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Home Parenteral Nutrition: Part II: Clinical Management and Monitoring

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Patients with prolonged acute and chronic intestinal failure (IF) will require parenteral nutrition (PN) after hospital discharge. Those who qualify for parenteral nutrition at home require meticulous follow-up with clinicians knowledgeable of the intricacies and potential complications of PN management. In the United States there are few centers with specialized teams that are equipped to manage patients on HPN. Geographical distance and insurance reimbursement are barriers for patients to follow with experts trained to manage their complex medical needs. Therefore, it is incumbent for primary care providers, gastroenterologists, surgeons, and oncologists to understand the basics of HPN management. This review is the second in a four-part series focused on the basic requirements for safe transitions of PN-dependent patients from acute care to home, and the recommended approach to minimize the risks associated with HPN.

INTRODUCTION

Patients requiring parenteral nutrition (PN) beyond acute hospitalization should be evaluated for eligibility for home PN (HPN) therapy. Eligibility is established based on the patient's diagnosis, insurance coverage, home environment and ability of patient/caregiver to learn the multi-step process of PN administration (see Part 1 of the series). Prior to hospital discharge, several key steps must be completed, including placement of secure central venous access, stabilization on the prescribed PN regimen, patient and caregiver education on PN administration and self-monitoring, and coordination of home infusion services (pharmacy and nursing). Patients transitioning with HPN require ongoing infusion education, metabolic monitoring, and central venous catheter (CVC) care to ensure safety and prevent complications. It is estimated that 25,011 patients in the United States (US) receive HPN,[1] many of whom require

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lifelong support. Accordingly, clinicians caring for these patients must have a solid understanding of the fundamental principles of HPN management. This review will discuss the various aspects of patient and caregiver education, troubleshooting CVC-care, and metabolic monitoring of patients on HPN.

Transition of Care Coordination

Prior to discharge from the hospital, the inpatient care coordinator, or case manager, will make referrals to home infusion companies for PN and nursing services. The home infusion clinical team will use the patient's clinical documentation provided by the hospital to do its own assessment of the patient's diagnosis, insurance coverage (with particular attention to ensuring coverage with supporting documentation if the patient is insured by Medicare), home environment and ability of patient/caregiver to learn the multi-step process of PN administration. Any concerns will be communicated and addressed prior to acceptance of service. The infusion pharmacy will also determine if their own nurses can provide/bill for the in-home nursing care or if a nursing agency is needed. For the latter, the infusion pharmacy will confirm that the nursing agency meets established competency and quality standards to support the patient on this complex home therapy.

When the patient is ready for discharge, the care coordinator transmits the physician's final orders for the HPN formula, infusion supplies, therapy-associated labs, and weekly line care to the home infusion pharmacy. The infusion pharmacy will compound the PN, pack infusion supplies (Box 1), and deliver the formula and associated supplies to the patient's home. This process takes a minimum of 6-8 hours from start to finish if the infusion pharmacy is located in the patient's geographical region. However, some pharmacies require orders to be placed one day in advance as PN formulations and associated supplies may ship overnight. The patient, or a designated caregiver, must be present at home to receive the PN and infusion supplies as the PN bags and additives require refrigeration upon delivery. If no one is available to receive the PN bags and supplies, it may be possible to arrange for the delivery to the hospital to be transported home with the patient.

Box 1. Home PN Infusion Supplies

All Patients:
Infusion pump
IV pole and pump carrying case
Pump tubing and filter
Alcohol prep pads
Chlorhexidine wipes
Saline syringes
10 mL syringes
Needles and sharps containers
Batteries
CVC dressing change kits
Positive pressure caps/disinfecting port protectors

Based on Individual Patient Needs:
Gloves
Tape
Stat-lock securement device
Microclave connector
Backcheck valve

Once the patient is home, and the PN supplies have been received, the visiting nurse arrives to start the patient intake process, organize the infusion supplies, and begin the home education as discussed below. Unfortunately, in some cases a nursing visit may not be possible on the day of discharge. In these cases, either the patient is connected to the HPN prior to leaving the acute-care facility or rarely does the patient/caregiver receive a virtual-visit for PN-connection instructions. The latter situation is driven by either unavailability of home nurses in the patient's geographical area or cost-saving measures by the insurance company, neither of which is in the best interest of patient safety.

Home Infusion Education

After transitioning home, the PN education continues throughout the first days and weeks of therapy. On the day of hospital discharge the visiting nurse should reinforce both verbal instructions and hands-on training to:[2,3]

- Prepare the PN bag
- Connect the tubing between the CVC and the infusion pump
- Demonstrate proper use of the infusion pump
- Flush and care for the CVC

- Maintain a supply inventory
- Review signs and symptoms of complications
- Discuss what to do in the event of a problem
- Provide emergency contact phone numbers

During subsequent visits, the nurse will:

- Complete physical assessments and weigh the patient
- Monitor the CVC insertion site while changing the occlusive dressing
- Reinforce adherence to all care guidelines
- Report all findings to the PN provider and/or the nutrition support team (NST)

The goal for HPN training is to enable patient and caregiver independence with PN administration and catheter care. Once the patient/caregiver feels confident in their self-care, the visiting nurse certifies that they are safe and competent; and if the patient is no longer homebound, then home nursing services can be discontinued. Independence with HPN and catheter care allows for more freedom such as return to work or school and travel. However, until independence is achieved, nursing services can continue in the home or be transferred to an ambulatory infusion clinic.

Complications

Recognizing and addressing potential complications before they become life-threatening are essential skills for clinicians caring for patients on long-term HPN. Tables 1 and 2 list the most common CVC and PN infusion complications, their signs and symptoms, and recommendations for management.[4-6]

Catheter Infections

Central venous catheter infections may occur at the catheter insertion site, within the subcutaneous tunnel or port pocket, or more commonly, within the catheter lumen (intraluminal). Intraluminal infections can lead to bloodstream infections and are referred to as central line-associated bloodstream infections (CLABSIs). Reported CLABSI rates vary based on patient age and type of CVC device; overall prevalence rates are as high as 0.87 per 1,000 PN-days.[7] Catheter infections can result from systemic infections that seed the device. However, more often they arise from microbial contamination of the catheter hub during tubing connections, line flushing, or infusion cap changes. Importantly, CLABSIs are a serious complication and must be attended to expeditiously to prevent severe sepsis and death.

Any of these symptoms should raise serious concern for CLABSI and warrant medical evaluation, including peripheral and central line blood cultures in all HPN patients:[8]

- Elevated temperature (even low-grade elevation)
- Chills and/or rigors during PN infusion
- Hyperglycemia
- Elevated liver tests
- Leukocytosis
- Headache
- Malaise

If there is concern for infection the CVC should not be used. Both peripheral and CVC blood cultures should be drawn as soon as possible after onset of symptoms most often in the ER or possibly by the home infusion nurse if there is lower suspicion of infection. Blood cultures typically incubate for 4-5 days. Patients unable to maintain adequate hydration without PN during the blood culture incubation period may require hospital admission for peripheral intravenous hydration. Results of blood cultures will dictate the course of treatment. All attempts are made to salvage infected catheters for patients requiring long-term HPN to prolong each venous access point. However, sepsis and infections of difficult to eradicate bacteria and fungus warrant catheter removal, line holiday over several days while the patient receives intravenous antimicrobial therapy, and then CVC replacement once blood cultures are negative and the patient is clinically stable

Prevention of CLABSIs is accomplished by:[9]

- Strict antisepsis handwashing
- No-touch technique for cleansing the catheter
- Use of ethanol impregnated CVC caps
- Aseptic technique during PN bag preparation and connection to the CVC

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Prophylactic line locks (antibiotics, antifungals, taurolidine, sodium bicarbonate, or 70% ethanol) when the CVC is not in use can be utilized to prevent CLABSIs in patients with a history of recurrent line infections or those with limited central access. The type of catheter lock solution will depend on the country of residence, manufacturer availability, stability of compounded antibiotics and payer authorization (in the US).

Catheter insertion sites and tunnel/pocket infections are characterized by erythema, induration, and tenderness, with or without purulent drainage or fever. The infection may occur around the catheter insertions site and/or at any point along the track between the skin and venous puncture sites. These types of infections are difficult to treat if the catheter remains in situ as antimicrobial medications cannot sterilize foreign objects. Most often insertion site and tunnel infections require CVC removal and reinsertion at a new site once the infection has cleared. Prevention of these complications require strict adherence to aseptic techniques during catheter insertion and subsequent dressing changes.

Non-Infectious Catheter Complications

Longevity of CVC devices is important for those requiring long-term HPN. Unfortunately,

Table 1. Potential Complications of Central Venous Access Devices[4-6]

Complication	Signs and Symptoms	Management Recommendations
Infection	• Fever • Chills/rigors during infusion • Headache • Malaise • Hyperglycemia • Hyperbilirubinemia • Leukocytosis or leukopenia • Erythema or induration at the insertion site or along the tunnel • Pain at the catheter insertion site	• Urgent medical attention • Blood cultures from peripheral and central line (all lumens) • Do Not Use the CVC • Possible hospital admission for IV antibiotics and hydration • Line salvage or removal and replacement • Prevention – lock CVC with antibiotics, antifungals, taurolidine, sodium bicarbonate, or 70% ethanol
Mechanical	• Resistance with flushing • Bulging lumen with flush • Pump alarms (occlusion error)	• Urgent nursing assessment • Treatment with anti-thrombolytic, 70% ethanol, 0.1N hydrochloric acid, or sodium bicarbonate • Possible catheter replacement
Displacement	• CVC out of body • Increased length of external portion of CVC • Neck, arm, or breast pain	• CVC out – lay left-side down, apply pressure for 5 minutes, then occlusive dressing, and medical attention for replacement • Increased CVC length or pain with infusion - confirm CVC tip location with chest x-ray • Possible CVC replacement
Thrombosis	• Unilateral arm swelling or pain • Facial, neck, chest swelling	• Medical attention to evaluate for thrombus – ultrasound • Anticoagulation if deep vein thrombosis • Angiography to evaluate for venous stenosis or occlusion • Possible line removal • Stenotic vein - can reduce PN volume and slow infusion rate; possible angioplasty or re-site catheter

Abbreviations: CVC, central venous catheter; N, normal or molar; PN, parenteral nutrition

catheter materials deteriorate or break over time, compromising the catheter integrity. Cracks or perforations in the catheter require immediate attention to prevent air penetration and microbial contamination. If addressed promptly, it may be possible to repair the catheter or exchange it over a guidewire, allowing utilization of the same insertion site and tract.

Table 2. Potential Metabolic Complications of Long-Term HPN[4-6]

Complication	Signs and Symptoms	Management Recommendations
Dehydration	• Thirst, dry mouth • Weakness, fatigue, dizziness • Tachycardia • Rapid weight loss, > 2kg in 24 hours • Dark colored urine • 24-hour urine volume < 1L • Urine Na+ < 20 mEq/L	• Additional IV fluid • Assess PN volume and reformulate as needed • Measure 24-hour fluid losses • Assess protein needs, protein input (include oral/enteral protein intake), and possibly reduce PN amino acids
Edema	• Swelling • Rapid weight gain, > 2 kg in 24 hr • Hypertension	• 24-hour measurement of output – urine, ostomy/stool, drains • 24-hour measurement of intake – oral, enteral, parenteral • Assess PN volume and sodium concentration, and reformulate as needed • Elevate extremities as possible • Unilateral swelling - rule out thrombus
Liver Disease (steatosis, cholestasis, gallbladder sludge/stones)	• Elevated liver tests	• Maximize oral/enteral intake • Do not overfeed • Cycle PN • Allow daily fasting hours (no PN/oral/enteral intake) • Reduce dextrose to < 5 g/kg/d • Limit SO emulsion to < 1g/kg/d • Use mixed-oil lipid emulsion with fish oil
Metabolic Bone Disease (osteopenia, osteoporosis, osteomalacia)	• Often asymptomatic • Bone pain • Incidental fracture	• Screen for MBD risk factors • Routine DEXA (every 1-2 years) • Optimize calcium, copper, magnesium, vitamin D, and phosphate – PN and oral • Avoid excess protein/amino acid input • Prevent metabolic acidosis • Treat hypomagnesemia • Promote weight bearing exercise • Encourage smoking cessation • Consider use of anti-reabsorption medications with endocrinology consultation
Anemia	• Fatigue • Pallor • Dyspnea on exertion • Impaired ability to maintain body temperature (chilled)	• Monitor cell counts, ferritin, iron, and iron saturation • Oral or IV iron replacement

Abbreviations: HPN, home PN; CVC, central venous catheter; N, normal or molar; PN, parenteral nutrition; IV, intravenous; Na^+, sodium; SO, soybean oil; DEXA, dual-energy x-ray

Catheter occlusions may result from thrombus formation, drug or lipid precipitation, or extra-catheter mechanical resistance.[10] Each type of occlusion is amenable to different treatments. Anti-thrombolytic agents are indicated when blood clots are of concern. In cases of non-thrombotic occlusion, agents such as 70% ethanol, 0.1N hydrochloric acid, and sodium bicarbonate solutions can be instilled and withdrawn from difficult-to-flush catheters; however, these interventions require expert-level clinicians to salvage the catheter.[10] In some cases, particularly if the catheter cannot be flushed or used for infusion, replacement of the catheter is necessary.

The primary prevention of catheter occlusions is diligent CVC flushing before initiation and following completion of the PN infusion. In cases of multiple occlusions or ongoing flush resistance, evaluation of the PN solution with the infusion pharmacist and dietitian may identify risks of PN component precipitation potential.

Hepatobiliary Injury

Long-term PN support increases the risk of hepatobiliary diseases.[4,5] Left untreated, hepatic steatosis and cholestasis can progress to portal hypertension, cirrhosis, and end-stage liver disease. The etiology of intestinal failure-associated liver disease (IFALD) is not completely understood, but thought to be multifactorial related to:

- Short length of remnant bowel
- Absent colon
- Low or nil oral/enteral intake
- Excess energy input (hyperalimentation)
- Carnitine deficiency
- Phytosterols present in soybean oil-containing intravenous lipid emulsions
- Continuous PN infusion
- Recurrent infections or overgrowth of gut microbiota

Essential fatty acid (EFA) requirements of PN-dependent patients are met with intravenous soybean oil (SO) intravenous lipid emulsions. The ω-6 fatty acid and phytosterol contents of SO emulsions are known to upregulate the inflammatory cascade that contributes to hepatic disease and impaired immune function.[4,11] Mixed-oil lipid emulsions (such as Clinolipid® and SMOF®) contain SO to provide EFAs but utilize other plant and marine oils that are thought to be hepato-toxic while still a source of concentrated calories.[11,12]

Perturbed enterohepatic circulation of bile acids and enteric hormones may cause liver injury in those with altered GI anatomy. The proposed mechanism of injury involves downregulation of bile acid secretion from reduced enteral intake that alters enterocyte hormone signaling to the liver and ultimately dysregulation of hepatic glucose and lipid homeostasis.[13] Abnormal substrate metabolism likely exacerbates hepatic steatosis and progression of liver disease. Those with slow GI motility can develop dysbiosis with increased bile acid deconjugation leading to gut hormone dysregulation and liver disease.[13]

Routine monitoring of liver tests (total bilirubin, alkaline phosphatase, and transaminase levels) allows for early detection of hepatic injury and corrective modifications to the nutrition care plan. If abnormal liver tests develop, and other causes of liver disease are ruled out, then PN is the most likely cause of abnormal tests. Refractory IFALD is an indication for intestinal (or intestine with liver) transplantation. Primary management strategies for IFALD include:

- Optimization of oral/enteral nutrition intake
- Avoid overfeeding of calories
- Transition to mixed-oil lipid emulsion with lower ω-6/ω-3 fatty acid ratio
- Compress PN infusions to allow > 4-6 hours off PN each day
- Prevent/treat infections
- Manage GI stasis and bacterial overgrowth
- Removal of manganese and copper in the setting of cholestasis

Metabolic Bone Disease

Osteopenia, osteoporosis, and osteomalacia are associated with long-term PN use. Metabolic bone disease (MBD) develops in those with:

- Chronic inflammatory diseases
- Use of medications such as corticosteroid, heparin, and warfarin
- Malabsorption of calcium, magnesium, phosphorus, copper, vitamin D, and vitamin K

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- Prolonged metabolic acidosis
- PN contaminants (i.e., aluminum)
- Excess protein/amino acid intake

Periodic measurement of serum 25(OH) vitamin D levels and bone density by dual-energy x-ray absorption scan (DEXA) will help to stratify risk and identify early stages of MBD (osteopenia). Early detection allows for interventions to prevent disease progression and reduce fracture risk. Treatment of MBD in the setting of intestinal malabsorption (from massive intestinal resection or bypass) requires close oversight to prevent life-threatening hypocalcemia if bone mineral reabsorption is inhibited by medications and intestinal absorption of minerals are limited by disease.

Anemia

Iron-deficiency anemia may occur in patients on HPN. Iron is rarely added to PN formulations due to compounding incompatibility with solutions containing lipid emulsions and high risk of hypersensitivity reactions associated with IV iron preparations. Patients with altered upper GI anatomy (specifically with the duodenum out of continuity), malabsorption, and/or intermittent blood loss should be followed closely for iron-deficiency anemia. Oral iron supplementation may be possible to maintain iron stores, though if oral iron is not tolerated, or ineffective, then periodic IV iron infusions may be necessary.

Clinical Monitoring

Meticulous monitoring is essential when caring for patients receiving HPN. The indices to follow are stratified into physical examination and laboratory testing as outlined in Tables 3 and 4.[5,10,14,15] Assessment frequency is based on the patient's diagnosis, nutritional status, and stability of the PN regimen.

In addition to monitoring serum chemistries, patients on long-term HPN require periodic assessment of micronutrients levels. Table 4 outlines the micronutrients of primary concern and the recommended frequency of assessments. Intravenous multivitamin preparations (MVI) have low concentrations of vitamins D and E. Fat-soluble vitamin dzeficiencies are common and require oral supplementation because IV forms of individual fat-soluble vitamins are not available. Most MVI preparations contain phylloquinone (vitamin K) which will antagonize warfarin; initiation of PN with MVI may necessitate warfarin dose adjustments. Trace mineral preparations are available in oral and IV preparations.

When micronutrient deficiencies occur, it may be necessary for patients to take high-dose supplements for repletion - Box 2.[16,17] In the setting of high-dose supplementation of micronutrients, it is recommended to monitor serum levels every 4-6 weeks to prevent toxicity.[9]

Outpatient clinical follow-up with a NST is strongly recommended for all patients receiving HPN.[10,18] Table 5 outlines the responsibilities of each NST member during clinic visits. In-person encounters allow for direct visualization of the patient and their CVC. Assessment of hydration and strength is essential for weaning PN support, adjustment of medication and nutritional therapies, and for troubleshooting problems. Some patients

Table 3. Physical Monitoring Parameters and Frequency[10,14,15]

Parameter	Baseline	Frequent PN Solution Adjustments*	Stable PN Solution¥ (> Monthly)
Outpatient Clinic Visit		2-4 weeks	3-6 months
Weight	X	1-2 times weekly	Weekly
Temperature	X	Daily	Daily
CVC	X	Weekly	Weekly
Hydration Status	X	Weekly	At clinical encounters
DEXA	X		1-2 years

Abbreviations: PN, parenteral nutrition; CVC, central venous catheter; DEXA, dual-energy x-ray absorption scan
* PN regimens requiring frequent adjustments due to initiation, titration, metabolic instability, fluid shifts, or transition
¥ PN regimens that are established and for which the patient is clinically stable on the current regimen

Table 4. Metabolic Monitoring Parameters[5,10,14]

Parameter	Baseline	Frequent PN Solution Adjustments*	Stable PN Solution¥
Serum Metabolic and Chemistry Tests Sodium, potassium, chloride, bicarbonate, urea, creatinine, glucose, calcium, phosphate, magnesium	X	1-2 weeks	1-3 months
Liver Test Total protein, albumin, total bilirubin, alkaline phosphatase, AST, ALT, prealbumin	X	Monthly	1-3 months
Complete Blood Count	X	Monthly	1-3 months
Fatty Acid Panel	X		6-12 months
Vitamins A, 25(OH)D, E, B_{12}, Folate, INR	X	Monthly -if deficiency exists and high-dose supplementation required	6-12 months
Trace Minerals Copper Zinc Selenium Manganese	X	Monthly -if deficiency exists and high-dose supplementation required	6-12 months
Iron Studies - Iron, total iron binding capacity, iron saturation, ferritin	X	Monthly -if deficiency exists and high-dose supplementation required	3-12 months

Abbreviations: AST, aspartate aminotransferase; ALT, alanine aminotransferase; INR, international normalized ratio.
* PN regimens requiring frequent adjustments due to initiation, titration, metabolic instability, fluid shifts, or transition
¥ PN regimens that are established and for which the patient is clinically stable on the current regimen

Box 2. Oral Micronutrient Dosing Recommendations for Repletion in Adults[16,17]

Vitamin A – 10,000 – 20,000 units daily
Vitamin E – 400 units daily
Vitamin D2 or D3 – 6,000-10,000 units daily or 50,000 units weekly
Vitamin K – 10 mg IM injection once for repletion
Vitamin B_{12} – 1,000-2,000 mcg daily (alternative, 1 mg subcutaneous injection monthly)
Folate – 1 mg daily
Zinc – 50 mg zinc daily (elemental)
Copper – 1-2 mg daily
Selenium – 100-200 mcg daily
Iron – 100-200 mg daily (elemental)

feel more comfortable asking questions in-person, creating an opportunity for additional patient education.

The home infusion team, comprised of a dietitian, nurse, and pharmacist, is a valuable addition to the patient's care network. This team provides critical support to the ordering prescriber, particularly when the patient is not followed by a hospital-based NST. Each discipline on the home infusion team must demonstrate nutrition support competence, through certification, to ensure safe HPN management. Moreover, routine communication with the patient and documentation of all findings related to weight, fluid intake and losses, laboratory values and adherence to the

Table 5. HPN Clinic Visit Responsibilities by Discipline

Discipline	Clinic Visit Responsibilities
Physician, Nurse Practitioner, or Physician Assistant	• Physical exam – heart, lungs, abdomen, and extremities with attention to catheter insertion site, CVC integrity, GI function, and hydration status • Assess weight and vital signs • Review, order/reorder medications, PN formula • Order tests/procedures based on exam findings
Registered Dietitian Nutritionist	• Assess oral/enteral intake, weight, micronutrient supplements • Assess PN nutrient requirements • Provide nutrition education (diet, oral rehydration solutions, enteral feedings, etc.)
Clinical Pharmacist	• Review and update medications in the medical record • Review PN formulation and communicate changes to the compounding pharmacy • Advise on dosing medications • Obtain insurance authorizations for medications
Registered Nutrition Support Nurse	• Assessment and care of CVC • Troubleshoot problems with skin integrity, CVC, GI tubes, enterostomy • Provide ongoing HPN education • Assist physician with in-office procedures

Abbreviations: CVC, central venous catheter; GI, gastrointestinal; PN, parenteral nutrition.

prescribed regimen are essential and must be communicated in a timely manner to the prescriber/NST.[19] The home infusion team can serve as the "eyes and ears" and with their close follow-up can often identify a status change and possible cause. For example, a decline in serum electrolytes may be due to a missed infusion versus a need for an increase in the IV electrolytes in the HPN solution. Further, weaning readiness or other important regimen adjustments can be identified and brought to the attention of the managing team.

SUMMARY

Management of patients receiving long-term HPN requires meticulous oversight and attention to detail by knowledgeable clinicians. Adherence to standards of care and practice guidelines ensure patient safety. Awareness of how to anticipate and identify potential problems and proper management of complications is paramount to prevent life-threatening illness. Collaboration between the NST, the home care pharmacy, the visiting nurse, and the patient/family/caregivers is essential. Referrals to medical centers with expertise in the management of chronic intestinal failure, i.e., those patients requiring long-term HPN, may be in the patient's best interest. When those referrals are unfeasible, it may be incumbent on the ordering provider to seek consultation and collaboration with expert centers and on-line communities of medical professionals dedicated to the management of patients with intestinal failure, such as Learn Intestinal Failure Tele-ECHO (LIFT-ECHO) to ensure optimal management. ■

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