Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

ROYAL COLLEGE OF PHYSICIANS OF IRELAND

PAEDIATRICS

NATIONAL CLINICAL PRACTICE GUIDELINE

Guideline on the Use of Parenteral Nutrition in Neonatal and Paediatric Units

Clinical Strategy and Programmes Division
Health Service Executive

Endorsed by the Irish Society for Clinical Nutrition & Metabolism

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1.0 Aim of Guideline

The aim of this guideline is to ensure evidence-based safe prescribing, administration and monitoring of parenteral nutrition (PN) in neonatal and paediatric units in Ireland.

2.0 Purpose and Scope

The purpose of this guideline is to improve the management of neonatal and paediatric patients requiring PN support in hospital. These guidelines are intended for healthcare professionals involved in the provision and administration of PN in neonatal and paediatric units in Ireland. They are designed to guide clinical judgement but not replace it. In individual cases a healthcare professional may, after careful consideration, decide not to follow a guideline if it is deemed to be in the best interests of the child or neonate. These guidelines are also intended to provide essential information to units that use PN less frequently, and provide a pathway for support should it be required.

3.0 Background and Introduction

The availability of PN to sustain growth in neonates and children who are unable to meet nutritional requirements via the enteral route, or have severe functional intestinal immaturity, represents one of the most important therapeutic advances in paediatrics over the last four decades. Despite the known benefits, an assessment of PN use in the United Kingdom (UK) demonstrated sub-optimal practices in the prescribing, administration and monitoring of PN (Stewart *et al*., 2010). In order to safely provide PN, structures and processes need to be in place that ensure assessment of the patient's nutritional requirements, appropriate constitution and compounding of the PN, safe intravenous access (with meticulous aseptic insertion technique and subsequent catheter care) and rigorous monitoring of the patient's electrolytes and response to treatment (Stewart *et al.*, 2010).

4.0 Legislation/other related policies

5.0 Glossary of Terms and Definitions

AA	Amino Acid
ASPEN	American Society for Parenteral and Enteral Nutrition
CVAD	Central Venous Access Device
ESPGHAN	European Society for Paediatric Gastroenterology, Hepatology and Nutrition
IU	International Units
IV	Intravenous
Kcals	Calories / kilocalories
NCHD	Non-consulant Hospital Doctor
NEC	Necrotising Enterocolitis
OFC	Occipital Frontal Circumference (head circumference)
PN	Parenteral Nutrition

RANP	Registered Advanced Nurse Practitioner
SMOFlipid®	Soybean oil, medium chain triglycerides, olive oil and fish oil (lipid blend)
TPN	Total Parenteral Nutrition

Parenteral Nutrition (PN)	The provision of nutrients via the intravenous (parenteral) route. PN is used for infants and children who cannot receive their full nutritional requirements via oral or enteral feeding. The terms PN and TPN are often used interchangeably when referring to parenteral nutrition, with 'TPN' referring to a patient's full or 'total' nutritional requirements being provided by parenteral nutrition, however 'PN' is the preferred term as enteral nutrition should be provided where possible in addition (provided the gastrointestinal tract is accessible / functioning). PN usually comprises of both aqueous and lipid solutions.
Patient-specific PN	A PN solution that is compounded based on a patient's individual nutritional requirements. Patient-specific PN may be referred to as 'individualised PN'.
Standard Concentration PN	This type of PN is often referred to as a 'stock bag' or 'stock PN solution'. It contains a fixed amount of nutrients. Standard concentration PN may be referred to as 'standardised PN'.
Working Weight / Dosing Weight	The weight used by the clinician in determining nutrient doses. Dependent on institutional or professional preference, the dosing weight may be the actual, ideal, or adjusted body weight of the individual patient.
Extremely low birth weight	ELBW Birth weight <1000g (Koletzko, 2014)
Very low birth weight	VLBW Birth weight <1500g (Koletzko, 2014)
Preterm	Defined as infants born alive before 37 weeks of pregnancy are completed. There are sub-categories of preterm birth, based on gestational age: - extremely preterm (<28 weeks) - very preterm (28 to <32 weeks) - moderate to late preterm (32 to <37 weeks) (WHO, 2015)
Transition	The period of physiologic and metabolic instability following birth which may last as long as 7 days (Tsang, 2005)

6.0 Roles and Responsibilities

This guideline should be reviewed by each hospital's local neonatal / paediatric governance group to appropriately plan implementation. This will ensure that the inpatient care of neonates/children admitted to their facility is optimised irrespective of location.

7.0 Clinical Guideline

7.1 Indications for Parenteral Nutrition

PN is used where it is not possible to meet nutritional requirements via the oral or enteral route, often due to intestinal immaturity or intestinal failure. The decision to commence PN will depend on the patient's individual circumstances, and their age and size. Children differ from adults in that their nutritional intake must be sufficient not only for the maintenance of body tissues but also for growth (Koletzko *et al*., 2005). This is particularly true in infancy and during adolescence when children grow extremely rapidly (Koletzko *et al*., 2005). Older children and adolescents, however, can tolerate longer periods of inadequate nutrition than pre-term infants where starvation for even a day can be detrimental (Koletzko *et al*., 2005).

Preterm infants are initially dependent on receiving nutrients parenterally because the immaturity of their gastrointestinal tract. They are also born with low nutritional reserves – a 1kg infant may become deficient in essential fatty acids within two days of birth and survive for only four days if not provided with appropriate nutrition (Van den Akker, 2010; Koletzko et al., 2005). The majority of preterm infants less than 30 weeks gestation will require PN for a period, with duration determined by gestation, birth weight and other concurrent morbidities (Ehrenkranz, 2007; Koletzko *et al.*, 2005). In preterm infants, once indicated, PN should be commenced immediately following confirmation of line placement and ideally within six hours of birth (Ibrahim, 2004).

PN should be continued until adequate nutritional intake from oral or enteral feeding is tolerated, i.e. ideally until at least 75% of nutritional requirement (120ml/kg/day enteral feeds in preterm infants) is tolerated enterally (Miller *et al*., 2014).

Absolute Indications	▪ Functional immaturity, i.e. preterm infants <32 weeks gestation or <1.5kg consider PN to supplement advancing enteral nutrition and prevent subsequent growth failure ▪ Intestinal failure, e.g. pseudo-obstruction, short bowel ▪ Post-gastrointestinal surgery ▪ Necrotising enterocolitis (NEC) ▪ Congenital gastrointestinal defects, e.g. gastroschisis, intestinal atresia
Relative Indications	▪ Preterm infants ≥32 weeks gestation or ≥1.5kg who are not expected to receive adequate enteral intake (i.e. ≥75% of nutritional requirements) within approximately 3-5 days ▪ Term infants or children who are not expected to receive adequate enteral intake within 3-5 days ▪ Severe intrauterine growth retardation with associated absent or reduced end-diastolic flow ▪ Intractable diarrhoea or vomiting ▪ Chemotherapy-induced intestinal failure ▪ Inflammatory bowel disease ▪ Malabsorption syndromes ▪ Acute pancreatitis

Examples of Indications for Parenteral Nutrition

7.2 Constituents of Parenteral Nutrition

PN solutions are available in several forms:

- Aqueous or '2-in-1' macronutrient solutions containing amino acids and carbohydrate
- Lipid solutions, which may also have added vitamins
- 'All in one' or '3-in-1' macronutrient solutions containing amino acids, carbohydrate and lipid

PN solutions will contain some or all of the following constituents:

7.2.1 Fluid (Water)

7.2.1.1 Water is an essential carrier for nutrients and metabolites and it comprises a major part of human body mass at any age.

7.2.1.2 Total fluid requirements include maintenance requirements, and requirements for growth.

7.2.1.2.1 Water and electrolyte requirements per kilogram are very high after birth and decrease with age until adulthood.

7.2.1.3 Preterm infants can have high insensible losses via their skin.

7.2.1.4 See Appendix 1 for further information on fluid requirements.

7.2.2 Energy

7.2.2.1 Energy is required for maintenance requirements and new tissue synthesis (i.e. growth).

7.2.2.1.1 Requirements will be increased in the presence of metabolic stress, fever or sepsis, correction of faltering growth, and other clinical conditions.

7.2.2.1.2 Parenteral energy requirements are generally less than enteral requirements as there is no energy lost in the stools or in thermogenesis.

7.2.2.1.3 Energy requirements can be calculated based on non-protein calories as protein requirements are calculated only for maintenance and tissue deposition, not as an energy source.

7.2.2.1.4 The terms 'non-protein energy' or 'non-protein calories' are used to describe energy coming from carbohydrates and lipid only.

7.2.2.2 Energy in PN solutions is provided by carbohydrate and lipid to ensure proper utilisation of protein (amino acids).

7.2.2.2.1 Lipid and glucose are increased in a stepwise approach, as tolerated.

7.2.2.2.2 If energy provision is insufficient, protein will be used for energy instead; and with excess intake the energy will be deposited as fat.

7.2.3 Amino Acids (Protein / Nitrogen)

7.2.3.1 Proteins are the major structural and functional components of all cells in the body and are made up of chains of amino acids (AAs).

7.2.3.1.1 Amino acids are the source of nitrogen in PN solutions.

7.2.3.1.2 The equivalent amino acid ≡ protein ≡ nitrogen will vary depending on the amino acid solution used in PN (refer to current manufacturer information).

7.2.3.2 Infants and children need amino acids in their PN solution to repair tissue and to grow.

7.2.3.3 Certain AAs are not fully metabolised by neonates, for this reason it is important to use an AA solution that is primarily designed for this patient group.

7.2.3.4 Certain AAs are essential for neonates, therefore for those less than 10kg a profile of AAs based on that of breast milk are currently recommended.

7.2.3.5 It is important that AAs are used for anabolism and not as a source of energy.

7.2.3.5.1 Non-protein calorie to amino acid ratio describes the relationship between the non-protein energy and amino acid content of the PN solution and may be used to assess whether the amino acid (or protein) intake is sufficient to maintain muscle tissue.

7.2.3.5.2 In preterm infants, 20-25 non-protein calories per gram of AA should be used to allow for efficient net use of the AAs in protein building (Koletzko, 2014).

7.2.3.5.3 Pre-term infants require a minimum of of 1.5g AA on the first day of life, increasing to a maximum of 4g/kg/day.

7.2.3.5.4 In paediatric patients, 25-33 non-protein calories per gram of AA should be used (Shaw and Lawson, 2007).

7.2.3.5.4 Each gram of AA contains approximately 3.7kcals (see separate documents for details on currently available PN solutions).

7.2.3.6 Refer to Appendix 1 for further information on protein requirements.

7.2.4 Carbohydrate (Glucose)

7.2.4.1 Carbohydrate is the main source of energy in PN.

7.2.4.1.1 Glucose is the preferred intravenous carbohydrate source as it can be utilised by all cells and serves as metabolic fuel for muscle, liver, heart and kidneys as well as the brain, renal medulla and erythrocytes which need glucose as their energy source.

7.2.4.2 It is recommended that approximately 60-75% of non-protein kcals come from carbohydrate in maintenance PN.

7.2.4.3 Each gram of anhydrous dextrose, the main carbohydrate source used in PN, contains approximately 3.4kcals.

7.2.4.4 Glucose provision should be calculated as glucose infusion rate (mg/kg/min) in neonates.

7.2.4.4.1 The minimum glucose requirement in preterm infants is 4-8mg/kg/min at birth (6-11.5g/kg/day).

7.2.4.4.2 A maximum glucose infusion rate in preterm infants of 12.5mg/kg/min (18g/kg/day) should not be exceeded.

7.2.4.4.3 Glucose requirements based on glucose production rates for all other age groups are as follows (Shaw and Lawson, 2007):

Age	Glucose (mg/kg/min)
Infants	8-9
Toddlers and children	5-7
Adolescents and adults	2-4 at night

7.2.4.4.4 In older infants and children, glucose provision is usually calculated as g/kg/day and will vary depending on the child's age and weight, e.g. 16-18g/kg/day in small infants to 6-8g/kg/day in older children (refer to Appendix 1).

7.2.4.5 Glucose should be increased gradually as tolerated by approximately 2-3g/kg/day (1.4-2ml/kg/day), with consideration of glucose provided from other sources, e.g. other infusions or medications containing glucose, or affecting glucose metabolism e.g. steroids.

7.2.4.6 Refer to Appendix 1 for further information on carbohydrate requirements.

7.2.5 Lipid

7.2.5.1 Lipid emulsions are used in neonatal and paediatric PN as a non-carbohydrate source of energy, to provide a source of essential fatty acids and as a means of delivering fat-soluble vitamins.

7.2.5.2 It is recommended that approximately 25-40% of non-protein kcals come from lipid in patients receiving PN as a sole source of nutrition.

7.2.5.3 The lipid solution currently used is SMOFlipid®, as it is thought to reduce the incidence of parenteral nutrition associated liver disease (Attard *et al.*, 2012). SMOFlipid® contains fish oils (n-3 fatty acids), which may have anti-inflammatory properties (Schade et al., 2008), and reduce risk of hypertriglyceridaemia and cholestasis.

7.2.5.4 In an intravenous lipid solution, each gram of fat contains approximately 10kcals (see separate documents for details on currently available lipid products).

7.2.5.5 To prevent essential fatty acid deficiency a minimum linoleic acid intake of 0.25g/kg/day is required (1.35g SMOFlipid/kg/day or 0.5g Intralipid/kg/day) (Koletzko et al., 2005).

7.2.6 Acetate

7.2.6.1 Chloride in PN (as sodium chloride or potassium chloride) can be partly replaced by acetate (as sodium acetate or potasium acetate) to reduce metabolic acidosis and/or hyperchloraemia (Peters *et al*., 1997).

7.2.6.2 Acetate may be commenced at 1-2mmol/kg/day, up to a maximum of 6mmol total dose (Mirtallo, 2004).

7.2.6.3 The ability to add acetate is dependent on the amount of sodium and potassium prescribed.

7.2.6.4 Acetate is metabolised in the liver to produce bicarbonate on a 1:1 molar ratio.

7.2.7 Electrolytes

7.2.7.1 Standard concentration PN contains fixed amounts of electrolytes.

7.2.7.2 Electrolytes can be added to patient-specific PN according to requirements.
7.2.7.2.1The main electrolytes added are:

- Sodium
- Potassium
- Calcium
- Magnesium
- Phosphate

7.2.7.3 See Appendix 1 for further information on electrolyte requirements. Consider other sources of electrolytes such as intravenous fluids and medications.

7.2.8 Trace Elements

7.2.8.1 There are two solutions currently used to add trace elements to PN – Peditrace® and Additrace®.

7.2.8.2 Peditrace® is used to meet maintenance requirements for trace elements in children up to 40kg and contains:

Trace element	Peditrace® composition per ml
Copper	20 microgram (0.315µmol)
Manganese	1 microgram (18.2nmol)
Iodine	1 microgram (7.88nmol)
Fluoride	57 microgram (3µmol)
Selenium	2 microgram (25.3nmol)
Zinc	250 microgram (3.82µmol)

7.2.8.2.1 For patients up to 15kg it is prescribed at 1ml/kg up to a maximum of 15ml daily.
7.2.8.2.2 For patients between 15-40kg 15ml total daily dose is prescribed.
7.2.8.2.3 In preterm infants, current recommended dose of 1ml/kg/day does not meet requirement for zinc of 450-500µg/kg/day.

7.2.8.3 For additional zinc, supplement with zinc sulphate – please refer to ESPGHAN guidelines and PN provider for information on how to prescribe same.
7.2.8.3.1 Peditrace® does not contain iron; refer to 7.2.8.5 if addition of iron to PN is required.

7.2.8.4 Additrace® is currently used for children over 40kg at a dose of 10ml, and contains:

Trace element	Additrace® composition per 10ml vial
Copper	20µmol
Manganese	5µmol
Iodine	1µmol
Fluoride	50µmol
Selenium	0.4µmol
Zinc	100µmol
Iron	20µmol
Chromium	0.2µmol
Molybdenum	0.2µmol

7.2.8.5 Iron is not routinely added to PN solutions or commercially available trace element preparations.

7.2.8.5.1 Iron supplementation may be considered if infants and children require PN for longer than three weeks (Koletzko, 2005).

7.2.8.5.2 Iron chloride can be added to PN at a dose of 1ml/kg to provide 1.79µmol/kg/day (Koletzko, 2005).

7.2.8.5.3 This is not equivalent to nutritional requirement for iron as parenteral iron is administered directly, while enteral iron absorption is 5-20% at best (Toronto Sick Kids, 2007).

7.2.9 Vitamins

7.2.9.1 Both water soluble and fat soluble vitamins are added to PN.

7.2.9.1.1 Water soluble vitamins are vitamins B and C, and fat soluble vitamins are vitamins A, D, E and K.

7.2.9.1.2 SolivitoN® is used to cover the daily requirements of water soluble vitamins, and is prescribed at 1ml/kg up to a maximum of 10ml per day.

7.2.9.1.3 SolivitoN® can be added to the aqueous or lipid phase of the PN.

7.2.9.1.4 Composition of SolivitoN®:

Vitamin	SolivitoN® composition per ml
Thiamine (B_1)	0.25mg
Riboflavin (B_2)	0.36mg
Niacin (B_3)	4mg
Pantothenic Acid (B_5)	1.5mg
Pyridoxine (B_6)	0.4mg
Biotin (B_7)	6µg
Folic Acid	40µg
Cobalamin (B_{12})	0.5µg
Ascorbic Acid (C)	10mg

7.2.9.1.5 VitlipidN® Infant is used to cover the daily requirements of fat soluble vitamins in infants and children up to the age of 11 years, at a dose of 4ml/kg/day in infants up to 2.5kg, and at 10ml per day total dose above 2.5kg.

7.2.9.1.6 VitlipidN® Adult is used in children over the age of 11 years at a dose of 10ml.

7.2.9.1.7 VitlipidN® is added to the lipid phase of the PN.

7.2.9.1.8 Composition of VitlipidN®:

Vitamin	VitlipidN® Infant (per ml)	VitlipidN® Adult (per 10ml)
Vitamin A (Retinol)	69µg (230IU)	990µg (3300IU)
Vitamin D (Ergocalciferol)	1µg (40IU)	5µg (200IU)
Vitamin E (α tocopherol)	0.64mg (0.7IU)	9.1mg (10IU)
Vitamin K (Phytomendione)	20µg	150µg

7.2.10 Carnitine

7.2.10.1 A Cochrane meta-analysis (Cairns, 2000) found insufficient evidence to support routine supplementation with carnitine in preterm infants receiving PN.

7.2.10.2 Carnitine may be indicated in some paediatric patients with inherited metabolic disorders.

7.2.10.3 If prescribed, the recommended dose is 10mg/kg/day.

7.3 Assessment of Nutritional Requirements for Parenteral Nutrition

Nutritional requirements should meet specified criteria of nutritional adequacy, preventing deficiency or excess. For preterm infants, stores of nutrients are limited and needs are high, and recommended intakes should be achieved within days of birth. For very preterm infants, postnatal adaptations are critical in defining nutrient needs. Recommended intakes for preterm infants for initial feeding, the transition phase, and the goals that should be reached for optimal growth are summarised in Appendix 1.

Requirements in catabolic or unwell children vary and research suggests that actual energy requirements are less than previously thought (Shaw and Lawson, 2007). A dietitian will calculate nutritional requirements, monitor growth and biochemistry, and ensure adequacy of nutrient provision within fluid restriction on a case by case basis to give a more accurate assessment of energy and other nutritional needs.

7.4 Prescribing and Ordering Parenteral Nutrition

7.4.1 It should be determined daily if PN is required, and whether a standard concentration PN solution or a patient-specific PN solution is needed.

7.4.2 In very fluid restricted patients, it may not be possible to achieve nutritional requirements and advice on optimising nutrient provision should be sought from appropriate multidisciplinary team members.

7.4.2.1 It is important that the appropriate volume of PN is ordered, especially in critically ill patients who will be receiving multiple other infusions, as this ensures best possible provision of nutrition within available volumes.

7.4.3 Prescribing Patient-specific PN

7.4.3.1 Patient-specific PN should be ordered using the usual method for each institution, e.g. paper-based form or an electronic calculator.

7.4.3.2 In all cases, the following should be completed on the prescription/order form, regardless of whether it is a paper or electronic form:

- Patient hospital number
- Patient name
- Patient date of birth
- Location (ward)
- Date of order
- Date of infusion
- Day of PN
- Central/peripheral access (if glucose concentration is greater than 12.5%, a central venous access device must be used)
- Working weight or dosing weight (kg)
- Amino acid (g/kg)
- Glucose (g/kg)
- Lipid (g/kg)
- Sodium (mmol/kg)
- Potassium (mmol/kg)
- Calcium (mmol/kg)
- Magnesium (mmol/kg)
- Phosphate (mmol/kg)
- SolivitoN® (ml/kg)
- VitlipidN® (ml/kg) – paediatric or adult
- Peditrace or Additrace (ml/kg)
- Other requirements (as necessary), e.g. acetate
- PN volume per kg (ml/kg)
- Non-protein energy (kcals/kg)
- Hours of infusion (hours)
- Infusion rates for both aqueous and lipid solutions (ml/hr)
- Glucose infusion rate (mg/kg/min) and/or glucose concentration (%)

7.4.3.3 If using an electronic form, a paper copy should then be printed.

7.4.3.4 Hand written prescriptions must be legible.

7.4.3.5 PN may be ordered by a consultant, non-consultant hospital doctor (NCHD), dietitian, pharmacist or advanced nurse practitioner (ANP), but the prescription must be reviewed, authorised and signed by a doctor to make it a valid, legal prescription as all intravenous (IV) products regardless of content are deemed to be medicinal products.

7.4.3.6 PN prescriptions should be double-checked by a suitable second person before transmitting to the PN manufacturer.

7.4.3.6.1 PN prescriptions may be validated by pharmacists in many institutions prior to transmitting to the PN manufacturer.

7.4.3.7 Currently, all PN orders on weekdays should be sent before 10am for hospitals outside Dublin, before 12pm for hospitals in Dublin, and may be required earlier on bank holidays.

7.4.3.7.1 Where 7-day service exists, orders may be required earlier on Saturday / Sunday to ensure that solutions are compounded that day.

7.4.4 Prescribing Standard Concentration PN

7.4.4.1 Some institutions, particularly those dealing principally with neonates, may use standard concentration PN.

7.4.4.1.1 These solutions have longer shelf lives, and can be kept as regular stock on wards.

7.4.4.1.2 They are useful to avoid delays associated with ordering patient-specific PN.

7.4.4.1.3 Some standard concentration PN solutions may not contain adequate amino acids to support growth in extremely low birth weight (ELBW) infants until a substantial additional volume of enteral nutrition is tolerated. Patient-specific PN should be considered in these cases.

7.4.4.1.4 Standard concentration PN solutions do not contain vitamins and trace elements, and so are only suitable for short-term use, i.e. 2-3 days, or as a supplement to enteral nutrition.

7.4.4.2 As with all PN, when standard concentration PN is used biochemistry should be carefully assessed to determine first whether a standard concentration PN solution is suitable for the patient's needs.

7.4.4.2.1 See separate documents for details of currently available standard concentration PN solutions.

7.4.4.2.2 These solutions are principally aimed at the neonatal population.

7.4.4.3 The amount of the various constituents will change depending on the volume of standard concentration PN prescribed, for example 90ml/kg of a standard concentration PN solution will provide more sodium than 70ml/kg of the same solution.

7.4.4.3.1 Some units have electronic calculators to work out nutrient provision of standard concentration PN solutions at different infusion rates.

7.4.4.3.2 Other units may use other prescribing aids such as posters, tables, etc.

7.4.4.3.3 If the infusion rate is changed from that documented, the nutrients provided must be recalculated based on the new infusion rate to ensure safety. This must be clearly documented on the prescription.

7.4.4.4 Where standard concentration PN is not suitable, e.g. high sodium requirements, high glucose requirements, patient-specific PN should be ordered.

7.4.4.5 In preterm and term infants, patient-specific PN may be switched to standard concentration PN when tolerating advancing enteral nutrition at 60-80ml/kg/day, unless nutrients are required in amounts that cannot be achieved with standard concentration PN.

7.4.4.6 Standard concentration PN may be ordered by a consultant, non-consultant hospital doctor (NCHD), dietitian, pharmacist or advanced nurse practitioner (ANP), but the prescription must be reviewed, authorised and signed by a doctor to make it a valid, legal prescription as all intravenous (IV) products regardless of content are deemed to be medicinal products.

7.5 Delivery and Storage of Parenteral Nutrition

7.5.1 Patient-specific PN solutions are delivered directly by the manufacturer to the ward on the same day they are ordered, usually in the evening.

7.5.2 All PN should be stored in a designated refrigerator at 2 to 8°C.

7.5.3 The expiry date / shelf life of all PN solutions (lipid and aqueous) should be checked regularly, and stock rotated so that solutions with the shortest expiry date are used first.

7.5.4 The aqueous solution and lipid solution should be removed from the fridge in advance, approximately one hour prior to commencing the infusion.

7.6 Administration of Parenteral Nutrition

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

7.6.1.1 Infection prevention and control considerations are essential, including:

- National care bundles for CVAD insertion and maintenance and peripheral venous access (available at www.hpsc.ie)
- Monitoring of CVAD infection as part of overall surveillance programme

7.6.1.2 A dextrose concentration greater than 12.5% should not be infused via a peripheral line (Koletzko *et al*., 2005).

7.6.1.3 The addition of electrolytes and minerals further increases the osmolarity of the solution, with potential for tissue damage if infiltration or extravasations occur.

7.6.1.4 It is recommended that CVADs are used for PN in neonates (Koletzko *et al*., 2005; Ainsworth *et al.,* 2007).

7.6.1.5 CVADs must be inserted under strict aseptic conditions and proper care of the site, all connections and tubing is essential to reduce the risk of infection.

7.6.2 The requirement for a CVAD should be reviewed daily and the line removed promptly if no longer required.

7.6.3 Ideally, the venous line used for PN should not be interrupted for giving antibiotics or medications; a separate IV line should be used (Mirtallo *et al.*, 2004; Koletzko *et al*., 2005).

7.6.3.1 Mixing of medication with PN administration lines should be avoided unless validated by the manufacturer.

7.6.3.2 If co-infusion is unavoidable through the same line, medication stability and compatibility with the PN must be established and verified by the responsible pharmacist before administration (Mirtallo *et al.*, 2004; Koletzko *et al*., 2005).

7.6.3.3 If there is no information available regarding compatibility the medication should be infused separately from the PN.

7.6.3.4 If the line used for PN administration is required for other infusions, this must be risk assessed by the consultant.

7.6.4 A transparent dressing should be used to secure the intravenous cannula/catheter and should remain in place.

7.6.4.1 Routine dressing changes are not recommended to avoid damaging the skin, the catheter itself or dislodging the catheter.

7.6.4.2 If the dressing is wet or no longer occlusive it should be changed using sterile technique.

7.6.5 Infiltration/extravasation is a risk with any intravascular device. Signs include swelling of the area affected.

7.6.5.1 The infusion should be inspected hourly and peripheral cannula insertion site inspected for signs of extravasation.

7.6.5.2 The insertion site of a CVAD should be inspected at least 8-12 hourly for signs of infection and to ensure the dressing remains dry and intact.

7.6.5.3 Check for swelling in limb and the area where the tip is located and not just at the insertion site.

7.6.5.4 Catheter tip position should be checked after insertion and on subsequent chest xrays (upper limb insertion) to ensure the line has not moved and position remains satisfactory.

7.6.6 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 minimise infusion related complications.

7.6.6.1 The pump should have free flow prevention if inadvertently opened during use and have lockable settings (Koletzko *et al*., 2005)

7.6.7 The infusion (solution, syringe and lines) should be protected from light to prevent peroxidation and degradation of light sensitive vitamins (Mirtallo *et* al.; 2004; Chessex, 2015).

7.6.7.1 When lipid requirements exceed 40ml per day, lipid may be supplied in a bag rather than syringe which is infused using a standard giving set attached to the lipid line.

7.6.7.2 Administering vitamins with the lipid emulsion using light protected dark tubing is recommended as the most effective way to prevent peroxidation of the lipid and minimise vitamin loss, and is especially recommended during phototherapy (Silvers *et al,* 2001; Koletzko *et al.*, 2005; Chessex *et al*., 2015).

7.6.8 PN solutions may contain particulate matter and biochemical interactions can result in chemical precipitations in addition to the risk of bacterial contamination.

7.6.8.1 It is recommended that all PN solutions are administered via an infusion set containing a terminal filter (Koletzko *et al.*, 2005).

7.6.8.2 A 1.2 micron filter is recommended for 3-in-1 admixtures (ASPEN, 2004; *Koletzko et al.*, 2005). The current PN infusion set contains filter membranes with pore sizes of 1.2 micron (lipid line) and 0.2 microns (aqueous line).

7.6.8.3 The lipid solution and infusion line should be changed every 24 hours, and the aqueous PN solution and the rest of the infusion set should be changed every 24-48 hours (HSE, 2014; Fox *et al*., 1999; O'Grady *et al*., 2011)

7.6.8.3.1 The lipid line can be removed separate to the aqueous line, allowing the lipid syringe and line to be changed after 24 hours without the need to remove the aqueous part of the infusion set.

7.6.9 Nursing Administration of Parenteral Nutrition

7.6.9.1 The following checks (by two nurses) are required before commencing infusion of PN:

7.6.9.1.1 Check delivery sheet and solution labels.

7.6.9.1.2 Check PN/fluid order against the label on each PN solution to be infused and verify the following:

- Correct name, date of birth and hospital number
    - Date of infusion
    - Expiry date
- Volume to be infused over 24 hours, infusion route (central/peripheral) and rate (ml/hr)
- Composition, including quantity of each constituent ordered and the percentage glucose, matches prescription
- Remove the outer cover and visually inspect the bag, gently shake to dislodge any particles that may have formed and hold up to the light at a slight angle to inspect
- Check aqueous solution: This is a pale straw / yellow coloured clear solution – if the solution is cloudy or has visible crystals / particles it should not be used and should be returned to Pharmacy
- Check lipid solution: This should be uniformly opaque with no visible particles. If not, do not use and return to Pharmacy.

7.6.9.1.3 Both nurses must sign prescription sheet if correct, before commencing infusion.

7.6.9.2 Recommended procedure for administration via a CVAD:

7.6.9.2.1 Adoption of rigorous aseptic technique has been shown to markedly reduce incidence of line infections. To ensure high standards of asepsis two nurses are required: one will assist while the other prepares and connects the infusion.

7.6.9.2.2 Prepare supplies, then both nurses decontaminate their hands.

7.6.9.2.3 Clean trolley with disinfection wipes.

7.6.9.2.4 Prepare sterile field using sterile drape.

7.6.9.2.5 Decontaminate hands.

7.6.9.2.6 Use hat, sterile gloves (Aly *et al.,* 2005) and gown.

7.6.9.2.7 Prime infusion set aseptically using a non-touch technique and protecting key parts.

7.6.9.2.7.1 The administration set and filter should be primed with with the lipid solution first, followed by the amino acid solution mixing at the point of entry to the access device.

7.6.9.2.8 Check the patient's identity with the PN order and infusion, in line with hospital medication administration guidelines.

7.6.9.2.9 'Scrub the Hub' for 30 seconds with 2% chlorhexidine and 70% alcohol, e.g. Clinell®, **and** allow to dry (O'Grady *et al.*, 2011; Lockmann *et al.*, 2011; Simmons *et al.*, 2011; Munoz-Price *et al.*, 2012).

7.6.9.2.10 Attach new infusion set preventing contamination of key parts by using sterile gauze to hold the outer surface of the connections.

7.6.9.2.11 Check that all connections are tight and clamps are open.

7.6.9.2.12 Remove gloves and decontaminate hands; commence infusion at prescribed rate (both staff to check and verify rate) and dispose of old infusion set.

7.6.9.2.13 Document volume infused hourly (includes hourly volume and running total), and changes to the infusion rate which may occur.

7.6.9.2.14 Ensure infusions (bag and lipid line) are light protected.

7.6.9.2.15 Set rate and volume infused are recorded hourly and infusion site, lines and connections checked.

7.6.9.2.16 The infusion pump must be secured onto the infusion stand and whenever possible run off mains electricity, ideally it should be placed below the level of the patient.

7.6.9.3 Recommended procedure for administration via a peripheral line:

7.6.9.3.1 The same procedure as outlined in 7.6.9.2 above should be followed for peripheral administration.

7.7 Cycling Parenteral Nutrition

Intermittent administration or 'cycling' of PN may reduce the risk of cholestasis (especially in long term patients), help with partial or complete weaning off PN, enable compatible medications to be delivered through a single intravenous site, and allow a stable patient to have more freedom during the day for other activities (Shaw and Lawson, 2007). Cycling of PN is not common in preterm infants.

7.7.1 Considerations when cycling PN:

7.7.1.1 Ensure that the patient is medically stable.

7.7.1.2 Introduce in a controlled, step-wise fashion by reducing the infusion time by 1-2 hours each day of both aqueous and lipid solutions as tolerated, generally down to a minimum of 12 hours infusion.

7.7.1.3 Consider maximum recommended infusion rates – 20mg/kg/min glucose and 0.13-0.17g/kg/hour lipid (Koletzko et al., 2005).

7.7.1.4 Monitor blood glucose and lipid tolerance throughout the process.

7.7.1.5 During the final hour of infusion, reduce the infusion rate to approximately half of the previous rate to prevent rebound hypoglycaemia. This applies to 2-in-1 solutions (containing AAs and carbohydrate) and 3-in-1 solutions (containing Aas, carbohydrate and lipid). Lipid infusions do not require step down infusion.

7.8 Weaning Parenteral Nutrition

Optimum provision of nutrition and normal glucose levels should be maintained when moving from parenteral to enteral or oral nutrition.

Preterm Infants

7.8.1 In preterm infants, once enteral nutrition volumes are increased beyond trophic / minimal amounts (>30ml/kg/day) and are clinically considered to be tolerated, their contribution to nutritional intake should be considered when calculating PN requirements.

7.8.1.1 As enteral nutrition volumes increase, PN should be reduced accordingly without compromising nutritional intake.

7.8.1.2 Lipid should be reduced with advancing enteral nutrition to ensure maximum lipid tolerance not exceeded (see table below for suggested weaning of lipid in preterm infants).

7.8.1.3 Lipid infusion and aqueous PN solutions should be continued until the infant tolerates at least 100-120ml/kg/day enteral nutrition.

7.8.1.4 The total fluid volume provided may be increased above 150ml/kg/day if required once there are no contraindications.

Total Volume of Enteral Nutrition Tolerated	Parenteral Lipid Provision
≤ 60ml/kg/day	3g/kg/day
Greater than 60ml/kg/day	2g/kg/day

Suggested Weaning of Parenteral Lipid in Preterm Infants

Older Children

7.8.2 Practical considerations when weaning PN in older children include the following:

7.8.2.1 There should be a gradual transition from parenteral nutrition once a clinical decision has been made to commence feeding (enteral nutrition or oral diet).

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

7.8.2.3 When reducing PN, ensure that aqueous and lipid solutions are reduced in correct proportion to each other.

7.8.2.3.1 PN composition will vary depending on the individual order, and in most cases the nutritional content of PN will not be equivalent to the same volume of enteral nutrition, i.e. 1ml of PN is not the same as 1ml of enteral nutrition.

7.9 Monitoring of Parenteral Nutrition

7.9.1 Monitoring is essential to assess tolerance of PN as well as nutritional adequacy to support growth. Infants and children receiving PN must be monitored closely, especially when the PN is being increased or adjusted or if the patient is clinically unstable.

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

7.9.2.1 Weight should be monitored as clinically indicated

7.9.2.2 Length and head circumference should be measured regularly, ideally every week

7.9.2.3 Measurements should be plotted on the appropriate growth charts for each patient

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

7.9.4 The recommended biochemical monitoring is detailed in Appendix 2. Guidance on the management of biochemical complications is detailed in Section 7.10.

7.10 Complications of Parenteral Nutrition

7.10.1 Infectious Complications

7.10.1.1 Infection is one of the most common and potentially fatal complications of CVADs (Koletzko *et al.*, 2005).

7.10.1.2 Infection rates in paediatric patients vary depending on the underlying condition, with the highest rates being reported in children receiving PN for gastrointestinal dysfunction (Dudeck *et al.*, 2013).

7.10.1.3 **Prevention of catheter-related infection:**

7.10.1.3.1 Infection prevention and control considerations are essential, including:

- National care bundles for CVAD insertion and maintenance and peripheral venous access (available at www.hpsc.ie)
- Monitoring of CVAD infection as part of overall surveillance programme

7.10.1.3.2 PN should be prepared in a suitable aseptic environment.

7.10.1.3.3 Amino acid/glucose infusion sets can be left in situ for up to 48 hours, but lipid sets should be changed every 24 hours (Koletzko *et al.*, 2005).

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

7.10.1.3.5 CVADs must be dressed using a transparent dressing to cover insertion site.

7.10.1.3.6 The dressing must be changed when visibly soiled, damp or loose.

7.10.1.3.7 Infusions sets must be primed using an aseptic non-touch technique, protecting key parts.

7.10.1.3.8 An aseptic non-touch technique must also be used to access the catheter and the hub cleaned with alcohol-containing chlorhexidine wipes to reduce contamination.

7.10.1.3.9 If the PN solution is disconnected from CVAD it must be discarded, PN should not be reconnected to same or other sites.

7.10.1.4 Management of suspected catheter-related infection:

7.10.1.4.1 Infection should be suspected in any patient with a CVAD that develops fever (temperature >38°C), metabolic acidosis, thrombocytopenia or glucose instability (Koletzko *et al*., 2005).

7.10.1.4.1.1 In preterm infants with temperature instability (hypothermia/pyrexia) infection should be suspected.

7.10.1.4.2 PN should be stopped and central blood cultures obtained, ideally a peripheral blood culture should be obtained at the same time.

7.10.1.4.3 Broad spectrum antibiotics should be commenced promptly.

7.10.1.4.3.1 The choice of antibiotics should be based on local antimicrobial guidelines.

7.10.1.4.4 Antibiotics should be changed to narrow spectrum once the infective organism has been identified (Koletzko *et al*.,, 2005).

7.10.1.4.4.1 The duration of antibiotics is guided by the identified organism.

7.10.1.4.5 Removal of CVAD is indicated in all patients with positive fungal cultures, multi-resistant bacteria, patients with signs of septic shock such as hypotension, or patients not responding to appropriate antibiotic use after 48-72 hours (Chesshyre et al., 2015)

7.10.1.4.6 CVAD infection should be managed in conjunction with local infection specialists and national best practice guidelines.

7.10.2 Catheter-related Complications

7.10.2.1 In children, CVADs are the most frequent cause of venous thromboembolism, and are responsible for over 80% of venous thromboembolism in newborns and 40% in other children (Koletzko *et al*., 2005).

7.10.2.2 In the event of clinical suspicion of a thrombotic event and/or a thrombus is identified on a Doppler ultrasound, Haematology input should be sought as early as possible.

- The decision to commence low molecular weight heparin must only be made in conjunction with a Haematology specialist taking into consideration the clinical status of the patient.

7.10.3 Biochemical Imbalances

Amino Acids

7.10.3.1 Insufficient provision of amino acids in PN can inhibit protein synthesis and limit growth (Shaw and Lawson, 2007).

- Low plasma urea levels, especially in preterm infants, may indicate inadequate amino acid provision.

7.10.3.2 A rising blood urea nitrogen level or rising serum ammonia level may indicate excess provision or poor tolerance of protein / amino acids.

7.10.3.3 Steroids cause a reduction in growth by increasing protein breakdown and can contribute to a rise in blood urea nitrogen levels.

- Amino acid tolerance should be monitored in neonates receiving steroids, and amino acid load reduced according to tolerance.

Glucose

7.10.3.4 Glucose intolerance is uncommon in children and infants without risk factors, e.g. critically unwell, steroid administration, therefore unexplained glucose instability should be regarded as an early sign of sepsis.

7.10.3.5 Glucose tolerance should be monitored more closely when starting, cycling or weaning PN.

7.10.3.6 Hyperglycaemia:

- Glucose intake beyond individual tolerance may be responsible for hyperglycaemia.
- If blood sugar level above 12mmol/L (10mmol/L in preterm infants) and/or marked glycosuria consider decreasing glucose infusion rate by 1-2mg/kg/min (1.5-3g/kg/day) to a minimum of 4mg/kg/min (5.8g/kg/day). All cases should be considered individually.
- Insulin infusion may be used in very preterm infants with hyperglycaemia while on PN, but the safety and effects on clinical outcome requires further evaluation.
- The use of insulin should be restricted to conditions where reasonable adaptation of glucose infusion rate does not control marked hyperglycaemia.

7.10.3.7 Hypoglycaemia:

- Blood sugar levels of <2.5mmol/L should be avoided
- Can be precipitated by significant reduction or discontinuation of glucose infusions
- Urinalysis for ketones is indicated to exclude other metabolic causes for hypoglycaemia
- Ensure PN has been delivered appropriately, e.g. adequate rates, functioning catheter
- Treat hypoglycaemia according to local policy

Lipid

7.10.3.8 Refer to Appendix 2 for lipid monitoring guidance and management of abnormal values.

Sodium

7.10.3.9 The sodium intake needs of individual patients may deviate significantly from the ranges of intakes recommended in this document, depending on clinical circumstances such as fluid restriction, dehydration or excessive water losses.

7.10.3.10 Large variation in serum sodium concentration in the very preterm neonate is an independent risk factor for poor neuromotor outcome at two years (Baraton *et al*., 2009).

7.10.3.11 Hyponatraemia:

- Hyponatraemia is defined as a serum sodium level usually less than 135mmol/L. Symptoms are likely with serum sodium levels <125mmol/L or with rapid fall in levels.

- Routine studies in evaluation of hyponatraemia include serum sodium, potassium, chloride, glucose, serum osmolality, urea and creatinine levels, urine sodium and osmolality.
- Identify and correct the cause(s) for hyponatraemia.
- Rapid correction of hyponatraemia, especially in patients with chronic hyponatraemia can lead to osmotic demyelination syndrome.
- The maximum recommended rate of sodium correction is 8mmol/L per day.

7.10.3.12 Hypernatraemia:

- Hypernatremia is defined as serum levels >146mmol/L.
- Mild hypernatremia (Na 146-149mmol/L) is relatively common and not generally associated with problems, however risk increases with increase in serum sodium levels.
- Severe symptoms occur at sodium levels > 160mmol/L.
- Assess for causes of hypernatremia, including dehydration, sodium intake in PN, enteral nutrition, medications and other infusions.
- If mild hypernatremia is due to sodium intake, decrease content of sodium in PN.
- Identify and correct causes of hypernatremia.

Potassium

7.10.3.13 Hypokalaemia:

- Hypokalaemia is generally defined as a serum potassium level of less than 3.5mmol/L.
- Hypokalaemia is rarely a cause for concern until the serum potassium level is less than 3.0mmol/L.
- Hypokalaemia can result from chronic diuretic use and unreplaced electrolyte loss from nasogastric drainage.
- Electrocardiographic manifestations of hypokalaemia include a flattened T wave, prolongation of the QT interval, or the appearance of U waves.
- Correct hypokalaemia slowly by increasing content in PN or adding enteral supplements if tolerated. If supplementing intravenously, this should be in accordance with *Irish Medication Safety Network Best Practice Guidelines for the Safe Use of Intravenous Potassium in Irish Hospitals* (2013).
- If severe hypokalaemia an IV correction with Potassium Chloride (KCl) might be needed. Outside of the intensive care units, the risks and benefits of such an infusion need to be assessed by the treating consultant.

7.10.3.14 Hyperkalaemia:

- Hyperkalaemia is defined as a serum potassium level of generally greater than 5.5mmol/L measured in a non-haemolysed specimen.
- Hyperkalaemia is of far more concern than hypokalaemia, especially when serum potassium levels exceed 6.5mmol/L or if electrocardiographic changes have developed (peaked T wave, wide QRS, bradycardia/tachycardia/ ventricular arrhythmias).
- Severe acidosis and decreased urinary potassium excretion contribute to elevations in serum potassium.
- If non-haemolysed potassium level >5.5mmol/L all potassium supplementation should be stopped and the patient should be place on cardiac monitoring.

- If asymptomatic and with normal ECG and serum potassium <6mmol/L consider if treatment necessary; salbutamol can be used.
- If potassium levels >6mmol/L, in an asymptomatic child with normal EEG – consider salbutamol, insulin/glucose IV, correct metabolic acidosis if present.
- If potassium level >7.0mmol/L or changes in ECG present or patient clinically unstable contact tertiary unit and consider transfer; dialysis might be indicated. Calcium gluconate IV and sodium bicarbonate are indicated in this case.

Calcium

7.10.3.15 Ionised calcium values, rather than total values, correlate better with calcium functions such as cardiac contractility in preterm infants. Corrected calcium is a good indicator of serum calcium in term neonates, older children and adults.

7.10.3.16 Hypercalcaemia:

- Defined as a total serum calcium concentration of higher than 2.75mmol/L or an ionised calcium concentration of higher than 1.25mmol/L (Rodd et al., 1999) or higher than 1.45mmol/L in preterm infants (Hsu and Levine, 2004).

7.10.3.17 Hypocalcaemia:

- More common, defined as a total serum calcium concentration of less than 1.75mmol/L or an ionised calcium concentration of less than 1mmol/L or 0.9mmol/L in preterm infants (Hsu and Levine, 2004).
- Early onset hypocalcaemia may occur within the first 3 days of life in preterm infants born to mothers with poorly controlled diabetes or in infants who experienced perinatal asphyxia.
- Additional calcium should be provided if the total serum calcium level is less than 1.62mmol/L or if the ionised level is less than 0.8-0.9mmol/L.
- Late-onset hypocalcaemia can develop after the first week of life and is usually associated with conditions with high serum phosphate levels, including hypoparathyroidism, maternal anticonvulsant use, and vitamin D deficiency.

Magnesium

7.10.3.18 Magnesium plays an important role in skeletal development and in the maintenance of electrical potential in nerves and muscles membranes.

7.10.3.19 Calcium homeostasis is controlled in part by magnesium mechanism which releases parathyroid hormone.

7.10.3.20 Inadequate intake of calcium, phosphate, magnesium and vitamin D may induce rickets, fractures, impaired bone mineralisation and reduced linear growth.

7.10.3.21 Hypermagnesaemia occurs when serum concentration is greater than 1.25mmol/L. Most cases occur in severe renal failure where magnesium intake has been excessive.

- Reduce magnesium intake, e.g. reduce / stop magnesium containing infusions or supplements, and commence cardiac monitoring (P-R interval prolongation, intraventicular conduction delay).
- If the patient is symptomatic (evidence of arrhythmias, wide QRS complex, systemic hypotension, loss of deep tendon reflexes) seek immediate input from Neonatal or Paediatric Intensive Care Unit.

7.10.3.22 Hypomagnesaemia can lead to neuromuscular manifestations, electrocardiographic abnormalities or arrhythmias, and/or metabolic manifestations including hypokalaemia and hypocalcaemia.

7.10.3.23 Serum magnesium levels should be monitored and intake adjusted accordingly.

7.10.3.24 Serum magnesium levels in preterm infants born at <32 weeks gestation may be high in the first few days of life if the mother received magnesium sulphate antenatally, and magnesium provision in PN may need to be delayed or reduced (Sherwin et al., 2014).

Phosphate

7.10.3.25 Hypo- and Hyperphosphataemia:

- In the presence of a low phosphate intake the kidney retains phosphate and it disappears from the urine.
- Hypercalcaemia and hypercalciuria may result from phosphate deficiency.
- Deficiency of phosphate results in bone demineralisation and rickets.
- Extreme hypophosphataemia can be precipitated by nutritional restitution (*refeeding syndrome*) and can result in muscle paralysis, cardiac dysfunction and respiratory failure.
- Excess phosphate intake may lead to hyperphosphataemia, hypocalcaemia and secondary hyperparathyroidism.

Refeeding Syndrome

7.10.3.26 Refeeding syndrome is a potentially fatal complication observed in severely malnourished children, or preterm infants with severe intrauterine growth retardation commencing PN after birth. Appropriate and early identification will help to prevent refeeding syndrome when commencing nutrition support.

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

7.10.3.28 It may result in red cell dysfunction, rhabdomyolosis, respiratory failure and sudden death.

7.10.3.29 To reduce risks of refeeding syndrome:

- Reduce water and sodium intake depending on hydration state
- Monitor weight, serum and urinary electrolytes at least once daily in the early phase of refeeding
- Maintain blood glucose homeostasis
- Correct potassium deficit slowly with monitoring of renal and cardiac function
- Correct phosphate depletion with monitoring of neurological status and renal function
- In children and adolescents, reduce energy initially to approximately 20kcals/kg/day, with gradual increase in provision over the first week of refeeding until the patient is metabolically stable (INDI, 2015)
- Patients may be at risk of thiamine deficiency, therefore supplementation with thiamine and a multivitamin is essential (Mehanna, 2009)

7.10.4 Complications in Long-term Parenteral Nutrition

Metabolic Bone Disease

7.10.4.1 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.

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

7.10.4.3 Regular assessment of bone mineralisation should be undertaken in children on home PN.

Hepatobiliary Complications

7.10.4.4 Although the pathogenesis of PN-associated liver disease is unknown, hepatobiliary complications of PN are in most cases moderate and reversible.

7.10.4.5 Patients requiring long-term PN are at high risk of developing PN-related liver disease.

7.10.4.6 Risk factors include:

- Absence of oral feeding increases risk of biliary sludge formation.
- Short bowel syndrome may be associated with disruption of bile acid enterohepatic circulation, and bacterial overgrowth is known to contribute to PN-related cholestasis.
- Recurrent septic episodes, either catheter-related or gastrointestinal tract-related may cause liver injury.
- Prematurity is a known risk factor especially when necrotising enterocolitis or sepsis occurs.
- Excessive or inadequate amino acid supply.
- Excessive glucose intake and/or continuous PN infusion lead to hyperinsulinism and subsequently to steatosis.

7.10.4.7 <u>Prevention and treatment of cholestasis:</u>

- Reduce risk factors where possible (i.e. prevention).
- Introduce enteral nutrition as soon as possible, even if only minimal amount.
- Try to cycle PN as soon as clinically possible (see Section 7.7).
- Consider possible intestinal bacterial overgrowth.
- Consider decreasing/stopping lipid infusions if unexplained and sustained rise of conjugated bilirubin occurs.
- Ursodeoxycholic acid might be indicated in patients with continuous rise of transaminases, conjugated bilirubin and alkaline phosphatase. Seek input from Gastroenterology team.
- Refer early to the Gastroenterology team if signs of impairment of liver synthetic function (platelets <100, high prothrombin time, low albumin) or signs of hepatic fibrosis.

8.0 Implementation, Revision and Audit

- Distribution of guideline to all members of the Faculty of Paediatrics, Royal College of Physicians of Ireland.
- Distribution to the Acute Hospitals Division of the HSE for dissemination through hospital groups and line management in all acute hospitals.
- Distribution to other interested parties and professional bodies.
- The guideline development group has agreed that this guideline will be reviewed on a 2-yearly basis.

8.1 Education and Training

All healthcare professionals should have education on parenteral nutrition relevant to their setting prior to undertaking practice in this area. An eLearning programme to support this guideline is available on www.hseland.ie

8.2 Audit

Regular audit of implementation and impact of this guideline through outcome and process measures is recommended to support continuous quality improvement. The audit process should be coordinated in each neonatal or paediatric unit under the local neonatal/paediatric governance committee and should be taken from a multidisciplinary perspective where appropriate.

8.2.1 Each unit should audit their use of PN annually based on a sample of the previous month's activity and a review of ten patients for appropriateness.
8.2.1.1 See Appendix 3 for national audit template.

8.2.2 The National Clinical Programme for Paediatrics and Neonatology PN Expert Group will collate this information on an annual basis in order to monitor and report on national trends and key issues.

8.2.3 The incidence of CVAD infection should be monitored as part of an overall surveillance programme.

9.0 References

Aly H., Herson V., Duncan A.,Herr J., Bender J., Patel K., & El-Mohandes A.A. (2005) *Is blood stream infection preventable among premature infants? A tale of two cities.* Pediatrics 115(6), 1513-1518.

American Society for Parenteral Nutrition Board of Directors and Standards Committee (2005) *Definition of Terms, Style, and Conventions Used in A.S.P.E.N. Guidelines and Standards* Nutr Clin Pract April 2005 vol. 20(2):281-285

Attard M.I. Patel N., Simpson J. (2012) *Change from intralipid to SMOF lipid is associated with improved liver function in infants with PN associated liver disease* Arch Dis Child 2012;97:A54-A55

Baraton, L., Ancel P.Y., Flamant C., Orsonneau J.L., Darmaun D., Roze J.C. (2009). *Impact of changes in serum sodium levels on 2-year neurologic outcomes for very preterm neonates* Pediatrics 124(4): e655-661.

Balegar V.K., Azeem M.I., Spence K., Badawi N. (2013) *Extending total parenteral nutrition hang time in the neonatal intensive care unit: is it safe and cost effective?* J Paediatr Child Health 2013;49:E57–E61.

British Association of Perinatal Medicine (2016) *The Provision of Parenteral Nutrition within Neonatal Services – A Framework for Practice*

Cairns P., Stalker D.J. (2009) *Carnitine supplementation of parenterally fed neonates* Available at: https://www.nichd.nih.gov/cochrane_data/cairnsp_01/cairnsp_01.html

Chen C.Y. Tsao P.N., Chen H.L., Chou H.C., Hsieh W.S., Chang M.H. (2004) *Ursodeoxycholic acid (UDCA) therapy in very-low-birth-weight infants with parenteral nutrition-associated cholestasis* J Pediatr. Sep;145(3):317-21.

Chessex P., Laborie S., Nasef N., Masse B., Lavoie J.C. (2015) *Shielding Parenteral Nutrition From Light Improves Survival Rate in Premature Infants: A Meta-Analysis*. JPEN J Parenter Enteral Nutr 2015 Sep (epub ahead of print)

Chesshyre E., Goff Z., Bowen A. and Carapetis J. (2015) *The prevention, diagnosis and management of central venous line infections in children* J Infect. 2015 Jun;71 Suppl 1:S59-75

Dudeck M.A., Weiner L.M., Allen-Bridson K., Malpiedi P.J., Peterson K.D., Pollock D.A., Sievert D.M., Edwards J.R. (2013) *National Healthcare Safety Network (NHSN) report, data summary for 2012. Device-associated module* Am J Infect Control 2013 Dec; 41(2): 1148-66

Ehrenkranz R.A. (2007) *Early, aggressive nutritional management for very low birth weight infants: what is the evidence?* Semin Perinatol 31: 48–55

Fox M., Molesky M., Van Aerde J.E., Muttitt S. (1999) *Changing parenteral nutrition administration sets every 24 h versus every 48 h in newborn infants* Cana J Gastroenterol 1999;13:147–151.

Fuchs C. and Jocham F. (2005) *Water, sodium, potassium and chloride* in *Nutrition of the Preterm Infant: Scientific Basis and Practical Guidelines*. Tsang R.C., Uauy R., Koletzo B. and Zlotkin S.H. Cincinnati, Digital Educational Publishing Inc. 2nd Revised edition.

Health Services Exceutive (2014*) Prevention of Intravascular Catheter-Related Infection in Ireland: Update of 2009 National Guideline*. Available at http://www.hse.ie/guidelines

Hsu S.C. and Levine M.A. (2004) *Perinatal calcium metabolism: physiology and pathophysiology* Semin Neonatol 2004;9:23–36

Ibrahim H.M., Majied A., Jeroudi M.D., Baier R.J. (2004) *Aggressive early total parenteral nutrition in low birth weight infants* J Perinatology 2004(24): 482-86

Irish Medication Safety Network (2013) *Best Practice Guidelines for the Safe Use of Intravenous Potassium in Irish Hospitals* Available at: http://www.imsn.ie/all-news/23-guidelines/57-potassiumg201307

Irish Nutrition and Dietetic Institute (2015) *Nutrition Support Reference Guide*

Josephson A., Gombert M.E., Sierra M.F., Karanfil L.V., Tansino G.F. (1985) *The relationship between intravenous fluid contamination and the frequency of tubing replacement.* Infect Control 1985; 6:367–70.

Kanarek, K. S., Santeiro, M.L. et al. (1991) *Continuous infusion of insulin in hyperglycemic low-birth weight infants receiving parenteral nutrition with and without lipid emulsion* JPEN J Parenter Enteral Nutr 15(4): 417-420.

Koletzko B., Goulet O., Hunt J., Krohn K., Shamir R.; Parenteral Nutrition Guidelines Working Group; European Society for Clinical Nutrition and Metabolism; European Society of Paediatric Gastroenterology, Hepatology and Nutrition; European Society of Paediatric Research (2005) *Guidelines on Paediatric Parenteral Nutrition of the European Society of Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) and the European Society for Clinical Nutrition and Metabolism (ESPEN), Supported by the European Society of Paediatric Research (ESPR)* J Pediatr Gastroenterol Nutr 41 Suppl 2: S1-87

Koletzko B., Poindexter B., Uauy R. (2014) *Nutritional Care of Preterm Infants: Scientific Basis and Practical Guidelines* Basel: Karger AG

Lockman, L.L., Heitmiller E.S., Ascenzi, J.A., Berkowitz I. (2011) *Scrub the Hub! Catheter Needleless Port Decontamination.* Anesthesiology, 114 (4) 958 Downloaded From: http://anesthesiology.pubs.asahq.org/ on 23.02.16

Maki D.G., Botticelli J.T., LeRoy M.L., Thielke T.S. (1987) *Prospective study of replacing administration sets for intravenous therapy at 48-vs 72hour intervals. 72 hours is safe and cost-effective.* JAMA 1987; 258:1777–81.

Matlow A.G., Kitai I., Kirpalani H., Chapman N.H., Corey M., Perlman M. (1999) *A randomized trial of 72- versus 24-hour intravenous IV tubing set changes in newborns receiving IV lipid therapy.* Inf Control Hosp Epidem 1999;20:487-493.

Mehanna H., Nankivell P.C., Moledina J., Travis J. (2009) *Refeeding syndrome – awareness, prevention and management* Head Neck Oncol 2009;1:4

Miller M., Vaidya R., Rastogi D., Bhutada A., Rastogi S. (2014) *From parenteral to enteral nutrition: a nutrition-based approach for evaluating postnatal growth failure in preterm infants.* J Parenter Enteral Nutr 2014;38:489-97

Mirtallo J., Canada T., Johnson D., Kumpf V., Peterson C., Sacks G., Seres D., Guenter P. (2004) *Safe Practices for Parenteral Nutrition* Task Force for the Revision of Safe Practices for Parenteral Nutrition JPEN J Parenteral Enteral Nutrition 2004 28(6): S39-70

Munoz-Price L. S., Dezfulian C., Wyckoff M., Lenchus J.D. , Rosalsky, M., Birnbach D. J., Arheart K. L. (2012) *Effectiveness of stepwise interventions targeted to decrease central catheter-associated bloodstream infections.* Critical Care Medicine 40 (5): 1464-1469

O'Grady N.P., Alexander M., Burns L.A., Patchen Dellinger E., Garland J.,Heard S.O., Lipsett P.A., Masur H., Mermel L.A., Pearson M.L., Raad I.I., Randolph A., Rupp M.E., Saint S., and the Healthcare Infection Control Practices Advisory Committee (HICPAC) (2011) *Guidelines for the Prevention of Intravascular Catheter-Related Infections.* Available from: http://www.cdc.org/guidelines

Peters O., Ryan S., Matthew L., Cheng K., Lunn J. (1997) *Randomised controlled trial of acetate in preterm neonates receiving parenteral nutrition* Arch Dis Child Fetal Neonatal Ed 1997;77:F12-F15

Report of the Paediatric Chief Pharmacists Group (November 2011) *Improving practice and reducing risk in the provision of parenteral nutrition for neonates and children*
Available at: http://www.rpharms.com/support-pdfs/minimising-risk-pn-children-(6).pdf

Rodd C. and Goodyer P. *Hypercalcemia of the newborn: etiology, evaluation, and management Pediatr Nephrol* 1999 Aug 13(6):542-7

Scientific Advisory Committee on Nutrition (SACN) (2011) *Dietary Reference Values for Energy* London: SACN

Shaw V. and Lawson M. (Editors) (2007) *Clinical Paediatric Dietetics Third Edition* Oxford: Blackwell Publishing

Sherwin, C. M.T., Balch, A., Campbell, S. C., Fredrickson, J., Clark, E. A.S., Varner, M., Stockmann, C., Korgenski, E. K., Bonkowsky, J. L. and Spigarelli, M. G. (2014) *Maternal Magnesium Sulphate Exposure Predicts Neonatal Magnesium Blood Concentrations* Basic & Clinical Pharmacology & Toxicology 114:318–322

Simmons, S., Bryson, C. and Porter, S. (2011) *Scrub the Hub: Cleaning Duration and Reduction in Bacterial Load on Central Venous Catheters.* Critical Care Nursing Quarterly, 34(1), 31-35

Snydman D.R., Donnelly-Reidy M., Perry L.K., Martin W.J. (1987) *Intravenous tubing containing burettes can be safely changed at 72 hour intervals.* Infect Control 1987; 8:113–6.

Stewart D.A.G., Mason D.G., Smith N., Protopapa K., Mason M. (2010) *A Mixed Bag: An enquiry into the care of hospital patients receiving parenteral nutrition A report by the National Confidential Enquiry into Patient Outcome and Death*
Accessed at: http://www.ncepod.org.uk/2010report1/downloads/PN_report.pdf

Nutrition Team, Toronto Sick Kids (2007) *Guidelines for the Administration of Enteral and Parenteral Nutrition in Paediatrics (3rd Edition)* Available at: https://www.sickkids.org/pdfs/Clinical-Dietitians/19499-Enteral_Parenteral_Nutrition.pdf

Tsang R.C., Uauy R., Koletzko B., Zlotkin S.H. (2005) *Nutrition of the Preterm Infant: Scientific Basis and Practical Guidelines, 2nd Edition* Cincinatti: Digital Education Publishing

Van den Akker C., Vlaardingerbroek H., van Goudoever J.B. (2010) *Nutritional support for extremely low-birth weight infants: Abandoning catabolism in the neonatal intensive care unit* Curr Opin Clin Nutr Metab Care 13:327–335

World Health Organisation (2015) *Preterm birth, Fact sheet N°363*
Available at: http://www.who.int/mediacentre/factsheets/fs363/en/

10.0 Qualifying Statement

These guidelines have been prepared to promote and facilitate standardisation and consistency of practice, using a multidisciplinary approach. Clinical material offered in this guideline does not replace or remove clinical judgement or the professional care and duty necessary for each child. Clinical care carried out in accordance with this guideline should be provided within the context of locally available resources and expertise.

These guidelines do not address all elements of standard practice and assumes that individual clinicians are responsible for:

- Discussing care with the child, parents/guardians and in an environment that is appropriate and which enables respectful confidential discussion.
- Advising children, parents/guardians of their choices and ensure informed consent is obtained.
- Meeting all legislative requirements and maintaining standards of professional conduct.
- Applying standard precautions and additional precautions, as necessary, when delivering care.
- Documenting all care in accordance with local and mandatory requirements.

11.0 Appendices

Appendix 1 Recommended Parenteral Nutrition Intakes and Requirements for Preterm Infants, Term Infants and Children

Estimated Fluid Requirements

When calculating fluid requirements, consider weight, urine output and overall fluid balance, as well as clinical condition. Fluid requirements may be reduced in critically ill patients.

Recommended fluid intake (ml/kg body weight/day) during the first postnatal week (Koletzko, 2005):

	Days following birth					
	1st day	2nd day	3rd day	4th day	5th day	6th day
Preterm neonate <1500g	80-90	100-110	120-130	130-150	140-160	160-180
Preterm neonate >1500g	60-80	80-100	100-120	120-150	140-160	140-160
Term neonate	60-120	80-120	100-130	120-150	140-160	140-180

In older children, consider other fluids provided such as enteral nutrition, oral intake or medications:

Patient weight 10-20kg	1000ml + 50ml for each kg above 10kg up to a maximum of 2500ml per day
Patient weight >20kg	1500ml + 20ml for each kg above 20kg up to a maximum of 2500ml per day

Estimated Parenteral Nutritional Requirements for Preterm Infants <2.5kg (2500g)

TABLE 1: PRETERM INFANTS <2.5kg	Day 1 of LIFE	Day 1 of PN (if > 1 day old)	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Total Energy (kcals/kg/day) **Non-protein Energy (kcals/kg/day)** A preterm infant receiving PN requires less kcals than an infant receiving enteral nutrition, as there is no energy lost in the stools and there is less thermogenesis.	60-80 40-60	60-80 40-60	80-100 60-80	100-120 85-100	100-120 85-100	Minimum 30-40 non-protein kcals/kg/day required to reduce protein catabolism by 80% (BAPM, 2016). 50 non-protein kcals/kg/day required to prevent weight loss. Tsang (2005) also advises 75-85kcals/kg/day during transition phase day 2-7 of life and 90-115kcals/kg/day in maintenance PN.
Amino acids (g/kg/day) 1g amino acids (Vaminolact®) = 3.7kcals Convert to Nitrogen equivalent by dividing amino acid (g) by 7.02	≥2 (Koletzko, 2014)	≥2 (Koletzko, 2014)	≥3.5 (Koletzko, 2014)	3.5-4 (Koletzko, 2014)	3.5-4 (Koletzko, 2014)	Minimum 1.5g/kg/day needed to achieve nitrogen balance Maximum 4g/kg/day Amino acid tolerance reduced if on steroids
Carbohydrate (g/kg/day) 1g glucose(dextrose) = 3.4kcals **Glucose infusion rate (mg/kg/min)**	6-8 4.2-5.6	6-8 4.2-5.6	8-10 Increase by 1.5-3g/kg/day (1-2mg/kg/min) 5.6-7	10-12 Increase by 1.5-3g/kg/day (1-2mg/kg/min) 7-8.3	12-15 Increase by 1.5-3g/kg/day up to 15g/kg/day 8.3-10.4	Minimum 6g/kg/day (4.2mg/kg/min). Maximum 18g/kg/day (12.5mg/kg/min). In hyperglycaemia, reduce carbohydrate infusion by 2mg/kg/min to a minimum of 4mg/kg/min.
Lipid (g/kg/day) 1g lipid = 10kcals Maximum infusion rate 0.13-0.17g/kg/hour	1-2	1-2	2-3	3	3-4	To prevent essential fatty acid deficiency a minimum linoleic acid intake of 0.25g/kg/day is required (1.35g SMOFlipid/kg/day or 0.5g Intralipid/kg/day) (Koletzko et al., 2005). Lipid can be increased slowly as tolerated by 1g/kg/day provided triglyceride levels available. Koletzko (2014) advises ≥2g/kg/day safe from day 1 of life. Maximum recommended lipid intake 3-4g/kg/day, however in practice up to 3.5g/kg/day used.
Sodium (Na) (mmol/kg/day) Note: Take account of additional Na if on IV fluids, check biochemistry and adjust PN sodium dose accordingly.	0-1 Prior to diuresis	2-5 From onset of diuresis	2-5 From onset of diuresis	2-5 (7)	3-5 (7)	**Transition phase:** **Can be up to day 7 of life** **2-5mmol/kg/day** Up to 7mmol/kg/day may be required for late hyponatraemia (Tsang, 2005). In practice, requirements may be higher, ensure close monitoring.
Potassium (K) (mmol/kg/day)	0-2 Prior to	1-3 From onset of	2-3 From onset of	2-3	2-3	**Transition phase:** **Can be up to day 7 of life**

TABLE 1: PRETERM INFANTS <2.5kg	Day 1 of LIFE	Day 1 of PN (if > 1 day old)	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
	diuresis	diuresis	diuresis			**0-2mmol/kg/day** K^+ supplementation should only commence after onset of diuresis
Calcium (Ca^{2+}) (mmol/kg/day) **NB:** Calcium used in PN must be calcium gluconate	0.6-1	1	1.3-1.5	1.3-1.5	1.6-2.5 (Koletzko, 2014)	Maintenance 1.6-2.5mmol/kg. Achieving 2.5mmol/kg may be restricted by stability of PN solution. Ca^{2+} requirement varies depending on growth rate of baby. Requirement = 2mmol Ca/10g newly grown body weight. This may be difficult to apply in practice.
Phosphate (PO_4) (mmol/kg/day) **NB:** Phosphate source used in PN must be sodium glycerophosphate	0.6-1.0	1.0	1.3-1.5	1.3-1.5	1.6-2.5 (Koletzko, 2014)	Maintenance 1.6-2.5mmol/kg/day. Achieving 2.5mmol/kg/day may be restricted by stability of PN. PO_4 requirement varies depending on growth rate of baby. Requirement = 1.52mmol PO_4/10g newly grown body weight. This may be difficult to apply in practice, and also not possible to meet high requirements.
Magnesium (Mg) (mmol/kg/day)	0-0.12	0-0.12	0.1-0.2	0.2-0.3	0.3-0.4 In practice 0.2-0.3 is often used as maintenance dose	Maximum 0.3-0.4mmol/kg/day with normal renal function. Maternal receipt of $MgSO_4$ prior to delivery may reduce infants' magnesium requirements in first few days of life. (Koletzko, 2014)
Trace Elements - Peditrace® (ml/kg) Contraindicated in patients with renal insufficiency (urine output <1ml/kg/hour) and/or hepatic dysfunction.	0 (withheld on day one of life)	0-1 provided there is adequate urinary output	0-1 provided there is adequate urinary output	1	1	Dose 1ml/kg/day Up to maximum 15ml/day total dose. In long term PN (>3weeks) iron supplementation may need to be considered unless repeated blood transfusions have been given or oral iron commenced.
Water Soluble Vitamins - Solivito N® (ml/kg)	1	1	1	1	1	Dose 1ml/kg/day Up to maximum 10ml/day total dose.
Water Soluble Vitamins - VitlipidN® (Infant) (ml/kg)	4	4	4	4	4	Dose 4ml/kg/day. Up to maximum 10ml/day total total dose. Consider reducing dose to 2ml/kg/day if infant very fluid restricted and additional volume required to meet minimum amino acid and carbohydrate requirements.

Estimated Parenteral Nutritional Requirements for Term Infants 0-1 years

TABLE 2: TERM INFANTS 0-1 YEAR	Day 1 of LIFE	Day 1 of PN (if > 1 day old)	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Energy (kcals/kg/day)		Energy requirements are approximately as follows: • 50 non-protein kcals/kg/day required to prevent weight loss • 30 non-protein kcals/kg/day required to reduce protein catabolism by 80% Requirements (SACN, 2011) 0-6months 96-120kcals/kg/day 7-12months 72kcals/kg/day The recommendations above are for guidance only. Assessment of requirements based on clinical condition and regular weight monitoring is essential when prescribing PN.				Maximum calorie density for peripheral line = 0.7-0.8kcals per ml
Amino Acids (g/kg/day) 1g amino acids (Vaminolact®) = 3.7kcals Convert to Nitrogen equivalent by dividing amino acid (g) by 7.02	2	1.5-2	2.2-2.5	2.5-3	2.5-3 3g/kg for first month of life 21-35 non-protein kcals required per g amino acids	1.5g/kg/day minimum required intake PN + enteral nutrition combined should not provide >4.5g amino acids/kg/day If urea ≥20mmol/L restrict to 1.8g amino acids/kg/day Amino acid tolerance reduced if on steroids.
Carbohydrate (g/kg/day) 1g carbohydrate = 3.4kcals **Glucose infusion rate (mg/kg/min)**	7 4.8	8 5.5	12 8.3	14 9.7	16-18 11.1-12.5	If hyperglycaemia, reduce glucose infusion by 2mg/kg/min to a minimum of 4mg/kg/min Maximum carbohydrate / dextrose concentrations: Peripheral access <12.5% CVAD up to 25%
Lipid (g/kg/day) 1g lipid = 10kcals Maximum infusion rate 0.13-0.17g/kg/hr	1	1	2	3	3	If lipid intake 3g/kg/day for one week and weight gain poor, lipid intake can be increased to a maximum of 3.5-4.0g/kg/day. Monitor triglyceride levels closely. To prevent essential fatty acid deficiency a minimum linoleic acid intake of 0.25g/kg/day is required (1.35g SMOFlipid/kg/day or 0.5g Intralipid/kg/day)
Sodium (Na) (mmol/kg/day)	0-1	2-3	2-3	2-3	2-3	**Transition phase:** **Can be up to day 14 of life** **2-5 mmol/kg/day** Infants usually started on 3mmol/kg if serum Na levels are within normal range and postnatal diuresis. In practice requirements may be higher, ensure close monitoring. Calculate Na+ if on IV fluids, check biochemistry and adjust PN accordingly.
Potassium (K) (mmol/kg/day)	0-2	1-3	1-3	1-3	1-3	**Transition phase:** **Can be up to day 14 of life** **1-3mmol/kg/day** Note: K^+ supplementation should only commence after onset of diuresis. Minimum K^+ requirement during 1st month of life 1.5mmol/kg/day. Infants usually started on 2.5mmol/kg/day if serum K levels

TABLE 2: TERM INFANTS 0-1 YEAR	Day 1 of LIFE	Day 1 of PN (if > 1 day old)	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
						are within normal range and postnatal diuresis.
Calcium (Ca) (mmol/kg/day) **NB:** Calcium used in PN must be calcium gluconate	0.6	1.3 during first month of life 0.8 1-6 months 0.5 7-12 months	1.3 during first month of life 0.8 1-6 months 0.5 7-12 months	1.3 during first month of life 0.8 1-6 months 0.5 7-12 months	1.3 during first month of life 0.8 1-6 months 0.5 7-12 months	**Transition phase:** **Can be up to day 14 of life** **0.6-1mmol/kg/day** Ca^{2+} requirement varies depending on growth rate of baby.
Phosphate (mmol/kg/day) **NB:** Phosphate source used in PN must be sodium glycerophosphate	0.6	1 during first month of life 0.5	1 during first month of life 0.5	1 during first month of life 0.5	1 during first month of life 0.5	**Transition phase:** **Can be up to day 14 of life** **0.6-1.0mmol/kg/day** PO_4 requirement varies depending on growth rate of baby.
Magnesium (mmol/kg/day)	0-0.1	0.2	0.2	0.2	0.2	
Peditrace® (ml/kg) Contraindicated in patients with renal insufficiency (urine output <1ml/kg/hr) and/or hepatic dysfunction. Withheld on day one of life	0	1 provided there is adequate urinary output	1	1	1	**Maximum dose 15ml/day.** Note the current dose of 1ml/kg/day Peditrace does not meet requirement for Zn^{2+}, for additional Zn - supplement with zinc sulphate, please refer to ESPGHAN guidelines and PN provider on how to prescribe same. Contact tertiary unit for further advice. In long term PN (>3-5weeks) iron supplementation may need to be considered unless repeated blood transfusions have been given or oral iron commenced.
Solivito N® (ml/kg)	1ml/kg/day	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	Maximum 10ml/day
VitlipidN® (Infant) (ml/kg)	2-4	4	4	4	4	Maximum 10ml/day Consider reducing dose to 2ml/kg/day if infant very fluid restricted and additional volume required to meet minimum amino acid and carbohydrate requirements.

Estimated Parenteral Nutritional Requirements for Children 1-12 years

TABLE 3: CHILDREN 1-12 YEARS	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Energy (kcals/kg/day)	Energy requirements are approximately as follows: • 50 non-protein kcals/kg/day required to prevent weight loss • 30 non-protein kcals/kg/day required to reduce protein catabolism by 80% EAR for 1-7 years = 67-80kcals/kg/day EAR for 8-12 years = 53-67kcals/kg/day (SACN, 2011) However, EAR will often overestimate requirements in children receiving PN as physical activity levels often reduced and there is no energy lost in the stools or in thermogenesis.. It is recommended that BMR is calculated initially and an appropriate activity or stress factor determined if appropriate.				Caution – may exceed EAR if using full carbohydrate and lipid recommendations below.
Amino Acids (g/kg/day) 1g amino acids (Vaminolact®) = 3.7kcals 1g amino acids (Aminoven®) = 3.7kcals Convert to Nitrogen equivalent by dividing amino acid (g) by 7.02 for Vaminolact® in <10kg patient or by 5.88 for Aminioven® in >10kg patient	1.5-2 depending on clinical condition and requirements	1.5-2	1.5-2	1.5-2 21-35 non-protein kcals required per gram of amino acids	For children <3 years give 2-3g/kg/day Critically ill patients may require up to 3.0g/kg/day
Carbohydrate (g/kg/day) 1g carbohydrate = 3.4kcals Minimum infusion 4-6mg/kg/min Aim to provide 60-75% non-protein kcals as carbohydrate.	10-15kg: 6 15-20kg: 4 20-30kg: 4 >30kg: 3	10-15kg: 8 15-20kg: 6 20-30kg: 6 >30kg: 5	10-15kg: 10 15-20kg: 8 20-30kg: 8 >30kg: 8	10-15kg: 12-14 15-20kg: 10-12 20-30kg: <12 >30kg: <10	Recommendations need to be adapted to the clinical situation, e.g. refeeding syndrome in severe malnutrition, to oral/enteral intake and to required weight gain. It is best to be prudent with carbohydrate in critically ill children, limit glucose intake to 5mg/kg/min unless blood glucose levels are stable (Koletzko, 2005). Maximum carbohydrate / dextrose concentrations: Peripheral access <12.5% CVAD up to 25%
Lipid (g/kg/day) 1g lipid = 10kcals Infusion rate 0.08-0.13g/kg/hr	1	2	2-3	2-3	To prevent essential fatty acid deficiency a minimum linoleic acid intake of 0.25g/kg/day is required (1.35g SMOFlipid/kg/day or 0.5g Intralipid/kg/day) 3.0g/kg rarely required, this depends on clinical condition and energy requirements.
Sodium (Na) (mmol/kg/day)	1-3	1-3	1-3	1-3	Children usually started on 3mmol/kg if serum Na levels are within normal range
Potassium (K) (mmol/kg/day)	1-3	1-3	1-3	1-3	K+ to be added provided that there is adequate diuresis. Children usually started on 2.0mmol/kg/day if serum K levels are within normal range, if weight between 10-15kg start on 2.5mmol/kg/day.
Calcium (Ca) (mmol/kg/day) **NB:** Calcium used in PN must be calcium gluconate	0.2	0.2	0.2	0.2	If serum calcium levels low, Ca content of PN may need to be increased. Refer to BNF for Children.
Phosphate (mmol/kg/day) **NB:** Phosphate source used in PN must be sodium glycerophosphate	0.2	0.2	0.2	0.2	If serum phosphate levels low, PO_4 content of PN may need to be increased. Refer to BNF for Children.
Magnesium (mmol/kg/day)	0.1	0.1	0.1	0.1	
Trace Elements: Peditrace® (ml/kg)	1ml/kg, up to maximum of 15ml total dose	1ml/kg, up to maximum of 15ml total dose	1ml/kg, up to maximum of 15ml total dose	1ml/kg, up to maximum of 15ml total dose	Maximum 15ml/day in >15kg and <40kg. If >40kg may need to consider Additrace®.

TABLE 3: CHILDREN 1-12 YEARS	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Contraindicated in patients with renal insufficiency (urine output <1ml/kg/hr) and/or hepatic dysfunction.	per day, and provided there is adequate urinary output	per day.	per day.	per day.	Consider commencing iron if patient receiving PN >3 weeks. Additional Zn and Se can be added to PN if Peditrace held or reduced on ongoing basis.
Water Soluble Vitamins: Solivito N® (ml/kg)	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	1ml/kg/day up to a maximum 10ml total dose per day	If <10kg give 1ml/kg/day
Fat Soluble Vitamins: VitlipidN® (Infant) (ml)	10ml total dose per day	10ml total dose per day	10ml total dose per day	10ml total dose per day	
VitlipidN® (Adult) if >11 years (ml)	10ml total dose per day	10ml total dose per day	10ml total dose per day	10ml total dose per day	

Estimated Parenteral Nutritional Requirements for Adolescents 13-18 years

TABLE 4: ADOLESCENTS 13-18 YEARS	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Energy (kcals/kg/day)	Energy requirements are approximately as follows: • 50 non-protein kcals/kg/day required to prevent weight loss • 30 non-protein kcals/kg/day required to reduce protein catabolism by 80% EAR = 43-56kcals/kg/day (SACN, 2011) However, EAR will often overestimate requirements in children receiving PN as physical activity levels often reduced and there is no energy lost in the stools or in thermogenesis.. It is recommended that BMR is calculated initially and an appropriate activity or stress factor determined if appropriate.				Caution – may exceed EAR if using full carbohydrate and lipid recommendations below.
Amino Acids (g/kg/day) 1g amino acids (Aminioven®) = 3.6kcals Convert to Nitrogen equivalent by dividing amino acid (g) by 5.88 for Aminoven®	1.5 depending on clinical condition and requirements	1.5-2 depending on requirements	1.5-2	1.5-2 21-35 non-protein kcals required per gram of amino acids	Critically ill patients may require higher protein intakes e.g. 2.5g/kg
Carbohydrate (g/kg/day) 1g carbohydrate = 3.4kcals Minimum infusion 4-6mg/kg/min CHO should provide 60-75% of non-protein kcals	>30kg: 3	>30kg: 5	>30kg: 8	>30kg: <10	Recommendations need to be adapted to the clinical situation, e.g. refeeding syndrome in severe malnutrition, to oral/enteral intake and to required weight gain. It is best to be prudent with carbohydrate in critically ill children, limit glucose intake to 5mg/kg/min unless blood glucose levels are stable (Koletzko et al., 2005). Maximum carbohydrate / dextrose concentrations: Peripheral line <12.5% With a CVAD up to a maximum of 25% may be necessary in fluid restricted patients.
Lipid (g/kg/day) 1g lipid = 10kcals Infusion rate 0.08-0.13g/kg/hr	1	2	2-3	2-3	To prevent essential fatty acid deficiency a minimum linoleic acid intake of 0.25g/kg/day is required (1.35g SMOFlipid/kg/day or 0.5g Intralipid/kg/day) 3.0g/kg rarely required, this depends on clinical condition and energy requirements.
Sodium (Na) (mmol/kg/day)	1 -3	1-3	1-3	1-3	In practice, commence on 3.0mmol/kg/day if serum Na levels within normal range
Potassium (K) (mmol/kg/day)	1-3	1-3	1-3	1-3	K+ to be added provided that there is adequate diuresis. In practice, commence on 2.0mmol/kg/day if serum K levels within normal range
Calcium (Ca) (mmol/kg/day) **NB:** Calcium used in PN must be calcium gluconate	0.2	0.2	0.2	0.2	If serum calcium levels low, Ca content of PN may need to be increased. Refer to BNF for Children.
Phosphate (mmol/kg/day) **NB:** Phosphate source used in PN must be sodium glycerophosphate	0.2	0.2	0.2	0.2	If serum phosphate levels low, PO_4 content of PN may need to be increased. Refer to BNF for Children.
Magnesium (mmol/kg/day)	0.1	0.1	0.1	0.1	
Trace Elements: Peditrace® if >15kg and <40kg (mls) or Additrace ® if >40kg (ml/kg)	Peditrace: 15mls total dose per day. Additrace: 0.2ml/kg up to	Peditrace: 15mls total dose per day. Additrace: 0.2ml/kg up to	Peditrace: 15mls total dose per day. Additrace: 0.2ml/kg up to	Peditrace: 15mls total dose per day. Additrace: 0.2ml/kg up to	For patients on Peditrace only, consider commencing iron if patient receiving PN >3 weeks.

TABLE 4: ADOLESCENTS 13-18 YEARS	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Contraindicated in patients with renal insufficiency (urine output <1ml/kg/hr) and/or hepatic dysfunction.	maximum 10ml total per day provided there is adequate urinary output	maximum 10ml total per day provided there is adequate urinary output	maximum 10ml total per day provided there is adequate urinary output	maximum 10ml total per day provided there is adequate urinary output	
Water Soluble Vitamins: Solivito N® (ml/day)	10ml per day total dose	10ml per day total dose	10ml per day total dose	10ml per day total dose	
Fat Soluble Vitamins: VitlipidN® (Adult) (ml/day)	10ml per day total dose	10ml per day total dose	10ml per day total dose	10ml per day total dose	

Volume of Individual PN Solution Constituents

Constituent	Volume	Quantity of Nutrient Provided
Vaminolact®	15.3ml	1g amino acids
Aminoven® 25	6.7ml	1g amino acids
50% glucose/dextrose	2ml	1g carbohydrate
SMOF Lipid 20%	5ml	1g lipid
30% NaCl	1ml	5mmol sodium
15% KCl	1ml	2mmol potassium
10% calcium gluconate	1ml	0.226mmol calcium
21.6% sodium glycerophosphate	1ml	1mmol phosphate + 2mmol sodium
10% magnesium sulphate	1ml	0.4mmol magnesium
30% sodium acetate	2.27ml	4.99mmol acetate + 4.99mmol sodium (1ml = 2.2mmol acetate + 2.2mmol sodium)
Zinc sulphate	1ml	50µmol zinc
Sodium selenite	1ml	200nmol selenium

Appendix 2 Recommended Monitoring in Parenteral Nutrition

Note:

- This is a guideline only, monitoring requirements may differ depending on the infant/child and the clinical situation.
- Monitoring may be required more frequently if clinically indicated and/or if PN regimen changes.
- More stable infants may require less frequent monitoring during the first week.
- Blood gas samples may be acceptable for monitoring electrolytes to minimise blood sampling, but should not replace serum monitoring until infant is stable on PN.
- Low serum albumin levels does not tend to correlate with nutritional status.
- Each unit should identify the individual(s) responsible for reviewing biochemistry results and taking appropriate action when results are abnormal.
- Urinary electrolytes may be monitored in certain circumstances.
- In long term PN (>3-5weeks) iron supplementation may need to be considered unless repeated blood transfusions have been given or oral iron commenced. Check serum ferritin weekly and restart iron once ferritin in normal range (Koletzko, 2014).
  If infant commences parenteral iron, monitor iron status closely. Ferritin levels should be checked weekly.
  NB: Monitor patient closely for any signs of adverse reaction when supplementing iron.

	First Week					***When Stable***			
	Every Day	**Day 1**	**Day 2**	**Day 3-4**	**Day 5-7**	**Every Day**	**Once Weekly**	**Fort-nightly**	**Monthly *Long-term PN***
Infusion site – assess hourly	✓					✓			
Fluid balance	✓					✓			
Weight	✓						✓		
Urinary glucose	✓ 6hrly								
Blood Glucose	✓ 6-8hrly					✓			
Electrolytes (Na, K, Cl)		✓	✓	✓	✓		✓		
Urea, Creatinine			✓		✓		✓		
Calcium			✓	✓	✓		✓		
Phosphate, Magnesium			✓		✓		✓		
Triglyceride – see below				✓	✓		✓		
LFTs, Alk Phos, Protein, Albumin					✓			✓	
Bilirubin				✓				✓	
Full Blood Count								✓	
Ferritin – if receiving IV Fe							✓		
Trace Elements: Zn, Cu, Mn, Se									✓
Vitamins A, D, E									✓
Growth (weight, OFC, length)		✓					✓		

Recommended Lipid / Triglyceride Monitoring Guideline

- While there is limited evidence to guide action based on triglyceride levels, the following guidelines may be used in practice.
- Triglyceride levels may need to be monitored more frequently if receiving high lipid doses, in sepsis / catabolism / critically ill, extremely low birth weight or severe unexplained thrombocytopenia, and dose adjusted as necessary.
- Triglyceride and bilirubin levels should be monitored in infants at risk of hyperbilirubinaemia, and lipid dose adjusted as necessary.
- If marked progressive cholestasis associated with PN, unrelated to acute infection – potential causes should be explored and a decrease or temporary interruption in IV lipid considered.
- Where available, lipaemic index may be monitored in line with local policy.

IV Lipid Infusion Based on Triglyceride Level	
TG Level	**Lipid Intake Prescribed (for infusion):**
<2.8mmol/L (<250mg/dL)	- Advance lipid intake as normal [a] - Assess TG 24-48hr after each increase of 1g/kg/day until optimal lipid intake tolerated [b] - When satisfactory lipid intake tolerated, assess TG once weekly
≥2.8-4.5mmol/L (>250mg/dL)	- Reduce lipid infusion to previously tolerated level - Recheck TG after 24hrs
>4.5mmol/L (>400mg/dL)	- Stop lipid infusion for 24hrs - Recheck TG and restart at previously tolerated level[c] - Repeat TG after 24hrs
Notes: [a] Normal rate of lipid advancement: start at 1g/kg/d (day 1 of life); advance by 0.5-1.0g/kg/d q24hr; [b] In preterms, aim for lipid intake 3g/kg/d (maintenance); maximum 3.5-4g/kg/d[1] - if increased lipid required [c] To prevent essential fatty acid deficiency in pre-term infants aim to provide minimum lipid intake of 0.25g linoleic acid (1.35g/kg/day SMOFlipid® or 0.5g/kg/day Intralipid®). In term infants aim to provide 0.1g linoleic acid (0.5g/kg/day SMOFlipid® or 0.2g/kg/day Intralipid®).	

Suggested Triglyceride Monitoring Guideline

Appendix 3 Audit Template

Please complete the following based on the previous month's activity:

How many patients received standard concentration PN?	Less than 5	5-10	11-20	21-30	>30
How many patients received patient-specific PN?	Less than 5	5-10	11-20	21-30	>30

How many patients received PN for each of the following:	Less than 48 hours	3-7 days	8-10 days	11-21 days	>21 days

Please indicate how many of each of the following types of PN were used over the last month:

Patient-specific		**Starter (EF)**	
Preterm		**Term**	
Babiven Concentrate		**Babiven Maintenance**	
SMOF Vits 100ml bag		**SMOF Lipid 100ml bottle**	
25ml lipid syringe with vitamins		**40ml lipid syringe with vitamins**	

Please indicate how many of each of the following types of PN were wasted over the last month, i.e. ordered but not used before expiry or no longer suitable for patient:

Patient-specific		**Starter (standard)**	
Preterm (standard)		**Term (standard)**	
Babiven Concentrate (standard)		**Babiven Maintenance (standard)**	
SMOF Vits 100ml bag		**SMOF Lipid 100ml bottle**	
25ml lipid syringe		**40ml lipid syringe**	

Please complete the following based on the previous month's activity:

How many incidences of catheter-related sepsis occured in patients receiving PN	0	1-3	4-6	7-9	10+
How many incidences of PN-related cholestasis occured in patients receiving PN	0	1-3	4-6	7-9	10+

Please indicate the proportion of staff who have received education in relation to PN provision over the last 12 months:

	Current Complement (Headcount)	Number Trained
Consultant		
Registrar		
Senior House Officer		
Intern		
CNM3		
CNM2		
CNM1		
ANP		
CNS		
Staff Nurse		
Dietitian		
Pharmacist		
Other (if appropriate)		

For a sample of ten patients who have received PN within the last month (or all patients if <10 patients in total), please review if PN was used for appropriate indication. In neonates, please also record the time between birth and PN commencement:

Patient	Indication for PN	Appropriate (Y/N)	Time commenced post-birth in neonates (age in hours)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Appendix 4 Acknowledgements

This guideline has been developed by the National Clinical Programme for Paediatrics and Neonatology Parenteral Nutrition Expert Group. The purpose of this group is to provide clinical expertise and determine standards for the use of parenteral nutrition (PN) in neonatal and paediatric units nationally.

The members of this group include medical, nursing, dietetic and pharmacy representatives from both neonatal and paediatric units:

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Appendix 5 Approval

Sign off by Parenteral Nutrition Expert Group	August 2016
Sign off by Neonatal Clinical Advisory Group	September 2016
Sign off by HSE CSPD Senior Management Team	January 2017