatal and pediatric populations.

Clinical Specialty: Pediatrics, Neonatology

Intended Users: Physicians, Advanced Practice Providers, Pharmacists, Dietitians, and Nurses

Objective(s): The objective of this guideline is to standardize the use of parenteral nutrition throughout the institution to improve patient outcomes and safety.

Target Population: Neonatal and pediatric patients requiring parenteral nutrition.

Interventions and Practices Considered: Initiation, modification, and discontinuation of parenteral nutrition in the neonatal and pediatric population.

Major Outcomes Considered: Appropriate management of patients receiving parenteral nutrition including:

Safe and effective infusion of parenteral nutrition, appropriate growth, alleviation of signs and symptoms of malnutrition, and limitation of complications of parenteral nutrition.

Methodology

Methods Used to Collect/Select the Evidence:

Electronic database searches (e.g., PUBMED) were conducted by the guideline author(s) and workgroup members to collect evidence for review. A review of PubMed database was conducted with combinations of the keywords: parenteral nutrition, intravenous fat emulsion, parenteral nutrition compatibility, electrolyte replacement, enteral nutrition, insulin management, parenteral nutrition stability, or special populations. References from the articles were also searched. Finally, the personal libraries of the authors were queried and expert opinion and clinical experience were also considered during discussions of the evidence.

Methods Used to Formulate the Recommendations:

The workgroup members agreed to adopt recommendations developed by external organizations and/or arrived at a consensus through discussion of the literature and expert experience. All recommendations endorsed or developed by the guideline workgroup were reviewed and approved by other stakeholders or committees (as appropriate).

Methods Used to Assess the Quality of the Evidence/Strength of the Recommendations:

Recommendations developed by external organizations maintained the evidence grade assigned within the original source document and were adopted for use at UW Health.

Internally developed recommendations, or those adopted from external sources without an assigned evidence grade, were evaluated by the guideline workgroup using a modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) methodology developed by the American Heart Association and American College of Cardiology[2] (see Appendix A).

Rating Scheme for the Strength of the Evidence/Recommendations:

See Appendix A for the rating scheme(s) used within this document.

Recognition of Potential Health Care Disparities:

Socioeconomic factors may affect parenteral nutrition provision. Home parenteral nutrition is an expensive therapy that often requires insurance pre-certification prior to coverage.[3,4] Therefore, socioeconomic status and insurance coverage may impact who can receive parenteral nutrition in the home care setting. Additionally, one study reported a potential for racial or geographic disparities in the provision and complication rates of parenteral nutrition in certain subsets of malnourished patients with inflammatory bowel disease, although the mechanism of this difference was not determined[4].

Definitions

1. Birth Weight Classification:
   1.1. Small for gestational age (SGA): < 10th percentile birth weight for gestational age
   1.2. Appropriate for gestational age (AGA): 10th to 90th percentile birth weight for gestational age
   1.3. Large for gestational age (LGA): > 90th percentile birth weight for gestational age
2. Classification of Preterm Infants by Birth Weight: ELBW ≤ 1000 gram, VLBW ≤ 1500 gram, LBW ≤ 2500 gram[5]
3. Dosing Weight: a patient-specific weight determined by the clinician to arrive at a specific nutrient dose. It may be the actual weight, birth weight (used in neonates until birth weight is regained following post-natal diuresis), ideal or adjusted body weight of the individual, depending on clinical status.
4. EN – Enteral nutrition is the provision of nutrients via the gastrointestinal (GI) tract through a tube, catheter, or stoma.
5. Gestational Age Classification: Preterm infants are those born < 37 weeks gestation, with late preterm infants classified as being born from 34 to 36 weeks. Term infants are born at 37 to 41 weeks gestation. Those born > 42 weeks are considered post-term.
6. Infant: Birth to 12 months of age.
7. ILE - Intravenous lipid emulsion is an oil-in-water emulsion of oils, egg yolk phospholipid, and glycerin.
8. Neonate: An infant during the first 28 days of life.
9. Obesity – BMI-for-age ≥ 95th percentile[6]
10. Osmolarity – the theoretical, calculated, osmotic concentration of a liquid expressed in osmoles or mOsmol per liter of a solution.
11. Overweight - BMI-for-age > 85th and < 95th percentile[6]
12. PN – Parenteral nutrition is the intravenous administration of nutrients.
    12.1. Central: PN administered into a large diameter vein, usually the superior vena cava, adjacent to the right atrium.
    12.2. Peripheral: PN administered through a peripheral vein; usually the hand or forearm. To reduce risk for phlebitis, the maximum osmolarity tolerated by a peripheral vein is 900 mOsm/L.
    12.3. Midline: midline is a 7-inch catheter inserted in the antecubital region with the tip located in the axillary region.
13. Starter PN: A pre-mixed PN solution containing AA 3 or 3.5% with Dextrose 10 or 12.5% (with minimal or no electrolytes) with or without heparin designed for the use immediately after birth in premature or term infants who weigh < 2 kg.
14. Underweight - < 5th percentile for weight-for-length or BMI-for-age[7]

Introduction

This guideline is designed to ensure safe and optimal provision of PN for neonatal and pediatric patients. The goal of PN is to provide substrates for daily metabolism as well as growth while oral or enteral feedings are insufficient to meet nutrition needs. Nutrients will be individualized to meet the infant or child's nutrition needs while minimizing iatrogenic effects secondary to PN administration. Transition to oral intake or EN will be initiated as soon as clinically able for all neonatal and pediatric patients.

Recommendations

1. Consider PN only if all attempts at EN or oral feeding are unsuccessful, the gastrointestinal tract is not functional, or it is anticipated that there will be a prolonged period of suboptimal EN provision or oral intake[8]. **(UW Health Class I, Level C)**
2. Indications
   - 2.1. Patients unable to meet needs through oral or enteral nutrition support. **(UW Health Class I, Level C)**
     - 2.1.1. A review of growth history, using the appropriate growth chart, including z-scores (if applicable), for age and sex, will assist with determining the nutritional status of the patient and thus timing for initiation of PN (Table 1).[7]

Table 1: Defining Pediatric Malnutrition

	Mild	Moderate	Severe
Weight-for-length OR BMI-for-age *z* score	-1 to -1.9	-2 to -2.9	-3 or greater
Length/height-for-age *z* score	No data	No data	-3 or greater
MUAC *z* score	-1 to -1.9	-2 to -2.9	-3 or greater
Weight gain velocity (<2 year of age)	< 75% of norm	< 50% of norm	< 25% of norm
Weight loss (2 to 20 years)	5% UBW	7.5% UBW	10% UBW
Deceleration in weight-for-length or BMI	Decline of 1 *z* score	Decline of 2 *z* scores	Decline of 3 *z* scores
Inadequate nutrient intake	51 to 75% estimated needs	26 to 50% estimated needs	≤ 25% estimated needs

Acute malnutrition ≤ 3 months duration and chronic malnutrition > 3 months

- 2.1.2. Lack of enteral access and/or inadequate EN for[9]:
  - 2.1.2.1. Newborn premature infant for < 24 hours[10,11] **(UW Health Class I, Level B)**
    - 2.1.2.1.1. Infant with BW < 2 kg will use starter PN immediately after birth for up to 1 to 2 days, or as clinically indicated.
  - 2.1.2.2. Newborn full-term infant for 2 to 3 days[9] **UW Health Class I, Level C)**
  - 2.1.2.3. Critically ill child [e.g. closed head injury (CHI), burn, multi-trauma] for < 2 days[12-15] **(UW Health Class I, Level C)**
  - 2.1.2.4. Child who is malnourished on admission for 3 to 5 days[16] **(UW Health Class I, Level C)**
  - 2.1.2.5. Well-nourished child for 5 to 7 days[17] **(UW Health Class I, Level C)**
  - 2.1.2.6. For recommendations on use of parenteral nutrition in a child with spinal muscular atrophy or other neuromuscular degenerative diseases, refer to the Pediatric Neuromuscular Disease Management (NMD) guideline.
- 2.1.3. Gut failure or absence:[8,9,18] **(UW Health Class I, Level C**
  - 2.1.3.1. Congenital or acquired anomalies of the GI tract: gastroschisis, bowel fistula(s), atresia(s)[9,19]

2.1.3.2. Severe pancreatitis refractory to EN[8]
2.1.3.3. Malabsorption syndromes: celiac sprue, inflammatory bowel disease, short bowel syndrome[9,20,21]
2.1.3.4. Suspicion for or confirmed necrotizing enterocolitis (NEC)[9,22]
2.1.3.5. Motility disorders: prolonged ileus, prolonged bowel obstruction[8]
2.1.3.6. Chronic intractable diarrhea or vomiting[9]
2.1.3.7. Side effects from antineoplastic therapy or bone marrow transplantation such as graft vs host disease, mucositis, typhlitis[9]
2.1.3.8. High output enterocutaneous fistula[9]

2.1.4. Chylous ascites or chylothorax if chylous output remains elevated despite use of high medium chain triglyceride (MCT)/low long chain triglyceride (LCT) feeding[23]. (**UW Health Class I, Level C)**

2.1.5. Patients on high-dose inotropes or with clinically significant hemodynamic instability[24]. **UW Health Class I, Level C)**

3. **Nutritional Requirements**

Determination of nutrition requirements for neonatal and pediatric patients is individualized. This includes evaluation of the patient's current anthropometrics, growth history, age, clinical status and overall goals as determined by the health care team. Nutrient needs should be determined by or in conjunction with a registered dietitian with neonatal or pediatric expertise.

3.1. Energy[25-28]

3.1.1. Provide adequate energy to meet patient specific requirements. **(UW Health Class IIa, Level C)**

3.1.1.1. For preterm and term infants, aim to provide 90 to 120 kcal/kg/day.
3.1.1.2. For older infants, children, and adolescents, please refer to Tables 2 & 3 for calculating energy requirements.[29,30]

Table 2. Estimating Energy Needs in Critical Illness

Estimating Energy Needs in Critical Illness			
Age (years)	Gender	Resting Energy Expenditure (REE) Equations (Kcal/day)	
		WHO[31]	Schofield[29]
0-3	Male	(60.9 x Wt) - 54	(0.167 x Wt) + (15.174 x Ht) - 617.6
	Female	(61.0 x Wt) - 51	(16.25 x Wt) + (10.232 x Ht) - 413.5
3-10	Male	(22.7 x Wt) + 495	(19.59 x Wt) + (1.303 x Ht) + 414.9
	Female	(22.5 x Wt) + 499	(16.969 x Wt) + (1.618 x Ht) + 371.2
10-18	Male	(17.5 x Wt) + 651	(16.25 x Wt) + (1.372 x Ht) + 515.5
	Female	(12.2 x Wt) + 746	(8.365 x Wt) + (4.65 x Ht) + 200

Weight in kilograms, height in centimeters

Table 3. Activity and Stress Factors for Estimating Energy Needs

Activity and Stress Factors x REE/BMR[30]					
Condition	Factor		Condition	Factor	
ICU on Ventilator	Activity 1.0 to 1.15		Pneumonia	Stress 1.3 to 1.4	
Major Surgery	Stress 1.2 to 1.3		Head Injury	Stress 1.3 to 1.4	
Multiple Fractures	Stress 1.2 to 1.3		Liver Failure	Stress 1.4 to 1.5	
Peritonitis	Stress 1.2 to 1.5		Sepsis	Stress 1.4 to 1.5	
Cardiac Failure	Stress 1.25 to 1.5		Burns	Stress 1.5 to 2.0	

3.1.2. Provide approximately 10% fewer calories for PN than is required for EN due to the absence of the thermic effect of food (TEF), calories required for digestion and absorption[32]. **(UW Health Class I, Level C)**
3.1.3. For obese patients, may use actual body weight when estimating calories and aim for initial goal of calculated REE.[33,34] **(UW Health Class IIb, Level C).**
3.1.4. Avoid overfeeding[35-37]. **(UW Health Class III, Level C)**
3.1.4.1. Overfeeding can contribute to glycogen deposition, mild fatty changes in hepatocytes leading to elevated liver function tests and does not contribute to further anabolism
3.1.4.2. Overfeeding may result in hyperglycemia, increased carbon dioxide production and associated morbidity and mortality.
3.1.4.3. Predictive equations can be utilized to prevent overfeeding by estimating resting energy expenditure (REE) and basal metabolic rate (BMR).
3.1.4.4. The best way to prevent overfeeding is by the use of indirect calorimetry.
3.1.5. Indirect calorimetry[35,38,39] **(UW Health Class I, Level C)**
3.1.5.1. Use indirect calorimetry (IC) to measure REE when energy estimates are in question and those at risk for over or under feeding[35] (Table 4).

Table 4. Suggested Candidates for Indirect Calorimetry

Parameter	Specific Indicator [35]
Weight	Underweight: BMI-for-age or weight-for-length < 5th percentile Overweight/Obese: BMI-for-age > 85th percentile Weight change: gain or loss of > 10%
Respiratory	Failure to wean or need to escalate respiratory therapy, requires mechanical ventilation for > 7 days
Hypermetabolism	Status epilepticus, dysautonomic storms, SIRS, hyperthermia
Hypometabolism	Pentobarbital/midazolam coma, muscle paralytic, hypothermia
Diagnosis	Burns/thermal injury, oncologic diagnosis (including BMT), neurologic trauma (traumatic, hypoxic and/or ischemic)

SIRS – systemic inflammatory response syndrome

3.1.5.2. Energy requirements can be measured by the use of IC and can assist with optimization of caloric provision, particularly during critical illness. The oxygen and CO_2 concentrations of inspired and expired gas are measured to determine the respiratory quotient (RQ) which also may provide information on substrate utilization[35]. (See Appendix B)
3.1.5.3. Of note, current literature suggests that the RQ may not accurately represent substrate utilization during acute illness, but may be used to confirm validity of IC measurement[35].

3.2. Protein[25-28]
3.2.1. It is reasonable to provide adequate protein to meet patient requirements (Table 5). **(UW Health Class IIa, Level C)**. Crystalline amino acids are the principle parenteral protein source providing 4 kcal/gram.

Table 5: Pediatric Protein Requirements

Pediatric Classification	Protein[26]
Premature infant	3 to 4 g/kg/d
0 to 2 years	2 to 3.5 g/kg/d
2 to 13 years	1.5 to 2.5 g/kg/d
13 to 18 years	1.5 to 2 g/kg/d

3.2.2. It is reasonable to provide appropriate protein composition to meet patient needs.[25-28] **(UW Health Class IIb, Level C)**
- 3.2.2.1. TrophAmine® is recommended to meet the specific amino acid requirements from birth to 12 months of age (corrected age).
- 3.2.2.2. Clinisol® is recommended to meet the amino acid requirements for patients >12 months old.
- 3.2.2.3. For premature infants or term infants with birth weight < 2 kg, use starter PN to achieve an initial protein intake at approximately 2.5 to 3 g/kg depending on rate of infusion.
- 3.2.2.4. It is reasonable to consider adding cysteine (30 to 40 mg per gram of amino acid) for premature and infants up to 6 months of age.[40] **(UW Health Class IIb, Level B)**

3.2.3. Recommend starting at goal amino acid provision on day 1 of PN. [25-28] **(UW Health Class I, Level C)**

3.2.4. It is reasonable to provide protein at the expense of energy if fluid restriction prevents adequate provision of both[41]. **(UW Health Class IIa, Level C)**

3.2.5. Provide at least 1.1 g protein per kg to achieve net zero nitrogen balance and prevent catabolism in neonates.[42] **(UW Health Class I, Level B)**

3.3. Carbohydrate[25-28]

3.3.1. Provide adequate carbohydrate to meet minimal requirements and provide sufficient energy. Dextrose monohydrate is the primary calorie source in PN, which yields 3.4 kcal/g. **(UW Health Class I, Level C)**

3.3.2. Target acceptable glucose concentrations of 80 to 180 mg/dL[43,44] **(UW Health Class I, Level B)**

3.3.3. Use the following equation to calculate glucose infusion rate:

$$\textit{Glucose infusion rate (mg/kg/min)} = \frac{\textit{dextrose (grams/kg/day) x 1000 mg/gram}}{\textit{time in minutes}}$$

3.3.4. Initiation, advancement, and maximum glucose infusion rate (GIR) should vary based on the patient's age, weight, and clinical status. Please refer to Table 6 for initiation, advancement, and maximal GIR parameters.

Table 6. Initiation and Advancement of PN Macronutrients

Initiation [26,45,46]			(Daily) Advance By		Goals	
Infants (<1yr)	**Preterm**	**Term**	**Preterm**	**Term**	**Preterm**	**Term**
Protein (g/kg)	3 to 4	2 to 3.5	-	-	3 to 4	2 to 3.5
CHO (mg/kg/min)	4 to 6	6 to 9	1 to 2	2-3.5	10 to 14 (max 14-18)	12-14 (max 14-18)
Fat (g/kg)	0.5 to 1.5	1 to 2	0.5 to 1.5	1 to 1.5	3 to 3.5 (Max 0.17 g/kg/h)	3 (Max 0.15 g/kg/h)
Children (1-10 y)						
Protein (g/kg)	1.5 to 2.5		-		1.5 to 2.5	
CHO (mg/kg/min)	3-6 or dextrose 10% equivalent		2-3 or dextrose 5%/day		8 to 10	
Fat (g/kg)	1 to 2		0.5 to 1		2 to 2.5	
Adolescents						
Protein (g/kg)	1 to 2		-		1 to 2	
CHO (mg/kg/min)	3.5 or dextrose 10%		1 to 2 or dextrose 5%/day		5 to 7	
Fat (g/kg)	1		1		1 to 2	

CHO – carbohydrate

3.4. Intravenous Lipid Emulsion (ILE) [25-28]
- 3.4.1. Provide sufficient fat to meet calorie needs and prevent essential fatty acid deficiency (EFAD). Intralipid 20 percent provides 2 kcal/mL or 10 kcal/g of soybean-based fat. **(UW Health Class I, Level C)**
- 3.4.2. Administer ILE to prevent EFAD[26,45-47] **(UW Health Class I, Level B)**:
  - 3.4.2.1. At least 0.5 to 1 g/kg/day for infants and young children.
  - 3.4.2.2. At least 2 to 4 percent of total calories for older children and adolescents.
- 3.4.3. Administer < 60 percent of total calories as fat in order to prevent ketosis. (Exception: patients requiring the ketogenic diet). **(UW Health Class I, Level C)**
- 3.4.4. Do not exceed an infusion rate of 0.17 g/kg/h for neonates, 0.15 g/kg/h for infants and children or 0.11 g/kg/h for adolescents and adults. Rapid infusion can result in coagulopathy, hepatomegaly, elevated liver function tests, and thrombocytopenia.[48] **(UW Health Class I, Level B)**
- 3.4.5. The hang-time for an individual bag of ILE (lipids) is 12 hours to prevent microbial growth.[49] This may be administered as one or two separate infusions in a 24-hour period. **(UW Health Class I, Level C)**
- 3.4.6. Subtract propofol calories with sustained (usually continuous intravenous infusion) propofol therapy; decrease or discontinue ILE to avoid exceeding maximum ILE infusion rate. **(UW Health Class I, Level C)**
- 3.4.7. Levocarnitine:[50,51] **(UW Health Class IIa, Level C)**
  - 3.4.7.1. It is reasonable to add on day 1 of PN for infants at a dose of 5 mg/kg/day if no enteral source of nutrition is provided
  - 3.4.7.2. Increase or add at a dose of 10 to 20 mg/kg/day for patients with hypertriglyceridemia to assist with the transport of fatty acids from the cytosol into the mitochondria.
  - 3.4.7.3. Should be supplemented daily for those with carnitine deficiency or metabolic disorders.
  - 3.4.7.4. Should be considered in patients with cardiomyopathy or for patients with (or to prevent) anthracycline–induced cardiomyopathy [52-57]

3.5. Fluid[58] **(UW Health Class I, Level B)**
- 3.5.1. A standard approach to calculating a starting estimate of maintenance fluid requirements for the pediatric patient is as follows (Tables 7, 8):

Table 7. Holliday Segar Equation to Determine Daily Maintenance Fluid Requirements

Body Weight (kg)	Amount of Fluid per Day [58]
1 to 10	100 mL/kg
11 to 20	1000 mL plus 50 mL/kg for each kg > 10 kg
> 20 kg	1500 mL plus 20 mL/kg for each kg > 20 kg

Table 8. Initial Fluid Requirements for Preterm Neonates

Birth Weight	< 750 g	750 to 1000 g	1000 to 2500 g	> 2500 g
Fluid (mL/kg/d) (DOL 1) [59-61]	100	80 to 100	60 to 80	60
Advancement	20 to 40 mL/kg/d based on clinical status			
Goal	150 mL/kg/d			

- 3.5.2. Patients with cardiac anomalies and surgical neonates are commonly fluid-restricted. PN volume should adhere to total fluid goals.
- 3.5.3. PN can provide a portion or all of the daily fluids.

3.6. Electrolytes[62] **(UW Health Class I, Level C)**

3.6.1. Provide electrolytes to meet patients' individual needs and maintain blood concentrations within the normal range.
3.6.2. In the first 24 to 48 hours of life, premature and term infants usually do not require sodium, potassium, chloride, calcium (depending on clinical status) and phosphorus. Once adequate urine output has been established, electrolytes should be added according to clinical condition.

Table 9. Neonatal & Pediatric Daily Electrolyte Dose Recommendations

Electrolyte[26]	Preterm Neonates	Infants/Children	Adolescents and Children > 50 kg
Sodium	Initial: 1 to 2 mEq/kg Goal: 2 to 5 mEq/kg	2 to 5 mEq/kg	1 to 2 mEq/kg
Potassium	Initial: 0.5 to 2 mEq/kg Goal: 2 to 4 mEq/kg	2 to 4 mEq/kg	1 to 2 mEq/kg
Calcium	Initial: 1.5 to 2 mEq/kg Goal: 2 to 4 mEq/kg	0.5 to 4 mEq/kg	10 to 20 mEq
Phosphorus	Initial: 0.5 to 1 mMol/kg Goal: 1 to 2 mMol/kg	0.5 to 2 mMol/kg	10 to 40 mMol
Magnesium	0.3 to 0.5 mEq/kg	0.3 to 0.5 mEq/kg	10 to 30 mEq
Acetate	As needed to maintain acid-base balance		
Chloride	As needed to maintain acid-base balance		
See Appendix C. for usual adult electrolyte requirements.			

3.6.3. Provide calcium to phosphorus ratios for optimal bone accretion if clinical condition and PN compatibility allow.[49,63] Optimal mineral retention may be obtained with a calcium to phosphorus ratio of 2.2 to 2.6 mEq calcium to 1 mMol phosphorus. Ratios < 1.6 mEq calcium to 1 Mmol phosphorus or alternate-day infusions may result in mineral wasting and increased risk of metabolic bone disease.[64]
3.6.4. For peripheral lines, calcium content should be limited to 1 mEq/100 mL.[65]

3.7. Vitamins[62,66] **(UW Health Class I, Level C)**
3.7.1. Provide vitamins parenterally, enterally, or orally, depending on clinical condition and formulation. Dose is dependent upon age, weight, and development. (Table 10.)

Table 10. Pediatric Multivitamin Dosing

Weight (kg)	Dose
< 2.5	2 mL/kg
> 2.5	5 mL/day
Patients > 11 years old will use adult multivitamin (MVI-12); usual dose is 10 mL/day	

3.7.2. Altered Requirements[26] **(UW Health Class IIb, Level C)**
3.7.2.1. Hemodialysis, CRRT – May provide additional water soluble vitamins (e.g., thiamine, pyridoxine, folic acid) to replace vitamins removed during the dialysis process[67]
3.7.2.2. Liver failure or coagulopathy – may consider providing additional phytonadione 1 to 5 mg daily[66]

3.7.2.3. Refeeding syndrome – may consider providing additional thiamine 25 to 50 mg/day for three days to prevent encephalopathy[68]

3.8. Trace Elements[62] **(UW Health Class I, Level C)**

3.8.1. Provide trace elements parenterally, enterally, or orally, depending on clinical condition and formulation. Dose is dependent upon age, weight, and development. (Table 11)[41]

Table 11. Parenteral Trace Element Recommendations for Infants and Children

Trace Element	Premature Neonates (mcg/kg/day)	Term Infants (mcg/kg/day)	Children (mcg/kg/day)
Zinc	400	250 (< 3 month old) 50 (> 3 month old)	50 (max = 5 mg/day)
Copper	30	20	20 (max = 500 mcg/day)
Manganese	1	1	1 (max = 50 mcg/day)
Chromium	0.05 to 0.3	0.2 (max = 5 mcg/day)	0.2 (max = 5 mcg/day)
Selenium	1.5 to 4.5	1 to 3	1 to 3 (max = 100 mcg/d)
Iodine	1	1 mcg/day	1 mcg/day

3.8.2. Premature infants or infants and children who are anticipated to be on long-term PN (> 2 to 4 weeks) may have trace elements dosed separately (due to contamination of the PN products with aluminum, manganese, chromium and other trace minerals during the manufacturing process).[49]

3.8.3. Altered Requirements **(UW Health Class IIb, Level C)**:

3.8.3.1. Cholestasis or severe liver dysfunction – may administer zinc, selenium, copper and chromium individually and remove multi-trace elements from PN [trace elements stored in the liver (e.g., manganese) may need to be removed when the direct bilirubin is > 2 mg/dL][69]

3.8.3.2. Renal disease – may consider removing chromium and selenium in patients with chronic renal failure.[41]

3.8.3.3. Long–term PN – may limit the amount of PN and duration of PN therapy since aluminum toxicity may occur, especially with premature infants, due to contamination of parenteral products.[41]

3.8.3.4. Burn or large wounds – Consider providing additional zinc and selenium[70]

3.8.3.5. Increased GI losses – Consider providing additional zinc at an amount based on diarrhea volume or fistula output.[71]

3.8.3.6. Iodine – available in Peditrace® product, but not supplied in US-manufactured pediatric trace element products

3.8.3.7. Iron – available in Peditrace® product, but not supplied in US-manufactured pediatric trace element products

3.8.3.7.1. Supplementation is required for patients on long-term PN as the sole nutrition source. **(UW Health Class I, Level C)**

3.8.3.7.2. Supplementation may be oral, enteral, or parenteral, depending on gastrointestinal tract anatomy and absorptive capacity

4. **Insulin**

4.1. Routine addition of insulin to PN is discouraged. If the pediatric patient requires less insulin or more glucose, the PN may need to be stopped, depriving the patient of nutrients.[43,44] **(UW Health Class III, Level C)**

4.2. Consider consulting pediatric endocrinology if patient requires insulin while on PN.

5. **Route of Administration[72-74] (UW Health Class I, Level B)**
   - 5.1. Central Parenteral Nutrition: percutaneous catheters advanced into the superior vena cava are preferred to a percutaneous jugular or femoral site to minimize the risk of infection with non-tunneled central venous catheters. **(UW Health Class I, Level B)**
   - 5.2. Peripheral Parenteral Nutrition[49], including midline catheters[75] **(UW Health Class IIb, Level C)**
     - 5.2.1. Peripheral administration may be considered as a temporizing measure for 48 to 72 hours.
     - 5.2.2. Limitations/Contraindications – Patients who are fluid-restricted, have limited venous access or if unable to meet at least 50% of nutritional requirements
     - 5.2.3. Maintain osmolality less than 900 mOsm/L[26,34] (See Appendix D for calculations) **(UW Health Class IIa, Level C)**
   - 5.3. Umbilical arterial catheters (UAC) or umbilical venous catheters (UVC) can be used to administer PN; add heparin 0.5 unit/mL to PN solutions through this route.[76] Nursing Patient Care Policy 1.48P – Care of Umbilical Catheters (Arterial and Venous)

6. **Administration[49] (UW Health Class I, Level B)**
   - 6.1. Maintain central and peripheral tubing according to Nursing Patient Care Policy 1.21 Maintenance and Discontinuation of Central Venous Access Devices – Non-PICC (Adult & Pediatric) and Policy 1.23 AP – Continuous Peripheral Intravenous Therapy (Adult & Pediatric)
   - 6.2. ILE - The hang time for an individual bag of lipids is 12 hours to prevent microbial growth. This may be administered as one or two separate infusions in a 24-hour period[77]
     - 6.2.1. If fat is < 2% of total volume, administer ILE as an infusion separate from PN *(not* as a 3-in1 PN or total nutrient admixture, TNA)
   - 6.3. Use filters to prevent infusion of intrinsic (e.g., aluminum) or extrinsic (introduced upon compounding) contaminants.[1,77]
     - 6.3.1. 1.2-micron filter is recommended for PN with ILE or ILE alone.
     - 6.3.2. 0.2-micron filter is recommended for aqueous parenteral nutrition solutions without ILE (e.g., 2-in-1) (a 0.2-micron filter should be avoided with TNAs or 3-in-1 PNs as the lipid emulsion cannot pass through the filter intact)
     - 6.3.3. At American Family Children's Hospital, PN with ILE or ILE alone will be filtered with a 1.2-micron filter. Aqueous PN without ILE will be filtered with a 0.2-micron filter.
     - 6.3.4. Filters may be changed every one to three days.
     - 6.3.5. Clogged filters indicate a problem and should be replaced with a new filter
   - 6.4. Cyclic PN (see 9.0 Cyclic (Intermittent) Parenteral Nutrition)
   - 6.5. Compatibility – see Appendix E

7. **Complications[49] (UW Health Class I, Level B)**
   - 7.1. Carbohydrate in the PN should be limited as excess carbohydrate can result in glycogen storage as fat, hepatic steatosis, increased carbon dioxide production.[78] (see section 3.3 Carbohydrate)
   - 7.2. Institute the following to decrease risk of cholestasis with long-term PN lack of EN.[79-81]
     - 7.2.1. Limit ILE dosage to 1 to 2 g/kg/day[82]
     - 7.2.2. Recommend cycling the ILE for the duration of the PN cycle
     - 7.2.3. Cycle the PN as soon as clinically feasible
     - 7.2.4. Start EN as soon as possible[83]
   - 7.3. Metabolic Bone Disease[84] **(UW Health Class I, Level C)**
     - 7.3.1. Limit duration of PN to minimize risk of metabolic bone disease.
     - 7.3.2. Provide adequate calcium/phosphate ratio to minimize metabolic bone disease.
     - 7.3.3. Start EN as soon as possible
     - 7.3.4. Supplement calcium and phosphate enterally to meet requirements for adequate bone mineralization
   - 7.4. Refer to UWHC Guidelines for Anti-Infective Lock Solutions to prevent line infections[85-87]

8. **Monitoring (UW Health Class I, Level C)**
   - 8.1. Baseline assessment – Obtain the following prior to PN initiation, if possible:[9]
     - 8.1.1. Anthropometrics
       - 8.1.1.1. Height or length
       - 8.1.1.2. Weight
       - 8.1.1.3. Weight for length or BMI for age
       - 8.1.1.4. Head circumference (for children under 36 months)
     - 8.1.2. Blood Chemistries
       - 8.1.2.1. Electrolytes (sodium, potassium, chloride, bicarbonate), BUN, creatinine, glucose, transaminases (alanine aminotransferase or ALT and aspartate aminotransferase or AST), alkaline phosphatase, total bilirubin [comprehensive metabolic panel (CMP)]
       - 8.1.2.2. Direct bilirubin, if indicated by clinical condition or age
       - 8.1.2.3. Magnesium
       - 8.1.2.4. Phosphate
       - 8.1.2.5. Triglycerides
   - 8.2. Clinical monitoring[41]
     - 8.2.1. In most patients, the following should be checked daily for the first four days of PN:
       - 8.2.1.1. Electrolytes (sodium, potassium, chloride, bicarbonate), BUN, creatinine, glucose [basic metabolic panel (BMP)]
       - 8.2.1.2. Magnesium
       - 8.2.1.3. Phosphate
     - 8.2.2. In certain patients (e.g. those on glucocorticoids, diabetics, neonates), point-of-care glucoses every two to six hours may be indicated
     - 8.2.3. Blood (or serum) triglycerides should be obtained within the first 24 to 72 hours of starting ILE therapy and once goal dose is achieved.
     - 8.2.4. The following should be considered at least once weekly for patients who continue PN for more than 5 days:
       - 8.2.4.1. Electrolytes (sodium, potassium, chloride, bicarbonate), glucose, BUN, creatinine, calcium, total bilirubin, direct bilirubin (in infants and others as indicated), AST, ALT, alkaline phosphatase [comprehensive metabolic panel]
       - 8.2.4.2. Magnesium
       - 8.2.4.3. Phosphate
       - 8.2.4.4. Triglycerides (if on ILE)
         - 8.2.4.4.1. Infants and young children: target triglycerides less than 250 mg/dL.
         - 8.2.4.4.2. Older children and adolescents: target triglycerides less than 400 mg/dL.
       - 8.2.4.5. C-reactive protein
     - 8.2.5. Long-term monitoring parameters
       - 8.2.5.1. For patients on PN for at least a month, obtain a carnitine level
       - 8.2.5.2. For patients on PN > 3 months, obtain the following quarterly to semi-annually, depending on clinical condition and ability to take enteral or oral nutrition
         - 8.2.5.2.1. Carnitine
         - 8.2.5.2.2. Vitamins A, D (specify 25-hydroxy-) and E.
         - 8.2.5.2.3. Trace elements: zinc, selenium, copper, chromium, manganese
         - 8.2.5.2.4. Iron studies (iron, total iron binding capacity or TIBC, percentage saturation, transferrin, and ferritin)
         - 8.2.5.2.5. Vitamins B-6
         - 8.2.5.2.6. Vitamin B-12 or methylmalonic acid
         - 8.2.5.2.7. Essential fatty acid profile (to evaluate triene:tetraene ratio)
   - 8.3. Premature infant specifics
     In those patients with elevated alkaline phosphate, consider checking fractionated alkaline phosphatase to determine etiology of elevation; consider consultation with Endocrinology.
   - 8.4. Please refer to Home Parenteral Nutrition section (Appendix F) for monitoring when initiating PN in the ambulatory setting.

Table 12. Growth Parameters

Parameter[41]	Initial Week	During Hospitalization	Outpatient for those with EN or PN
Weight **Infants** **Children**	 Daily Daily to Weekly	 Daily Daily to Weekly	 Weekly to Monthly Weekly to Every Clinic
Length **Infants** **Children**	 Baseline Baseline	 Weekly Monthly	Monthly or at Clinic
Head Circumference	Baseline	Weekly to Monthly	Monthly or at Clinic
Weight Gain	Daily to Weekly	Daily to Weekly	Weekly to Monthly
Linear Growth	Weekly to Monthly	Weekly to Monthly	Monthly

Table 13. Laboratory Monitoring for Home PN Patients

Laboratory Value[41]	Weekly	Monthly	Every 3 Months	Every 6 Months
Basic metabolic panel (BMP)	X			
Comprehensive metabolic panel (CMP)	First 1 to 4 weeks after discharge	Once stable *		
Pre-albumin	First 1 to 4 weeks after discharge	Once stable *		
Conjugated (or direct) bilirubin	Baseline	Once stable *		
Complete blood count (CBC) with differential	First 1 to 4 weeks after discharge	Once stable *		
GGT	Baseline	X		
Magnesium Phosphorus	X	Once stable *		
Triglycerides	First 1 to 4 weeks after discharge	Once stable *		
PT, PTT/INR			X	When stable
Iron Ferritin TIBC %Sat, Transferrin			First 3 to 6 months of PN	When stable *
25-OH Vitamin D Vitamin A Vitamin E				X
Copper Ceruloplasmin Chromium Manganese Selenium			If cholestasis present	For non-cholestatic patients
Zinc		If patient has ileostomy or increased stool losses	X	When stable *
Free & Total acyl-carnitine				X
Essential Fatty Acid Profile				X

***** stability refers to both the patient (clinically stable) and the lab value (little weekly variability)

9. **Cyclic (Intermittent) Parenteral Nutrition [28,88](UW Health Class I, Level C)**
   9.1. Cyclic PN should be considered, and, if clinically feasible, administered in:
      9.1.1. Patients on or anticipated to be on long-term PN (>2 to 4 weeks) to prevent cholestasis
      9.1.2. Patients who are on stable home PN
      9.1.3. Patients with cholestasis to prevent worsening hepatic dysfunction
      9.1.4. Patients who are ready to transition to oral intake to meet their needs
      9.1.5. Patients who will benefit from time off PN to increase mobility and/or improve quality of life

9.2. The duration of the cycle is dependent on:
  9.2.1. Expected time that patient can be without nutrition based on age and clinical status: For infants < 4 months of age, keep PN cycle ≥ to 20 hours until EN comprises > 20% nutrition needs.[79]
  9.2.2. Rate of potassium infusion should be < 0.2 mEq/kg/h during the maximal rate of infusion unless patient is on telemetry.
  9.2.3. Glucose infusion rate should be appropriate to maintain blood glucose without inducing hyper- or hypoglycemia as the PN is cycled on or off. Most cycles include a 1 to 2 hour ramp-up and ramp-down in rate.
9.3. Neonates should be at least 3 weeks of age prior to cycling[88]

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10. **Transition to Enteral Nutrition[24,89] (UW Health Class I, Level B)**
  10.1. For transition to EN in premature and surgical infants in the NICU, please refer to NICU enteral nutrition clinical practice guideline.
  10.2. For transition to EN in infants and older children, please refer to the AFCH Pediatric enteral nutrition clinical practice guideline.
  10.3. Because the enteral feeding route is preferred to the parenteral route, patients receiving PN should be evaluated daily for ability to begin oral feedings or EN.
  10.4. Small-volume EN (trophic feeding) should be initiated as soon as clinically feasible to preserve gut mucosa.
  10.5. During the transition to EN, PN should be continued while EN is increased so that adequate calorie/protein provision and growth are sustained.

11. **Discontinuation of Parenteral Nutrition[26] (UW Health Class I, Level C)**
  11.1. Most patients should have PN rates gradually weaned to off to prevent hypoglycemia.
  11.2. PN should be discontinued when patients can receive sufficient oral or enteral intake to meet a caloric and protein goal that will maintain health and support appropriate growth. This goal is individualized based on clinical condition, age, and underlying nutrition status.
  11.3. Patients should demonstrate appropriate nutrient intake and growth on enteral/oral nutrition after the termination of PN and prior to removal of the venous access device.[34,90,91]

12. **Home Parenteral Nutrition[92-95] (UW Health Class I, Level C)**
  12.1. Home PN may be indicated for patients who are stable enough for discharge but cannot receive sufficient energy and protein enterally or orally to meet their needs.
    12.1.1. Patients should be medically stable on the current PN.
    12.1.2. Care should be coordinated through a home care company and insurance coverage verified.
    12.1.3. Caregivers should be adequately educated on sterile technique and infusion pump use
    12.1.4. Follow-up with a physician who will assume responsibility for the patient's PN prescription and monitoring should be arranged prior to discharge.
  12.2. Formulas should, for the majority of patients, be individualized, and should provide sufficient calories and protein, including any enteral or oral intake, to meet their needs.
  12.3. Monitoring should be done on a routine basis. Please refer to Tables 11and 12 in the monitoring section.
  12.4. Initiation of PN in the home setting is strongly discouraged, with rare exceptions, due to the complex nature of PN therapy.
  12.5. See Appendix F. for further details on home PN.

13. **Physical Traits and Limitations of PN**
  13.1 Stability of 3-in-1 PNs[96] (used on older children whose fluid requirements permit use of this type of PN)
    13.1.1 In order to keep the lipid emulsion stable in a 3-in-1 PN, the macronutrients should be in the following percentages: amino acids greater than or equal to 4% of total volume, dextrose greater than or equal to 10% of total volume, and ILE greater than or equal to 2% of total volume.

13.1.2 In order to keep the lipid emulsion stable in a 3-in-1 PN, the total divalent and trivalent cation concentration (predominately magnesium and calcium) should be less than 20 mEq per liter.

13.2 Medications in or Y-sited with PNs

13.2.1 Medications should only be added to or Y-sited with the PN if they are deemed compatible by a reputable source (e.g., Trissel's Stability of Compounded Formulations, King Guide to Parenteral Admixture) at the dose or concentration being administered[97-100]. [Note: lack of evidence does NOT indicate compatibility or stability.] See Appendix E for specific information on compatibilities.

13.2.2 Levocarnitine may be added to PN with lipids at a dose of 200 mg/liter for 24 hours at room temperature or for 30 days at refrigeration. Levocarnitine may be added to PN without lipids at a dose of 420mg/L at room temperature for 24 hours **(UW Health Class I, Level C)**[101]

13.3 Physical/Chemical Limitations with PN

13.3.1 A reputable source (e.g. Abacus) should be consulted to determine calcium-phosphate compatibility or stability in the PN. (There is a limit to the amount of calcium and phosphate that can be added to the PN; this amount depends on pH, temperature, and PN additives; compatibility curves have been established to assist in this assessment. Exceeding this limit may result in calcium-phosphate precipitation with subsequent loss of IV access, soft tissue deposition, pulmonary embolus, and possibly death.)

13.3.2 The limit for sodium in the PN is 154 mEq/liter, which is the equivalent of 0.9% sodium chloride (for patient safety).

UW Health Implementation

Potential Benefits:

- Patient safety when advancing macronutrients
- Uniform, appropriate patient monitoring which conforms to national standards
- More optimal, clinically appropriate delivery of macronutrients (protein, dextrose, fat), fluid, electrolytes, specific amino acids, vitamins, and trace elements
- Cost-effective use of PN with earlier transition to oral feeding or EN.

Potential Harms:

- Possibility that patients may not have appropriate assessment or ongoing medical evaluation of PN or EN therapy.

Qualifying Statements:

Few randomized controlled trials are available for parenteral nutrition. Recommendations are often based on extrapolation from enteral or oral data and many are not well-supported by trails with parenteral nutrition. In the pediatric population, specifically children, including the critical care pediatric population, recommendations and best practice combine data extrapolated from adult populations and the neonatal populations, which tend to be better studied. Recommendations may change as more clinical trials are published.

Pertinent UW Health Policies & Procedures

1. Insertion, Maintenance, and Discontinuation of Central Vascular Access Devices for Prevention of Central Line-Associated Bloodstream Infection
2. Policy 1.23 AP – Continuous Peripheral Intravenous Therapy (Adult & Pediatric)
3. Nursing Patient Care Policy 1.48P – Care of Umbilical Catheters (Arterial and Venous)
4. Standard of Medical Care in Diabetes – Adult/Pediatric – Inpatient/Ambulatory Clinical Practice Guideline
5. UWHC Guidelines for Anti-Infective Lock Solutions
6. NICU enteral nutrition clinical practice guideline
7. AFCH Pediatric enteral nutrition clinical practice guideline

Implementation Plan/Clinical Tools

1. The guideline will be presented to the Pediatric Practice Committee at a monthly meeting, and members of the PNST will volunteer to present at individual nursing unit or departmental meetings.
2. A competency for practitioners will be developed and made available to physicians, pharmacists (will be required for pediatric and NICU pharmacists), dietitians, nurses, and other allied health professionals. The competency will be available via the Training and Education Gateway on UConnect.
3. PN and lipid orders and PN order sets will reflect and support the guideline recommendations with integration into Health Link

Disclaimer

Clinical practice guidelines assist clinicians by providing a framework for the evaluation and treatment of patients. This guideline outlines the preferred approach for most patients. It is not intended to replace a clinician's judgment or to establish a protocol for all patients. It is understood that some patients will not fit the clinical condition contemplated by a guideline and that a guideline will rarely establish the only appropriate approach to a problem.

Appendix A. Evidence Grading Scheme(s)

Figure 1. AHA/ACC Grading Scheme

SIZE OF TREATMENT EFFECT →

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT

	CLASS I *Benefit >>> Risk* Procedure/Treatment **SHOULD** be performed/ administered	CLASS IIa *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform procedure/administer treatment	CLASS IIb *Benefit ≥ Risk* *Additional studies with broad objectives needed; additional registry data would be helpful* Procedure/Treatment **MAY BE CONSIDERED**	CLASS III *Risk ≥ Benefit* Procedure/Treatment should **NOT** be performed/administered **SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**
LEVEL A Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	■ Recommendation that procedure or treatment is useful/effective ■ Sufficient evidence from multiple randomized trials or meta-analyses	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Sufficient evidence from multiple randomized trials or meta-analyses
LEVEL B Limited populations evaluated* Data derived from a single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is useful/effective ■ Evidence from single randomized trial or nonrandomized studies	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Evidence from single randomized trial or nonrandomized studies
LEVEL C Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	■ Recommendation that procedure or treatment is useful/effective ■ Only expert opinion, case studies, or standard of care	■ Recommendation in favor of treatment or procedure being useful/effective ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation's usefulness/efficacy less well established ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Only expert opinion, case studies, or standard of care
Suggested phrases for writing recommendations†	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown/unclear/uncertain or not well established	is not recommended is not indicated should not is not useful/effective/beneficial may be harmful

Appendix B. Respiratory Quotient for Single and Mixed Fuels, Lipogenesis

Substrate/Condition	Respiratory Quotient (RQ)
Carbohydrate oxidation	1
Mixed substrate oxidation	0.85
Fat oxidation	0.7
Protein oxidation	0.82
Lipogenesis	>1.0
non-steady state hyperventilation	>1.0

- A RQ > 1.0 is associated with overfeeding and is undesirable in patients with pulmonary compromise. Lipogenesis from overfeeding increases CO2 production and ventilatory demand which may impede attempts to wean intubated patients off mechanical ventilation.
- A RQ < 0.85 may be indicative of underfeeding.
- To order Indirect Calorimetry from Health Link Order Entry, select Pulmonary Function Lab Testing (Indirect Calorimetry). In order detail, enter the Reason for the Exam as determination of energy needs and in the Special Studies field select Nutrition Analysis.

Appendix C. Usual Adult Electrolyte Requirements

Electrolyte	Recommendations per 24 Hours
Calcium	10 to 15 mEq/day
Magnesium	8 to 20 mEq/day
Potassium	1 to 2 mEq/kg
Sodium	1 to 2 mEq/kg
Chloride	as needed to maintain acid-base balance
Acetate	as needed to maintain acid-base balance
Phosphorus	20 to 40 mMol/day

Appendix D. Calculating Osmolarity in Peripheral Parenteral Nutrition

Maintain total mOsm/L of PPN less than 900 mOsm/L

1. Dextrose grams/L x 5 = mOsm/L
2. Protein grams/L x 10 = mOsm/L
3. Convert mOsm/L of electrolytes in PN to mOsm/L

Electrolyte	mEq/mL	mOsm/mL
NaCl	4	8
Na Acetate	2	4
KCl	2	4
K Acetate	2	4
Na Phos Na Phos	4 3 mMol	7
K Phos K Phos	4.3 3 mMol	7.4
Ca++	0.465	0.68
Mg++	4	4.06

Appendix E. Compatibility of Parenteral Nutrition and Formulary Medications with Y-Site Administration

Ideally medications wouhould not be administered with PN, but many patients receive multiple intravenous medications with limited IV access. Multiple resources evaluate compatibility with PN; however, at times recommendations conflict and are not always reproducible[102-106]. Some studies evaluate physical compatibility only, while others evaluate both physical and chemical compatibility. If a medication is injected concomitantly with a PN through a Y-site, the time of admixture does not allow for substantial chemical degradation. (Potential exceptions are those situations where the flow rates are very low, as with neonatal PNs). Moreover, clinically significant chemical degradation reactions seldom occur in 4 hours or less. Unlike chemical incompatibilities, physical or visual incompatibility is identified by precipitants or changes in emulsion. Precipitants can be life-threatening, but are not always identifiable due to their small size, translucency, concomittant fat emulsion infusion. Compatibility data is not available for all medications; however, lack of data does not confer compatibility.

Key
C - Compatible
I - Incompatible
— - Compatibility data not available
C/I - Conflicting data with strength of evidence supporting compatibility
I/C - Conflicting data with strength of evidence supporting incompatibility
D5W - dextrose 5%
NS - sodium chloride 0.9%

Medication	Admixture type		
	2-in-1	lipids	3-in-1
Acetazolamide	I	—	—
Acyclovir sodium 7 mg/mL D5W	I	I	I
Albumin	I	I	I
Aldesleukin	C	C	—
Alprostadil (10 & 20 mcg/mL)	C	C/I	—
Amikacin sulfate 5 mg/mL D5W	C	C/I	C/I
Aminophylline 2.5 mg/mL D5W	C/I	C	C
Amphotericin B 0.6 mg/mL D5W	I	I	I
Ampicillin sodium 20 mg/mL NS	C/I	C	C
Ampicillin/Sulbactam 20/10 mg NS	C	C	C
Argatroban	C	—	—
Ascorbic acid	C	—	—
Atracurium besylate	C	—	—
Aztreonam 40 mg/mL D5W	C	C	C
Bumetanide 0.04 mg/mL D5W	C	C	C
Buprenorphine 0.04 mg/mL D5W	C	C	C
Butorphanol 0.04 mg/mL D5W	C	C	C
Calcium Chloride	C	C	C
Calcium Gluconate 40 mg/mL (0.19 mEq/mL) D5W	C	—	C
Caffeine citrate	C	—	—
Carboplatin 5 mg/mL D5W	C	C	C
Cefazolin 20 mg/mL D5W	I	C	C
Cefepime	C	—	—

Medication	Admixture type		
	2-in-1	lipids	3-in-1
Cefotaxime 20 mg/mL	C	C	C
Cefoxitin 20 mg/mL D5W	C	C	C
Ceftazidime 40 mg/mL	C	C	C
Ceftriaxone 20 mg/mL D5W	I	C	I
Cefuroxime 30 mg/mL D5W	C	C	C
Chloramphenicol	C	C	—
Chlorpromazine 2 mg/mL D5W	C	C	C
Ciprofloxacin 1 mg/mL D5W	I	C	C
Cisplatin 1 mg/mL undiluted	I	C	I
Clindamycin 10 mg/mL D5W	C	C	C
Cyclophosphamide 10 mg/mL D5W	C	C	C
Cyclosporine 5 mg/mL D5W	I	C/I	I
Cytarabine 50 mg/mL undiluted	C	C	I
Dexamethasone 1 mg/mL D5W	C	C	C
Diazepam	C	—	—
Digoxin 0.25 mg/mL undiluted	C	C	C
Diphenhydramine 2 mg/mL D5W Diphenhydramine 50 mg/mL undiluted	C —	C —	C C
Dobutamine 4 mg/mL D5W	C	C	C
Dopamine 3200 mcg/mL D5W	C	C/I	I
Doxorubicin 2 mg/mL undiluted	C	—	C
Doxycycline 1 mg/mL D5W	C	I	I
Droperidol 0.4 mg/mL D5W	C	I	I
Enalaprilat 0.1 mg/mL D5W	C	C	C
Epinephrine	C	—	—
Epoetin alfa	C	—	—
Ertapenem	—	—	—
Erythromycin	C	C	C
Fentanyl 12.5 mcg/mL D5W Fentanyl 50 mcg/mL undiluted	C C	C —	C —
Fluconazole 2 mg/mL undiluted	C	C	C
Fluorouracil 16 mg/mL	I	C/I	I
Folic acid	C	—	—
Foscarnet	C	—	—
Fosphenytoin 50 mg PE/mL	C	—	—
Furosemide 3 mg/mL D5W	I	C	C
Ganciclovir 20 mg/mL D5W	I	I	I
Gentamicin 5 mg/mL D5W	C	C	C
Haloperidol 0.2 mg/mL D5W	C	I	C
Heparin 100 Units/mL undiluted	C	I	I
Hydrocortisone 1 mg/mL D5W	C	C	C
Hydromorphone 0.5 mg/mL D5W	C	I/C	I
Hydroxyzine 2 mg/mL D5W	C	C	C

Medication	Admixture type		
	2-in-1	lipids	3-in-1
Ifosfamide 25 mg/mL D5W	C	—	C
Imipenem-Cilastatin 10 mg/mL NS	C	C	C
Immune Globulin	—	—	—
Insulin, regular human 1 units/mL D5W	C	C	C
Iron dextran	C/I	—	I/C
Isoproterenol	C	C	C
Leucovorin 2 mg/mL D5W	C	C	C
Lidocaine	C	C	C
Linezolid	C	—	—
Lorazepam 0.1 mg/mL D5W	C	I	I
Magnesium sulfate 100 mg/mL (0.81 mEq/mL) D5W	C	C	C
Mannitol 15% undiluted (150 mg/mL)	C	C	C
Meperidine 4 mg/mL D5W	C	C	C
Meropenem 20 mg/mL D5W	—	C	C
Mesna 10 mg/mL D5W	C	C	C
Methotrexate 15 mg/mL D5W	I	C	C
Methylprednisolone 5 mg/mL D5W	C	C	C
Metoclopramide 5 mg/mL D5W	I	C	C
Metronidazole undiluted	C	C	C
Midazolam 2 mg/mL	I	I	I
Milrinone	C	—	—
Mitoxantrone 0.5 mg/mL D5W	I	C	C
Morphine 1 mg/mL D5W Morphine 15 mg/mL undiluted	C —	C/I	C I
Nafcillin 20 mg/mL D5W	C	—	C
Nalbuphine 10 mg/mL undiluted	C	I	C
Nitroglycerin 400 mcg/mL D5W	C	C	C
Nitroprusside 400 mcg/mL D5W	C	C	C
Norepinephrine16 mcg/mL D5W	C	C	C
Octreotide 10 mcg/mL D5W	C	C	C
Ondansetron 1 mg/mL D5W	C	I	I
Oxacillin	C	C	C
Paclitaxel 1.2 mg/mL D5W	C	C	C
Penicillin G potassium	C	C	C
Penicillin G sodium	C	—	—
Pentobarbital 5 mg/mL D5W	C	I	I
Phenobarbital 5 mg/mL D5W	C	I	I
Phenytoin	I	I	—
Phosphate potassium 3 mmol/mL undiluted	I	I	I
Phosphate sodium 3 mmol/mL undiluted	I	I	I
Phytonadione	C	C	—
Piperacillin/Tazobactam 40/5 mg/mL D5W	C	C	C
Potassium chloride 0.1 mEq/mL D5W	C	C	C

Medication	Admixture type		
	2-in-1	lipids	3-in-1
Prochlorperazine 0.5 mg/mL D5W	C	C	C
Promethazine 2 mg/mL D5W	I	C	C
Propofol 10 mg/mL undiluted	C	—	—
Ranitidine 2 mg/mL D5W	C	C	C
Sodium bicarbonate 1 mEq/mL undiluted	I	I	I
Tacrolimus 1 mg/mL D5W	C	C	C
Ticarcillin/Clavulanate 30/0.1 mg/mL D5W	C	—	C
Tobramycin 5 mg/mL D5W	C	—	C
Trimethoprim-Sulfamethoxazole 0.8/4 mg/mL D5W	C	C	C
Vancomycin 10 mg/mL D5W	C	C	C
Vecuronium	C	—	—
Zidovudine 4 mg/mL D5W	C	C	C

Appendix F. Home Parenteral Nutrition

Parenteral nutrition can be provided in the home setting for patients requiring PN beyond their hospital stay who are medically and metabolically stable. Patients also need to be able to care for themselves or have a willing, capable caregiver in the home. Home PN is provided through collaboration of healthcare personnel within and outside the hospital including a home infusion pharmacy, a home health agency and the prescribing team to provide safe care for a patient. It is essential that care plan elements are in place prior to discharging a patient home. [92-95]

1. Home PN referral: Discharge planning for home PN begins when the team identifies the patient as requiring PN beyond their hospital stay. For patients who are currently inpatient at UWHC, a referral for home PN is initiated by the social worker or case manager. Chartwell Midwest Wisconsin is the UWHC affiliated home infusion pharmacy; however, patients are provided all of their options for in network home infusion pharmacies who participate with their insurer. Ultimately, the SNST will work closely with the home infusion pharmacy to coordinate the transition of PN therapy from hospital to home and ensure appropriate clinical information and orders (formula, lab schedule, ancillary orders) have been provided. In developing the home PN care plan, elements to consider may include immediate and long term nutritional goals, anticipated duration of therapy, and target weight or growth. Once the PN formula is stable, cycling goals have been met, the patients and/or caregiver have received adequate training, the outpatient care team has been confirmed, and the home infusion pharmacy is established, the patient can be safely discharged.
2. Outpatient accountable team managing patient: It is essential that an agreement has been reached with a physician to order and monitor PN in the outpatient setting prior to the patient being discharged from UWHC. As PN is a complex therapy, a knowledgeable multidisciplinary clinical team is needed to successfully minimize and manage the associated potential complications (metabolic, infectious, mechanical). For patients with the agreeable ordering physician in the UW Health system, the patient may have care coordinated for co-management under UWHC delegation protocol by a member of the UW SNST, PNST or Chartwell pharmacist team. This aspect of the care plan additionally requires confirmation prior to discharge and appropriate activation of the delegation protocol for the outpatient case.
3. IV access: The patient must have an appropriate functional central venous access device to safely receive PN in the home. Commonly used devices include implantable ports, tunneled central venous catheters or peripherally inserted central catheters. The home infusion pharmacy will require written documentation of line type and tip confirmation. Peripheral IV lines are not acceptable for use with home PN.
4. Outpatient PN initiation: Outpatient PN start is discouraged in most scenarios due to patient safety considerations. Certain patient populations can be at risk for electrolyte changes after TPN initiation and require close monitoring. In weighing risks and benefits, it is safer for most patients to be admitted to the hospital to initiate and stabilize the patient on an appropriate regimen before going home. Anticipating a 3-5 day stay to initiate PN in the hospital is reasonable.
5. Insurance aspects: Insurance considerations need to be kept in mind when arranging for home PN. Verifying reimbursement early in the home PN referral process is essential as insurance coverage and criteria can significantly impact the home PN care plan and documentation needs. Particularly for patients with Medicare, there are very stringent criteria from the Centers for Medicare and Medicaid Services which must be met and documented in the patient's clinical record prior to hospital discharge to meet Medicare B coverage. Requests for changes in the outpatient setting such as calorie changes, frequency of administration changes, oral intake status, or introduction of enteral nutrition may have impacts on Medicare B coverage of the PN therapy in the outpatient setting.
6. Patient expectations: Patients can expect extensive training and education in the hospital by Chartwell RNs (if Chartwell patient) and initial home health RN nvolvement with the expectation that the patient or caregiver become independent in administration with the PN. The aim of education is to reduce the risk of complications and optimize safe practices in the home setting. Patients will always have phone support from the home infusion pharmacy. Patients can expect to need labs drawn on a frequent basis (often weekly) that may decrease in frequency over time.

Patients will need to keep records of items such as weight and intake/output for the team. Some patients may need to check blood sugars. Patients need to maintain a relationship with the MD of record and have an office visit at least annually.

7. Outpatient monitoring: All PN patients are monitored closely after discharge from the hospital. The home infusion pharmacy and outpatient managing medical team work together to provide long-term ongoing monitoring of the patient. Adjustments in PN formulas are made based upon laboratory values, intake/output records, patient assessments and nutritional goals or desired end points.

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