وزارة الصحة
Ministry of Health

PEDIATRIC PARENTERAL NUTRITION

CLINICAL PRACTICE GUIDELINES

1. STATEMENT OF PURPOSE

1.1 To provide essential information for healthcare professionals involved in the provision and administration of parenteral nutrition (PN) in pediatric.

1.2 To improve the management of pediatric patients requiring PN support.

2. RELATED DOCUMENTS

2.1 **1431-201 CPP** High Alert Medication

2.2 **1431-290 CPP** Parental Nutrition

3. RELATED ACCREDITATION STANDARDS

3.1 **CBAHI 3rd edition:** MM.5, MM.27, & MM.32.6

3.2 **JCI standards 7th edition: MMU.5**

4. ABBREVIATIONS AND DEFINITIONS

4.1 **PN:** Parenteral Nutrition is the provision of nutrients via the intravenous route. PN is used for neonates who cannot receive their full nutritional requirements via enteral nutrition.

4.2 **EN:** Enteral nutrition

4.3 **GI**: Gastrointestinal

4.4 **PPN:** Peripheral Parenteral Nutrition

4.5 **CPN:** Central Parenteral Nutrition

4.6 **CVADs**: Central venous catheter devices

4.7 **AA:** Amino acid

4.8 **GIR:** Glucose infusion rate

4.9 **ILE:** Intravenous lipid emulsion

4.10 **EFAs:** Essential fatty acids

4.11 **NEC:** Necrotizing enterocolitis

4.12 **IUGR:** Intrauterine growth restriction

4.13 **ASPEN:** American Society for Parenteral and Enteral Nutrition

4.14 **TNAs:** Total nutrition admixtures

4.15 **CRBSI:** Catheter-related bloodstream infection

4.16 **SBS:** Short bowel syndrome

4.17 **EFAD:** Essential fatty acid deficiency

5. GUIDELINES/ PROTOCOL/PATHWAY

5.1 Introduction

5.1.1 The practice of parenteral nutrition (P) has been lifesaving in pediatric patients, such as premature neonates and patients with short bowel syndrome (SBS), who would otherwise not have been able to sustain themselves on an enteral diet alone. PN is a complex solution of macronutrients, micronutrients, fluid, electrolytes, and additives. The clinician's role in providing safe and effective PN support to pediatric patients requires knowledge of appropriate indications and access for PN, optimal macronutrient and micronutrient provision, and assessment for and management of complications. Safety in PN support must be ensured throughout the PN process, from prescribing to compounding and administration of PN, and to the transition to home

5.1.2 Physicians, Pharmacist, And Nursing Staff shall follow and adhere to this guideline.

5.1.3 All the Pediatrics Parenteral Nutrition plan, orders, and monitoring must document in the patient's medical record, and manual incase system in down.

5.2 Indications of PN:

5.2.1.1 PN is indicated in patients when the gastrointestinal (GI) tract is not functional or cannot be accessed, or when nutrient needs exceed what can be provided through enteral nutrition (EN).

5.2.1.2 Intestinal failure, e.g. pseudo-obstruction, short bowel

5.2.1.3 Post-gastrointestinal surgery

5.2.1.4 Necrotising enterocolitis (NEC)

5.2.1.5 Congenital gastrointestinal defects, e.g. gastroschisis, intestinal atresia

5.2.1.6 Critically ill: initiate PN when EN is unable to meet energy requirements for energy expenditure and growth.

5.2.1.7 Other indication for PN support in pediatric patients include: high output fistula, graft-vs-host disease, sever GI side effects of chemotherapy including radiation enteritis, cancer cachexia, diaphragmatic hernia, meconium aspiration, and organ failure (liver, renal, pulmonary, pancreas) when EN is contraindicated and the child is catabolic or in preparation for organ transplant in malnourished patients.

5.3 Time frame for initiating PN in Pediatric:

5.3.1 Infants aged 1 to 12 months: inability to achieve an adequate energy intake for more than 3 days

5.3.2 In children older than 1 year: inability to achieve an adequate energy intake for more than 5 days

5.3.3 Children not expected to meet an appropriate energy and nutrient intake for more than 7 days

5.3.4 Clinical condition leading to an absolute or relative contraindication to enteral nutrition

5.3.5 In children older than 1 year: duration of PN of at least 5 days except in undernourished children

5.4 Energy requirements (Appendix 1)

5.5 Fluid Requirement (Appendix 1)

5.6 Constituents of Parenteral Nutrition (Appendix 1)

PN solutions contain some or all of the following constituents

5.6.1 Amino Acids (Protein / Nitrogen)

5.6.1.1 Proteins are the major structural and functional components of all cells in the body and are made up of chains of amino acids

5.6.1.2 In the amino acid (AA) solutions currently used, each gram of AA contains approximately 4 kcals

5.6.1.3 Pediatric are in high need for certain AAs (conditional essential), for this reason it is important to use an AA solution that is primarily designed for this patient group

5.6.2 Carbohydrate

5.6.2.1 Carbohydrate is the main source of energy in PN, it is recommended that approximately 60% of non-protein energy comes from carbohydrate.

5.6.2.2 Each gram of dextrose contains 3.4 kcal

5.6.2.3 Glucose provision can be calculated as the glucose infusion rate (GIR), expressed as mg/kg/minute. GIR= (% of Dextrose X ml/kg/day) / 144

5.6.2.4 Final concentrations of dextrose in PN solutions used in pediatric patients range from 10% to 12.5% for PPN and up to 25% or higher for central PN.

5.6.3 Intravenous Lipid Emulsion (ILE)

5.6.3.1 ILEs are used in Pediatrics PN as a non-carbohydrate source of energy, to provide a source of essential fatty acids (EFAs)

5.6.3.2 It is recommended that approximately 25 - 40% of non-protein energy comes from lipids in patients receiving PN as a sole source of nutrition

5.6.3.3 The energy provided per gram of lipid in PN is approximately 10 kcal

5.6.3.4 Infusion rate should be as slow as possible and should not exceed 0.15 g/kg/h.

5.6.4 Electrolytes (Appendix 1)

5.6.4.1 The main electrolytes included in PN necessary for the maintenance of many cellular functions are:

- 5.6.4.1.1 Sodium (Na)
- 5.6.4.1.2 Potassium (K)
- 5.6.4.1.3 Calcium (Ca)
- 5.6.4.1.4 Magnesium (Mg)
- 5.6.4.1.5 Phosphate (P)

5.6.4.2 Electrolytes may be given to maintain normal serum concentrations or to correct deficits

5.6.4.3 Consider other sources of electrolytes such as intravenous fluids and medications when ordering PN

5.6.4.4 Adequate calcium, phosphate, and magnesium, together with vitamin D essential for bone mineralization, to support linear growth and to protect against rickets fractures

5.6.4.5 Electrolytes should be prescribed in the form of complete salts rather than individual ions to minimize the risk of dosing errors and ensure accurate preparation and administration

5.6.5 Calcium and Phosphate

5.6.5.1 The precipitation of calcium and phosphorus is a common interaction that is potentially life-threatening

5.6.5.2 The risk of precipitate formation is greater with:

- 5.6.5.2.1 Increased solution temperature and pH
- 5.6.5.2.2 Higher concentrations of calcium and phosphorus

5.6.5.2.3 Lower concentrations of amino acids and dextrose

5.6.5.2.4 Use of the chloride salt of calcium

5.6.5.2.5 Improper mixing sequence when adding calcium and phosphorus salts

5.6.5.2.6 The presence of other additives (including ILEs)

5.6.5.3 Steps to minimize the risk of calcium and phosphate precipitation in PN admixtures include:

5.6.5.3.1 The use of calcium gluconate instead of calcium chloride because it is less reactive

5.6.5.3.2 Use organic phosphate salt

5.6.5.3.3 Adding phosphate salts early in the mixing sequence, adding calcium last or nearly last, and agitating the mixture throughout the admixture process to achieve homogeneity

5.6.5.3.4 PN admixtures with a lower final pH should be used when clinically appropriate

5.6.5.3.5 Higher final concentrations of dextrose and AA and lower final concentrations of lipids favor a lower admixture pH.

5.6.5.4 AA product-specific solubility curves that are available from the manufacturer or primary literature should be consulted for calcium and phosphorous solubility.

6.6.6. Chloride and Acetate

6.6.6.1 Amount of chloride and acetate based on acid-base balance

6.6.6.2 Because the addition of bicarbonate to acidic PN admixtures may result in the formation of carbon dioxide gas and insoluble calcium and magnesium carbonates, sodium bicarbonate used in PN admixtures is not recommended. Use of a bicarbonate precursor salt such as acetate usually is preferred.

6.6.6.3 Acetate is metabolized in the liver to produce bicarbonate on a 1:1 molar ratio

6.6.6.4 Chloride in PN (as sodium chloride or potassium chloride) can be partly replaced by acetate (as sodium acetate or potassium acetate) to reduce metabolic acidosis and/or hyperchloremia

5.6.6 **Trace Elements** (Appendix 1)

5.6.6.1 Many trace elements are an important part of metalloenzymes and function as cofactors in a variety of regulatory metabolic pathways

5.6.6.2 Injectable trace elements are available as single trace element solutions and as multiple trace element combinations

5.6.6.3 Requirements for trace elements also vary on the basis of the patient's clinical condition

5.6.6.4 Higher doses of supplemental zinc likely are necessary for patients with high-output ostomies or diarrhea because the GI tract is the predominant excretion route for zinc.

5.6.6.5 Manganese and copper are excreted through the biliary tract, chromium, molybdenum, and selenium are excreted renally

5.6.6.6 Multi-trace dosage may require alteration in patients with increased gastrointestinal or skin losses or with hepatic or renal dysfunction

5.6.6.7 Additional zinc injectable solution in case of administration to preterm infants should be added to reach a total zinc parenteral intake of 400 mcg/kg/day

5.6.7 **Vitamins** (Appendix 1)

5.6.7.1 Both water-soluble and fat-soluble vitamins are added to PN

5.6.7.2 Water-soluble vitamins are the B group of vitamins and vitamin C; and fat-soluble vitamins are vitamins A, D, E, and K

5.6.8 **Other additives**

5.6.8.1 **Heparin**

5.6.8.1.1 Heparin is added to PN in a dose of 0.5 – 1 U/ml to maintain patency of the catheter and reduce vein irritation

5.6.8.1.2 Recent A.S.P.E.N. clinical guidelines do not support adding heparin to PN solutions for decreasing the risk of central vein thrombosis.

5.6.8.1.3 The risk associated with heparin delivery via PN outweighs the clinical benefit because of the potential compounding error. Therefore, it should not be given with lipid infusions on a routine basis, unless indicated for other reasons

5.6.8.2 **Carnitine**

5.6.8.2.1 Carnitine facilitates the transport of long-chain fatty acids across the mitochondrial membrane, improving the possibility of oxidation.

5.6.8.2.2 Carnitine supplementation (10 – 20 mg/kg/d) indicated for patients on long-term PN more than 4 weeks; hypertriglyceridemia; premature infants < 32 -34 weeks gestational age, and carnitine deficiency

5.7 Routes of PN administration

Peripheral route

5.7.1 Peripheral parenteral nutrition (PPN) is an option for mild to moderate stressed patients in whom adequate GI tract function is expected to return within 10-14 days.

5.7.2 Potential PPN candidates should not be fluid-restricted or require large nutrient amounts.

5.7.3 Lower concentration of dextrose (10-12.5% final concentration), and micronutrients must be used for peripheral route administration.

5.7.4 The risk of phlebitis is greater with solution osmolarities greater than 1000mOsmol/L for pediatrics.

Central route

5.7.5 Central Parenteral Nutrition (CPN) is the preferred route for PN delivery and is used predominantly for patients who require PN for a period of more than 7 to 14 days.

5.7.6 CPN is the preferred route for patients who have large nutrient requirements, poor peripheral venous access or fluctuating fluid requirements

5.7.7 Unlike peripheral veins, central veins have a higher blood flow, which quickly dilutes the hypertonic solution, PN can with higher osmolarities

5.8 Ordering and Prescribing Parenteral Nutrition

5.8.1 In all cases, the following should be included on the PN prescription/order:

- PN volume (ml/kg/day) or (ml/day)

- Central/peripheral access (if glucose concentration is greater than 12.5%, a central access must be used)
- Working weight / dosing weight (kg)
- Amino acid (g/kg/day)
- Glucose (mg/kg/min) or (%)
- Lipid (g/kg/day)
- Electrolytes as salt (mmol/kg)
- Water-soluble vitamins
- Fat-soluble vitamins
- Trace elements
- Other requirements (as necessary), e.g. heparin, carnitine, thiamine

5.8.2 PN prescriptions must be reviewed and verified by a PN pharmacist prior to transmitting to the PN compounding process.

5.9 Delivery and Storage of Parenteral Nutrition

5.9.1 PN should be collected by the nurse from the pharmacy before 5 PM

5.9.2 All PN should be stored in a designated medication refrigerator 2 to 8°C

5.9.3 The aqueous solution and lipid solution should be removed from the fridge in advance, approximately one hour prior to commencing the infusion. This allows it to come to a suitable temperature for infusion

5.10 Administration of Parenteral Nutrition by Nurse (Appendix 1)

5.10.1 PN solutions should be administered using volumetric pumps which are capable of accurately delivering low flow rates and have occlusive and air-in-line alarms to minimize infusion-related complications

5.10.2 PN can be infused via a peripheral (short-term use only) or central venous access device (CVAD).

5.10.3 Ideally, the venous line used for PN should not be interrupted for giving antibiotics or medications; a separate IV line should be used

5.10.4 If co-infusion is unavoidable through the same line, medication stability and compatibility with the PN must be established and verified before administration

5.10.5 PN solutions (solution, and lines) should be protected from light to prevent peroxidation and degradation of light-sensitive vitamins

5.10.6 The infusion set and lipid infusion line should be changed every 24 hours

5.10.7 ASPEN recommended using a 1.2 micron in-line filter for the administration of total nutrients admixture (TNAs), dextrose- amnio acid admixtures, and ILE. For TNAs, place the filter as close to the catheter hub as possible. For dextrose-amino acid admixtures below the Y-site where the dextrose-amino acid admixture and ILE co-infuse.

5.11 Transitioning from Parenteral Nutrition to Enteral Nutrition

5.11.1 There should be a gradual transition from PN once a clinical decision has been made to commence enteral nutrition.

5.11.2 Full PN volumes should continue until at least 25% of nutritional requirements are met from enteral or oral nutrition.

5.11.3 PN infusion should be continued until the pediatrics tolerates at least 60% of enteral nutrition.

5.12 Monitoring of Parenteral Nutrition by prescriber

5.12.1 Monitoring is essential to assess tolerance of PN as well as nutritional adequacy to support growth. Special attention is required when PN is being increased or adjusted especially if the patient is clinically unstable, or if PN is to be provided long term.

5.12.2 Anthropometry should be checked regularly as a measure of growth.

5.12.3 Fluid balance, including input and output from all sources, must be monitored daily and provision of fluid and electrolytes adjusted as required.

5.13 Complication of Parenteral Nutrition

5.13.1 **Infectious Complications**

5.13.1.1 Infection is one of the most common and potentially fatal complications of CVADs

5.13.1.2 Effective prevention of catheter-related infections requires strict adherence to antiseptic techniques

5.13.1.3 When Infection is suspected PN should be stopped and central blood cultures obtained, ideally a peripheral blood culture should be obtained at the same time

5.13.1.4 CVAD should be removed if indicated

5.13.1.5 Empirical antibiotic therapy for catheter related blood stream infection (CRBSI) should be started. The choice of antibiotics should be based on local antimicrobial guidelines

5.13.1.6 Antibiotics should be changed to narrow spectrum once the infective organism has been identified

5.13.1.7 The duration of antibiotics is guided by the identified organism

5.13.2 Refeeding Syndrome

5.13.2.1 Refeeding syndrome is a potentially fatal complication observed in preterm infants with severe IUGR commencing PN after birth

5.13.2.2 Refeeding syndrome is characterized by acute electrolyte imbalances, most notable hypophosphataemia, hypokalaemia, hypomagnesaemia and hypoglycaemia.

5.13.2.3 To reduce risks of refeeding syndrome:

- Initiate nutrition at a maximum of 40%–50% goal, but usually starting the glucose infusion rate around 4–6 mg/kg/min and advancing by 1–2 mg/kg/min daily as blood glucose levels allow until reach patient goal
- Check serum potassium, magnesium, and phosphorus before initiation of nutrition
- Monitor every 12 hours for the first 3 days in high-risk patients. May be more frequent based on clinical picture and replace low electrolyte
- Patients may be at risk of thiamine deficiency, therefore supplementation with thiamine and a multivitamin is essential
- Thiamin 2 mg/kg to a max of 100–200 mg/d before feeding commences or before initiating IV fluids containing dextrose in high-risk patients
- Maintenance requirement of thiamine for PN: children and adolescents: 1.2 mg/day

5.13.3 Metabolic Bone Disease

5.13.3.1 PN-related metabolic bone disease has been described in patients on long-term PN. It manifests with a decrease in bone mineral density, osteoporosis, pain and fractures.

5.13.3.2 Regular measurements of urinary calcium, plasma calcium, phosphorus, alkaline phosphatase, parathyroid hormone and vitamin D concentrations are advised.

5.13.3.3 Regular assessment of bone mineralisation should be undertaken in children on long-term or home PN.

5.13.4 Hepatobiliary Complications

5.13.4.1 Patients requiring long-term PN are at high risk of developing PN-associated liver disease PNALD and in most cases it is moderate and reversible.

5.13.4.2 **Risk factors include:**

5.13.4.2.1 Absence of enteral nutrition

5.13.4.2.2 Short bowel syndrome (SBS) which may be associated with disruption of bile acid enterohepatic circulation, and bacterial overgrowth

5.13.4.2.3 Recurrent septic episodes

5.13.4.2.4 Prematurity

5.13.4.2.5 Excessive carbohydrate intake and/or continuous PN infusion leading to hyperinsulinism and subsequently to steatosis

5.13.4.3 **Prevention and treatment of cholestasis:**

5.13.4.3.1 Introduce enteral nutrition as soon as possible, even if only minimal amount.

5.13.4.3.2 Try to cycle PN as soon as clinically possible, may be poorly tolerated in acutely ill neonates

5.13.4.3.3 Consider decreasing lipid infusions if unexplained and sustained rise of conjugated bilirubin occurs (> 2 mg/dl)

5.13.4.3.4 Ursodeoxycholic acid (10-15 mg/kg/dose orally every 12 hours) might be indicated in patients with a continuous rise of transaminases, conjugated bilirubin and alkaline phosphatase

5.14 PN product shortage consideration

5.14.1 Assess each patient as to the indication for PN and provide nutrition via the oral or enteral route when possible.

5.14.2 PN Amino Acids product shortage considerations

5.14.2.1 Only use Neonatal/Pediatric-specific amino acids or disease-specific amino acids for the indicated patient populations.

5.14.2.2 Different brands of amino acids products are not always directly substitutable, they may have different pHs, different calcium-phosphorus solubilities, different amounts of phosphorus, as well as other characteristics that should be considered.

5.14.3 PN Lipid Injectable Emulsion product shortage considerations

5.14.3.1 Prioritize supply of soybean oil-based ILE as follows:
Pediatric patients should continue the same ILE therapy as before the shortage to minimize the risk of adverse effects associated with essential fatty acid deficiency (EFAD) in this high-risk patient population. Priority for ILE during critical shortages should be given to neonates followed by pediatric patients and finally, adolescent patients.

5.14.3.2 Monitor closely patients receiving PN for developing EFAD during shortages. Increase awareness and assessment for signs and symptoms of EFAD. Signs and symptoms of EFAD include, but are not limited to, diffuse dry, scaly rash, alopecia, thrombocytopenia, anemia, and impaired wound healing. Biochemical evidence of EFAD is confirmed by a triene-to-tetraene ratio greater than 0.2. Using topical oils for prevention and treatment of EFAD has produced mixed results. Safflower and sunflower seed oils had beneficial results whereas vegetable oil (corn oil) did not.

5.14.3.3 In the event of a four-oil (soybean oil, medium chain triglycerides, olive oil and fish oil) ILE shortage use standard soybean oil-based ILE dosing and frequency to meet patients' EFAs needs.

5.14.4 PN Multivitamin product shortage considerations

5.14.4.1 Consider switching to oral or enterally administered multivitamins when oral/enteral intake is greater than 50% of needs (excluding patients with malabsorption syndromes).

5.14.4.2 Reserve pediatric intravenous multivitamins for children less than 2.5 kg or less than 36 weeks gestational age.

5.14.4.3 Consider use of adult intravenous multivitamins for children during the shortage; use 5 mL of adult multivitamins in all children weighing greater than or equal to 2.5 kg or gestational age of 36 weeks and older while saving the pediatric product for smaller neonates in order to conserve the supply. Supplement intravenous vitamin K daily (Preterm neonates: 10 mcg/kg/day, Term neonates: 200 mcg/day). The vitamin K content of the adult multivitamin product should be noted when supplementing with additional vitamin K.

5.14.4.4 If no pediatric intravenous multivitamins are available, infants less than 2.5 kg or less than 36 weeks gestation should receive an adult intravenous multivitamin at a daily dose of 1 mL/kg up to a maximum of 2.5 mL/day.

5.14.4.5 Adult intravenous multivitamins may contain more aluminum than pediatric products.

5.14.4.6 Use the full adult dose (10 mL) of adult intravenous multivitamins for children greater than 11 years of age.

5.14.4.7 If neither pediatric nor adult intravenous multivitamins are available, administer individual parenteral vitamin entities in doses that are appropriate for the patient's age and weight. Thiamine, ascorbic acid, pyridoxine, and folic acid should be given daily

5.14.5 PN Trace Elements product shortage considerations

5.14.5.1 Consider switching to oral or enterally administered multi-trace element supplement products when oral/enteral intake is initiated

5.14.5.2 Reserve intravenous trace elements for those patients receiving solely PN-dependent or those with a therapeutic medical need for intravenous trace elements.

5.14.5.3 If intravenous multi-trace element products are no longer available, administer individual parenteral trace element entities.

5.14.5.4 Reserve Pediatric intravenous multi-trace element products for pediatric patients.

5.14.5.5 Use the full dose of intravenous Adult multi-trace element product for children greater than 5 years of age.

5.14.5.6 The routine use of intravenous Adult multi-trace element products in pediatric and neonatal patients is not recommended.

6. APPENDICES

6.1 Appendix 1

7. REFERENCES

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Appendix 1:

- **Table 1: Recommended Parenteral Energy Intake by ASPEN 2019**

Age	Energy requirement (kcal/kg/day)
≥ 1 to 7 years	75 to 90
> 7 to 12 years	50 to 75
> 12 to 18 years	30 to 50

- **Table 2: Fluids Requirements in pediatric**

Body weight	Amount of fluid per day
1 to 10 kg	100 mL/kg
11 to 20 kg	1000 mL + 50 mL/kg for each kg >10 kg
>20 kg	1500 mL + 20 mL/kg for each kg >20 kg

- **Table 3: Dosing for Initiation and Advancement of PN Macronutrients by ASPEN 2019**

Children (1-10Y)			
	Initiation	**Advanced by**	**Goals**
Protein (g/kg/d)*	1.5 – 2.5	0.5 - 1	1.5 – 2.5
Dextrose (mg/kg/min)	3 - 6	1 - 2	8 - 10
ILE (g/kg/d)**	1 - 2	0.5 - 1	2 – 2.5 (Max 0.15g/kg/hr)
Adolescent			
Protein (g/kg/d)*	0.8 - 2	0.3 – 0.5	0.8 - 2
Dextrose (mg/kg/min)	2.5 - 3	1 - 2	5 - 6
ILE (g/kg/d)**	1	1	1 – 2 (Max 0.11g/kg/hr)

**Protein does not need to be titrated; protein needs are increased with critical illness.*
*** ILE dosing based on soybean oil-based emulsion. See manufacturer's product information for dosing of otherILE products.*

- **Table 4 PN Electrolyte Daily Dosing:**

	Infants/Children	Adolescent & Children greater than 50kg
Sodium	2-5 mmol/kg	1 – 2 mmol/kg
Potassium	2-4 mmol/kg	1 – 2 mmol/kg
Calcium	0.25-2 mmol/kg	5 – 10 mmol/kg
Phosphorus	0.5-2 mmol/kg	10 – 40 mmol
Magnesium	0.15-0.25 mmol/kg	5 – 15 mmol
Acetate	As needed to maintain acid base-balance	
Chloride	As needed to maintain acid base-balance	

**Use caution in prescribing calcium and phosphorus related to compatibility*

***The dosing of electrolyte will be adjusted based on patient level and maximum concertation for IV assess*

- **Table 5: PN Trace Element Daily Dosing**

Trace Element	Children 10 – 40 kg	Adolescents greater than 40 kg
Zinc	50 mcg/kg (Max 5000mcg/d)	2 – 5 mg
Copper	20 mcg/kg (Max 5000mcg/d)	200 - 500mcg
Manganese	1 mcg/kg (Max 55mcg/d)	40 - 100 mcg
Chromium	0.2 mcg/kg (Max 5mcg/d)	5 – 15 mcg/kg
Selenium	2 mcg/kg (Max 100mcg/d)	40 – 60 mcg

- **Table 6: Additives dosing recommendation**

Others	Dose
Thiamine	2 mg/kg/day
Carnitine	5-20 mg/kg/day
Copper	10-20 mcg/kg/day

- **Table 7: PN Daily Multiple Vitamin Requirement Dosing for Pediatric**

Vitamin	Infants	Children
Thiamine (Vitamin B1)	0.35 – 0.5 mg/kg/d	1.2 mg/d
Riboflavin (vitamin B2)	0.15 – 0.2 mg/kg/d	1.4 mg/d
Niacin (vitamin B3)	4.0 – 6.8 mg/kg/d	17 mg/d
Vitamin B6	0.15 – 0.2 mg/kg/d	1000 mcg/d
Folate (Vitamin B9)	56 mcg/kg/d	140 mcg/d
Vitamin B12	0.3 mcg/kg/d	1 mcg/d
Vitamin C	15–25 mg/kg/d	80 mg/d
Pantothenic acid (Vitamin B5)	1–2 mg/kg/d	5 mg/d
Biotin (vitamin B7)	5–8 mcg/kg/d	20 mcg/d
Vitamin A	700–1500 IU/kg/d	2300 IU/d
Vitamin D	40–160 IU/kg/d	400 IU/d
Vitamin E	2.8–3.5 IU/kg/d	7 IU/d
Vitamin K	10 mcg/kg/d in PN +500 mcg IM at birth	200 mcg/d +500 mcg IM at birth

- **Table 8: Recommended Monitoring Parameters While Patient on PN in children**

Parameter	Suggested frequency	
	Initial/hospitalized	Follow-up/home
Growth		
Weight	Daily	Daily to monthly
Height	Weekly	Weekly to monthly
Head circumference	Weekly	Weekly to monthly
Triceps skin fold	Monthly	Monthly to annually
Mid-arm muscle circumference	Monthly	Monthly to annually
Serum*		
Electrolytes	Daily to weekly	Weekly to monthly
BUN, creatinine	Weekly	Monthly
Calcium, phosphorus, magnesium	Twice weekly	Weekly to monthly
Acid-base status (venous bicarbonate)	Until stable	Weekly to monthly
Albumin	Weekly	Weekly to monthly
Prealbumin¶	Weekly	Monthly
Glucose	Daily to weekly	Weekly to monthly
Triglycerides	Daily while increasing lipid	Weekly to monthly
Liver function tests (AST, ALT, GGTP, and alkaline phosphatase)	Weekly	Weekly to monthly
CBC and differential	Weekly	Weekly to monthly
Platelets	Weekly	Weekly to monthly
PT, PTT, INR	Weekly	Weekly to monthly
TSHΔ	As indicated	Every 6 months
Iron indices◊	As indicated	Biannually to annually
Trace elements§	As indicated	Biannually to annually
Fat-soluble vitamins¥	As indicated	Biannually to annually
Carnitine	As indicated	As indicated
Ammonia	As indicated	Biannually to annually

Blood culture from central venous catheter	As indicated	Biannually to annually
CRP or ESR	As indicated	As indicated
Urine		
Glucose	2 to 6 times/day	Daily to weekly
Ketones	2 to 6 times/day	Daily to weekly
Iodine and creatinine (spot or 24-hour collection)Δ	As indicated	If TSH is elevated
Urine specific gravity	As indicated	As indicated
Urea nitrogen	As indicated	As indicated
Clinical observations		
Vital signs‡	Daily, or as indicated	Daily, or as indicated
Intake and output	Daily	Daily
Check administration system	6 to 12 times/day	2 to 6 times/day
Catheter site/dressing	6 to 12 times/day	2 to 6 times/day
Developmental milestones	As indicated	As indicated

Frequency depends on clinical condition.
ALT: alanine aminotransferase; AST: aspartate aminotransferase; BUN: blood urea nitrogen; CBC: complete blood count; CRP: C-reactive protein; ESR: erythrocyte sedimentation rate; GGTP: gamma-glutamyl transpeptidase; INR: international normalized ratio; PT: prothrombin time; PTT: partial thromboplastin time; TBA: thyroxine-binding prealbumin; TSH: thyroid-stimulating hormone; TIBC: total iron-binding capacity.
* Metabolically unstable patients may need more frequent checks.
¶ Prealbumin is also known as TBA or transthyretin. It is an index of the short-term adequacy of protein intake. However, prealbumin is also suppressed by the acute phase response, so it is not useful as a measure of adequate protein intake in the setting of inflammatory disease.
Δ Iodine deficiency can cause hypothyroidism. If parenteral nutrition is the sole source of nutrition, the child should be screened periodically for hypothyroidism by measuring serum TSH. If TSH is elevated, then iodine status should be evaluated by measuring 24-hour urinary iodine or spot urinary iodine and creatinine. Spot urinary iodine concentrations can be interpreted as follows: severe deficiency <20 micrograms/L; moderate deficiency 20 to 50 micrograms/L; mild deficiency 51 to 99 micrograms/L.
◊ Iron indices are serum iron (Fe), TIBC, ferritin, and/or soluble transferrin receptor levels.
§ Adequacy of trace elements is monitored by measuring whole-blood or erythrocyte manganese (Mn), copper (Cu), serum zinc (Zn) and alkaline phosphatase, and plasma selenium (Se). Chromium (Cr) concentrations should be monitored periodically in patients on long-term parenteral nutrition with kidney function impairment.
¥ Fat-soluble vitamins are measured as serum retinol (for vitamin A), 25-hydroxyvitamin D (for vitamin D), and alpha-tocopherol (for vitamin E). Serum concentrations of alpha-tocopherol are strongly influenced by concentrations of serum lipids, so the effective vitamin E levels are calculated as the ratio of alpha-tocopherol:(cholesterol + triglycerides), where a normal ratio is >0.8. For vitamin K, measurements of PT and PTT are used to screen for deficiency.
‡ Vital signs include respiratory rate, heart rate, temperature, and blood pressure.

- **Table 9: Recommended lipid/triglyceride monitoring and recommendation**

Recommended PN Intake and TG level
• Triglyceride levels are monitored daily as lipid intake is increased and then weekly once the dose is stable and levels are adequate. • Information regarding maximal infusion rate for pediatrics is limited, but it is well-documented that longer infusion rates,12-24 hours, improve tolerance to lipid infusions. • Decreasing the lipid dose or infusing lipids every other day or 3-5 times a week instead of daily in long-term PN patients will allow for further clearance of the lipid and possibly avoid triglyceride levels > 200 mg/dL (2.26mmol / L). • It is recommended to reduce or hold at current lipid infusion when levels are > 250 mg/dL (2.83 mmol/L). Limiting the dose and therefore decreasing phytosterol intake may also reduce the cholestasis commonly noted in pediatric patients receiving long-term PN.

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