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PAEDIATRICS

ROYAL COLLEGE OF PHYSICIANS OF IRELAND

NATIONAL CLINICAL PRACTICE GUIDELINE

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

Endorsed by the Irish Society for Clinical Nutrition & Metabolism

irspen Irish Society for Clinical Nutrition & Metabolism

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1.0 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 and neonatology in recent 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).

A multidisciplinary nutrition support team has an important role in promoting and coordinating optimum nutritional care, educating staff, developing guidelines, promoting research and reducing inappropriate use of PN. A team approach to the use of PN improves nutritional monitoring, assessment of requirements and reduces sepsis (Puntis *et al*, 2018). This guideline incorporates the most recent ESPGHAN 2018 recommendations and has been developed for use in Ireland by multidisciplinary teams to support safe practices in the ordering, prescribing and administration of PN for neonatal and paediatric patients.

1.1 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.

1.2 Purpose and Scope

The purpose of this guideline is to improve the management of neonatal and paediatric patients requiring PN support in hospital. This guideline is 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 infant. This guideline is also intended to provide essential information to units that use PN less frequently and provide a pathway for support should it be required.

2.0 Glossary of Terms, Abbreviations and Definitions

AA	**Amino Acid**
ALP	Alkaline Phosphatase
ANTT®	Aseptic Non Touch Technique
ASAP	Association for Safe Aseptic Practice
ASPEN	American Society for Parenteral and Enteral Nutrition
BAPM	British Association of Perinatal Medicine
BUN	Blood Urea Nitrogen
CHO	Carbohydrate
CRBSI	Catheter Related Blood Stream Infection
CSPN	Chinese Society of Parenteral and Enteral Nutrition
CVAD	Central Venous Access Device
EFAD	Essential Fatty Acid Deficiency
ELBW	Extreme Low Birth Weight
ESPGHAN	European Society for Paediatric Gastroenterology, Hepatology and Nutrition
ESPEN	European Society for Clinical Nutrition and Metabolism
ESPR	European Society for Paediatric Research
GI	Gastro-Intestinal
GIR	Glucose Infusion Rate
GIT	Gastro-Intestinal Tract
HSE	Health Service Executive
HPSC	Health Protection Surveillance Centre
ILE	Intravenous Lipid Emulsion
INDI	Irish Nutrition and Dietetic Institute
IPN	Individualised Parenteral Nutrition
IU	International Units
IUGR	Intra-Uterine Growth Restriction
IV	Intravenous
Kcals	Kilocalories / Calories
N2	Nitrogen
NCHD	Non-Consultant Hospital Doctor
NEC	Necrotising Enterocolitis
NICU	Neonatal Intensive Care Unit
NPE	Non Protein Energy (also referred to as Non Protein Calories (NPC) or Non Nitrogen Energy (NNE))
OFC	Occipital Frontal Circumference (head circumference)
PICU	Paediatric Intensive Care Unit
PN	Parenteral Nutrition
PNALD	PN Associated Liver Disease
RANP	Registered Advanced Nurse Practitioner
RD	Registered Dietitian
RCPI	Royal College of Physicians of Ireland
REE	Resting Energy Expenditure
SBS	Short Bowel Syndrome
SPN	Standardised Parenteral Nutrition
TPN	Total Parenteral Nutrition
TG	Triglycerides
VLBW	Very Low Birth Weight

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 enteral nutrition. 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 PN, however 'PN' is the preferred term as enteral nutrition should be provided where possible in addition (provided the gastrointestinal tract (GIT) is accessible / functioning). PN usually comprises of both aqueous and lipid solutions.
Enteral Nutrition	For the purpose of this guideline, the term 'enteral' refers to nutrition that is provided directly to the gastro-intestinal tract, both oral and via tube.
Individualised PN (IPN)	PN that is compounded based on a patient's individual nutritional requirements. IPN was formerly referred to as 'patient-specific PN'.
Standardised PN (SPN)	PN that contains fixed amounts of nutrients. SPN was formerly referred to as 'stock PN' or 'standard concentration PN'.
Working Weight / Dosing Weight	The weight used to determine nutrient doses. Dependent on institutional / local practice, the dosing weight may be the actual, ideal, or adjusted body weight of the individual patient.
Extremely low birth weight (ELBW)	Birth weight <1000 g
Very low birth weight (VLBW)	Birth weight <1500 g
Preterm	Infants born alive before 37 weeks of pregnancy are completed. There are sub-categories of preterm birth, based on gestational age: - extreme preterm (<28 weeks gestation) - very preterm (28 to <32 weeks gestation) - moderate to late preterm (32 to <37 weeks gestation)
Acute Phase of Critical Illness (Resuscitative Phase)	First hours to days when a patient is unstable and needs vital organ support e.g. sedation, mechanical ventilation, vasopressors, fluid restriction) (Mesotten *et al*, 2018)
Stable Phase of Critical Illness	Phase when a patient can be weaned from vital support (Mesotten *et al*, 2018)
Recovery Phase of Critical Illness	In children, phase when the patient is mobilizing (Mesotten et al, 2018).
Transition Phase	Phase when enteral nutrition is increasing and replacing PN.

3.0 Roles and Responsibilities

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

4.0 Clinical Guideline

4.1 Indications for Parenteral Nutrition

PN is used where it is not possible to meet nutritional requirements via the 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. Infants and children differ from adults in that their nutritional intake must be sufficient not only for the maintenance of body tissues but also for growth (Puntis et al., 2018). This is particularly true in infancy and during adolescence when children grow rapidly (Puntis et al., 2018). Older children and adolescents, however, can tolerate longer periods of inadequate nutrition than preterm infants where starvation for even a day can be detrimental (Puntis et al., 2018).

Very preterm infants are initially dependent on receiving nutrients parenterally because of the immaturity of their gastrointestinal tract (GIT) They are also born with low nutritional reserves, eg. a 1 kg infant may become deficient in essential fatty acids (EFAs) within two days of birth and survive for only four days if not provided with appropriate nutrition (Van den Akker et al., 2010; Puntis et al., 2018). The majority of preterm infants less than 32 weeks gestation will require PN for a period, with duration determined by gestation, birth weight and other concurrent morbidities (Ehrenkranz, 2007; Puntis et al., 2018). In preterm infants, once indicated, PN should be commenced as soon as possible following confirmation of line placement.

PN should be continued until adequate nutritional intake from enteral nutrition is tolerated, i.e. generally until 75% of nutritional requirement (120 ml/kg/day enteral feeds in preterm infants) is tolerated enterally (Brennan et al., 2018).

SPN solutions should generally be used over IPN solutions in the majority of paediatric and neonatal patients, including VLBW preterm infants. IPN should generally be used when the nutritional requirements cannot be met by the available range of SPN solutions, e.g., in very sick and metabolically unstable patients such as those with abnormal fluid and electrolyte losses; and in infants and children requiring PN for prolonged periods of time such as those with short bowel syndrome. (Riskin et al., 2018). At present in Ireland IPN is given to children over 10kg in the absence of appropriate SPN solutions.

Examples of Indications for Parenteral Nutrition

Absolute Indications	▪ Functional immaturity, e.g. preterm infants <32 weeks gestation or <1.5 kg, to supplement advancing enteral nutrition ▪ 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 ≥1.5 kg 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 restriction (IUGR) with associated absent or reduced end diastolic flow. ▪ Intractable diarrhoea or vomiting ▪ Chemotherapy-induced gastrointestinal failure ▪ Inflammatory bowel disease ▪ Malabsorption syndromes ▪ Acute pancreatitis

4.2 Phases of illness

The **acute phase** of critical illness (first hours to days) only covers the resuscitation phase when the unstable patient requires vital organ support (sedation, mechanical ventilation, vasopressors, fluid resuscitation). When a patient has been stabilised on, or can be weaned from, this vital support, he/she is in the **stable phase**. In children, when the child is mobilising, it is called the **recovery phase** (Mesotten *et al.*, 2018).

In the **stable phase** of critical illness, energy requirements can be increased by 1-3 times REE to enable growth and catch-up growth and is further increased in the recovery phase (Joosten et al., 2018).

In critically ill children, withholding PN for 1 week while giving micronutrients can be considered (Joosten et al., 2018 and van Goudoever et al., 2018).

4.3 Constituents of Parenteral Nutrition

PN solutions are available in several forms:

- Aqueous or '2-in-1' solutions, which contain amino acids (AAs), carbohydrate (CHO) electrolytes ± water soluble vitamins ± trace elements.
- Lipid solutions, which contain lipid ± fat soluble vitamins ± water soluble vitamins.
- 'All-in-one' or '3-in-1' solutions which combine both the Aqueous and Lipid solutions in a single solution, and contain AAs, CHO, lipid ± electrolytes ± vitamins ± trace elements.

PN solutions contain some or all of the following constituents:

4.3.1 Fluid (Water)

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

4.3.1.2 Total fluid requirements include maintenance requirements and requirements for growth.

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

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

4.3.1.4 See Appendix 1 for further information on fluid requirements.

4.3.2 Energy

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

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

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

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

4.3.2.1.4 The terms 'non-protein energy (NPE)' expressed as kilocalories (kcals) or 'non-protein calories (NPC)' are used to describe energy coming from carbohydrates and lipid only. NPE/NPC excludes energy from protein.

4.3.2.2 Energy in PN solutions is provided by CHO and lipid to ensure proper utilisation of protein for tissue growth.

4.3.2.2.1 Lipid and CHO are increased in a stepwise approach, as tolerated.

4.3.2.2.2 If energy intake is insufficient, protein will be used for energy instead of tissue growth; and with excess energy intake the excess energy will be deposited as fat.

4.3.3 Amino Acids (Protein / Nitrogen)

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

4.3.3.1.1 AAs are the source of nitrogen in PN solutions.

4.3.3.1.2 The equivalent AA ≡ protein ≡ nitrogen will vary depending on the AA solution used in PN (refer to current product information).

4.3.3.2 Infants and children need AAs in their PN solution to repair tissue and to grow.

4.3.3.3 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.

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

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

4.3.3.4.2 Preterm infants require a minimum of 1.5 g AA on the first day of life, increasing to a maximum of 3.5-4.0 g/kg/day (van Goudoever *et al.*, 2018, NICE 2020)

4.3.3.4.3 Preterm infants from postnatal day 2 onwards should receive an AA intake between 2.5 - 3.5 g/kg/day and should be accompanied by NPE intakes greater than 65 kcal/kg/day (van Goudoever *et al.*, 2018).

4.3.3.4.4 In paediatric patients, 30-40 kcals NPE per gram of AA should be used (van Goudoever *et al.*, 2018).

4.3.3.4.5 The energy provided per gram of AA in PN depends on the AA solution used. In the AA solutions currently used, each gram of AA contains approximately 3.7 – 4 kcals (see product information for details on currently available PN AA solutions).

4.3.3.5 Refer to Appendix 1 for further information on AA requirements.

4.3.4 Carbohydrate

4.3.4.1 Carbohydrate (CHO) is the main source of energy in PN.

4.3.4.1.1 Glucose / anhydrous dextrose is the preferred intravenous CHO 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.

4.3.4.2 It is recommended that approximately 60 - 75% of NPE comes from CHO.

4.3.4.3 Each gram of anhydrous dextrose contains 3.4kcal/g (rounded to 4kcals in clinical practice, Mesotten et al., 2018). (see product information for details on currently available PN anhydrous dextrose solutions).

4.3.4.4 Glucose provision can be calculated as the glucose infusion rate (GIR), expressed as mg/kg/minute (mg/kg/min). Calculation of GIR is recommended when determining glucose provision for infants.

4.3.4.4.1 Recommended parenteral glucose supply in preterm infants is to start on Day 1 with 4 - 8 mg/kg/min (5.8 - 11.5 g/kg/day) as soon as possible after birth.

4.3.4.4.2 Day 2 onwards the target GIR is 8 - 10 mg/kg/min (11.5 - 14.4 g/kg/day) with a minimum of 4 mg/kg/min (5.8 g/kg/day)

4.3.4.4.3 A maximum GIR in preterm infants of 12 mg/kg/min (17.3 g/kg/day) should not be exceeded.

4.3.4.4.4 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 - 18 g/kg/day in small infants to 6 - 8 g/kg/day in older children.

4.3.4.4.5 Newborn infants less than 28 days old who have an episode of acute illness (e.g. sepsis, infection) should temporarily receive the glucose supply of day 1 (i.e. 4 - 8 mg/kg/min) guided by blood glucose levels. See table below for recommendations for infants from 28 days old and children

Table 1: Recommended glucose supply in infants and children according to body weight and phase of illness

Body Weight	Acute Phase g/kg/day (mg/kg/min)	Stable Phase g/kg/day (mg/kg/min)	Recovery Phase g/kg/day (mg/kg/min)
28 days to 10 kg	2.9 – 5.8 (2 - 4)	5.8 - 8.6 (4 – 6)	8.6 – 14.4 (6 – 10)
11 to 30 kg	2.2 – 3.6 (1.5 – 2.5)	2.8 - 5.8 (2 – 4)	4.3 - 8.6 (3 – 6)
31 to 45 kg	1.4 - 2.2 (1 – 1.5)	2.2 - 4.3 (1.5 – 3)	4.3 - 5.8 (3 – 4)
>45 kg	0.7 - 1.4 (0.5 – 1)	1.4 - 2.8 (1 – 2)	2.8 - 4.3 (2 – 3)

(Mesotten et al., 2018)

4.3.4.5 Glucose should be increased gradually as tolerated in a stepwise manner over 2 to 3 days to 8 – 10mg/kg/minute (11.5 – 14.4g/kg/day) in preterm infants and to 5 – 10mg/kg/min (7.2 – 14.4g/kg/day) in term infants with consideration of glucose provided from other sources, e.g. other infusions or medications containing glucose or affecting glucose metabolism e.g. steroids Parenteral glucose intake should not exceed 12 mg/kg/min (17.3 g/kg/day) for term and preterm infants or be lower than 4 mg/kg/min (5.8 g/kg/day) in preterm infants and 2.5 mg/kg/min (3.6 g/kg/day) in term new-borns (Mesotten *et al* 2018).

4.3.4.6 Accuracy of point of care devices to measure blood glucose is still of concern. Therefore, blood glucose measurements should preferably be performed on blood gas analysers with glucose modules (Newman *et al.,* 2002; Peet *et al.,* 2002, Mesotten *et al.,* 2018).

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

4.3.5 Lipid (Fat)

4.3.5.1 IV lipid emulsions (ILEs) should be an integral part of PN, whether PN is the sole source of nutrition or supplementary to enteral nutrition (Lapillonne *et al.,* 2018).

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

4.3.5.3 It is recommended that approximately 25 - 40% of NPE comes from lipid in patients receiving PN as a sole source of nutrition.

4.3.5.4 The ESPHGAN recommendation is for use of a composite lipid with or without fish oils (Lapillone *et al*., 2018), however benefits of fish oil have been demonstrated in the prevention of intestinal failure associated liver disease (IFALD) or parenteral nutrition associated liver disease (PNALD), retinopathy of prematurity (ROP), bronchopulmonary dysplasia (BPD) and inflammation. Lipid emulsion containing fish

oils is currently in use in Ireland and IFALD/PNALD is currently an uncommon complication. The PN Expert Group consensus is to continue to use a lipid emulsion containing fish oil.

4.3.5.5 The lipid solution currently used is SMOFlipid®. SMOFlipid® is thought to reduce the incidence of parenteral nutrition associated liver disease (PNALD) (Attard *et al,* 2012). SMOFlipid® contains fish oils (n-3 fatty acids), which may have anti-inflammatory properties (Schade *et al.*, 2008) and reduce the risk of hypertriglyceridaemia and cholestasis. The ILE Intralipid® should no longer be used routinely.

4.3.5.6 The energy provided per gram of lipid in PN depends on the lipid solution used. In SMOFlipid®each gram of fat contains approximately 10 kcals (see product information for details on currently available PN lipid solutions).

4.3.5.7 To prevent essential fatty acid deficiency (EFAD), a minimum linoleic acid intake of 0.25 g/kg/day is required for preterm infants; or 0.1 g/kg/day for term infants and older children (Lapillonne *et al.,* 2018).

4.3.5.8 Refer to Appendix 1 for further information on lipid requirements.

4.3.6 Acetate

4.3.6.1 Severe metabolic acidosis (pH <7.2 with base deficit >10 mmol/L or bicarbonate <12 mmol/L) during PN may be induced by high cumulative chloride intake (3.3 – 4.5 mmol/kg/day on average) during the first 10 days (Kermorvant-Duchemin *et al*., 2012), in particular for infants at high risk (e.g. large patent ductus arteriosis (PDA)), weight loss >15%, ELBW).

4.3.6.2 Chloride in PN (as sodium chloride or potassium chloride) can be partly replaced by acetate (as sodium acetate or potassium acetate) to reduce metabolic acidosis and/or hyperchloraemia (Peters *et al*, 1997). The use of "Chloride-free" Na and K solutions should be considered in preterm infants on PN, in order to reduce the risk of hyperchloraemia and metabolic acidosis (Jochum *et al*, 2018).

4.3.6.3 Acetate may be commenced at 1 - 2 mmol/kg/day and increased as needed to maintain acid/base balance.

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

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

4.3.6.6 Refer to Appendix 1 for further information on acetate.

4.3.7 Electrolytes

4.3.7.1 The main electrolytes included in PN are:

- Sodium (Na)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Phosphate (P)

4.3.7.2 Electrolyte balance depends on clinical circumstances such as fluid restriction, dehydration or excessive water losses as well as intake.

4.3.7.3 In ELBW and VLBW infants, Na and K may be recommended from the first day of life when giving the recommended high AA and energy supply, providing that urine output is ascertained, and considering the potential for the development of nonoliguric hyperkalaemia (Jochum *et al.*, 2018).

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

4.3.7.5 Adequate calcium, phosphate, magnesium, together with vitamin D is essential for bone mineralisation, to support linear growth and to protect against rickets fractures.

4.3.7.6 See Appendix 1 for further information on electrolyte requirements.

4.3.8 Trace Elements / Minerals and Iron

4.3.8.1 There are three preparations currently available to add trace elements to PN – Peditrace®, Additrace® and Junyelt®.

4.3.8.2 Peditrace® is available to provide trace elements for infants and children up to 40 kg and contains:

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

4.3.8.2.1 For patients up to 15 kg, Peditrace® is recommended at a daily dose of 1 ml/kg up to a maximum of 15 ml daily.

4.3.8.2.2 For patients between 15 - 40 kg, Peditrace® is recommended at a total dose of 15 ml daily.

4.3.8.2.3 Peditrace® does not contain iron; refer to Section 6.3.8.5 if iron is required.

4.3.8.3 Additrace® is currently used to provide trace elements for children over 40 kg at a dose of 10 ml daily, and contains:

Trace element	Additrace® composition per 10 ml vial
Copper	1.3 mg (20 micromol)
Manganese	0.27 mg (5 micromol)
Iodine	0.13 mg (1 micromol))
Fluoride	0.95 mg (50 micromol)
Selenium	32 microgram (0.4 micromol)
Zinc	6.5 mg (100 micromol)
Iron	1.1 mg (20 micromol)
Chromium	10 microgram (0.2 micromol)
Molybdenum	19 microgram (0.2 micromol)

4.3.8.4 Junyelt® is available to provide trace elements for infants and children at a dose of 1 ml/kg/day up to a max of 20 ml per day and contains:

Trace Element	Junyelt® composition per 1ml
Zinc	100 microgram (1.53 micromol)
Copper	20 microgram (0.315 micromol)
Manganese	0.5 microgram (0.0091 micromol)
Iodine	1 microgram (0.0079 micromol)
Selenium	2 microgram (0.0253 micromol)

4.3.8.4.1 Commercial trace element preparations may not meet recommended trace element requirements and additional intakes may be required especially when receiving long term PN with minimal enteral nutrition. Please refer to ESPGHAN guidelines (Domellöf et al., 2018) and PN Compounding Facility for information.

4.3.8.5 Iron is not added to all PN solutions or commercially available trace element preparations.

4.3.8.5.1 If iron supplementation is required, it should be given enterally rather than parenterally, if tolerated. (Domellöf *et al* 2018)

4.3.8.5.2 Iron supplementation may be considered if infants and children require PN for longer than three weeks (Domellöf *et al* 2018), unless elevated ferritin (e.g. due to multiple blood transfusions) or enteral iron commenced. Infants and children receiving PN >3 weeks, who cannot

maintain adequate iron status using enteral iron supplements, should receive parenteral iron supplementation. If given daily, and assuming no enteral iron supplementation, ESPGHAN advises parenteral iron supplementation at a dose of 200 - 250 mg/kg/day in preterm infants and 50 - 100 mg/kg/day up to a maximum dose of 5 mg/day in infants and children. See Domellöf et *et al*, 2018, for further information.

4.3.8.6 Individual trace element and iron requirements may vary based on factors such as age, weight, duration of PN and underlying diseases.

4.3.8.7 Pay particular attention when providing trace elements and iron to patients on long-term PN or if renal or liver disease or impairment, in particular if reduced bile excretion, cholestatic liver disease, high gastro-intestinal (GI) losses, markedly reduced urinary excretion, if hyperthyroidism or if altered requirements are anticipated.

4.3.8.8 For further information including precautions and special warnings for the use of trace elements/minerals in PN, refer to ESPGHAN 2018 guidelines and to the manufacturer of trace mineral/element and iron solutions and the PN Compounding Facility.

4.3.9 Vitamins

4.3.9.1 Both water-soluble and fat-soluble vitamins are added to PN.

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

4.3.9.1.2 Solivito® N is used to provide water-soluble vitamins, and is recommended at a daily dose of 1 ml/kg up to a maximum of 10 ml per day.

4.3.9.1.3 Solivito® N can be added to the aqueous or lipid solution of PN.

4.3.9.1.4 Composition of Solivito® N:

Vitamin	Solivito®N composition per 1ml
Thiamine (B_1)	0.25 mg
Riboflavin (B_2)	0.36 mg
Niacin (B_3)	4 mg
Pantothenic Acid (B_5)	1.5 mg
Pyridoxine (B_6)	0.4 mg
Biotin (B_7)	6 microgram
Folic Acid (B_9)	40 microgram
Cobalamin (B_{12})	0.5 microgram
Ascorbic Acid (C)	10 mg

4.3.9.1.5 Vitlipid® N Infant / Adult is used to provide fat-soluble vitamins.

4.3.9.1.6 For infants and children up to the age of 11 years, Vitlipid®N Infant is used at a dose of 4 ml/kg/day for infants up to 2.5 kg, and at 10 ml per day total dose above 2.5 kg.

4.3.9.1.7 Vitlipid® N Adult is used to provide fat-soluble vitamins in children over the age of 11 years at a dose of 10 ml per day.

4.3.9.1.8 Vitlipid® N Infant/Adult can only be added to the lipid solution of PN.

4.3.9.1.9 Composition of Vitlipid® N:

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

4.3.9.1.10 Commercially available products may not always meet specific vitamin requirements (Bronsky *et al.,* 2018).

4.3.9.1.11 Refer to Appendix 1 for further information.

4.3.10 Carnitine

4.3.10.1 Carnitine supplementation may be considered in paediatric patients expected to receive PN for more than 4 weeks or in preterm infants on an individual basis (Lapillonne et al., 2018). Please refer to ESPGHAN guidelines and PN Compounding Facility for information.

4.4 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, therefore recommended intakes should be achieved within days of birth. For very preterm infants, postnatal adaptations are critical in defining nutrient needs. The nutritional course of the preterm infant has been described as three discrete phases: the parenteral nutrition (PN) phase when the infant is fully dependent on PN for nutrition, the enteral nutrition (EN) phase when the infant is fully established on milk feeds and the transition (TN) phase when PN is being weaned with advancing enteral feeds

(Brennan et al, 2018). Recommended intakes for preterm infants for initial PN, 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). It is important to calculate nutritional requirements, monitor growth and biochemistry, and optimise nutrient provision within the fluid allowance on a case by case basis. A dietitian can give a more accurate assessment of energy and other nutritional needs.

4.5 Ordering and Prescribing Parenteral Nutrition

4.5.1 Electronic prescription, whether for SPN or IPN, should be used in the ordering process of PN when possible, according to local practice (Riskin *et al* 2018). If this is not available, a paper-based prescription can be used as agreed locally. Hand written prescriptions must be legible.

4.5.2 It should be determined daily if PN is required, and whether a SPN solution or an IPN solution is needed.

4.5.2.1 SPN solutions have a longer shelf life and can be kept as regular stock on wards.

4.5.2.2 SPN solutions are useful to avoid delays associated with ordering IPN.

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

4.5.2.4 SPN contains fixed amounts of electrolytes. Electrolytes can be added to IPN according to requirements. Electrolytes may also be provided by other sources e.g. additional IV solutions.

4.5.2.5 See product information for details of currently available SPN solutions.

4.5.2.6 These solutions are principally aimed at the neonatal population.

4.5.2.7 Where SPN is not suitable, IPN should be ordered.

4.5.3 In very fluid restricted patients, it may not be possible to achieve nutritional requirements and nutrient provision should be optimised within the volume available. Seek advice from appropriate multidisciplinary team members.

4.5.3.1 It is important that the appropriate volume of PN is ordered, especially in patients receiving other infusions, as this ensures best possible provision of nutrition within the available volumes

4.5.4 Prescribing IPN

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

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

4.5.4.2 PN may be ordered by a consultant, non-consultant hospital doctor (NCHD), dietitian, pharmacist or registered advanced nurse practitioner (RANP), but the prescription must be reviewed, authorised and signed (electronically or hard copy) by a doctor or a nurse prescriber (within their scope of practice) to make it a valid, legal prescription, as all intravenous (IV) products regardless of content are deemed to be medicinal products.

4.5.4.3 PN prescriptions should be double-checked by a suitable second person before transmitting to the PN Compounding Facility.

4.5.4.3.1 PN prescriptions may be validated by a pharmacist prior to transmitting to the PN Compounding Facility.

4.5.4.4 Currently, all IPN orders on weekdays should be sent to the Compounding Facility before 10am for hospitals outside Dublin, before 12pm for hospitals in Dublin, and may be required earlier on bank holidays.

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

4.5.4.5 The amount of the various constituents will change depending on the volume of PN provided, for example 90 ml/kg of a PN solution will provide more sodium than 70 ml/kg of the same solution therefore If the infusion rate is changed from that documented, the nutrients provided should be recalculated based on the new infusion rate to ensure safety.

4.6 Delivery and Storage of Parenteral Nutrition

4.6.1 IPN solutions are delivered directly by the Compounding Facility to the hospital. IPN is generally is delivered on the same day it is ordered, usually in the evening.

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

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

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

4.7 Administration of Parenteral Nutrition

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

4.7.1.1 It is recommended that CVADs are used for PN in neonates (Puntis *et al*, 2018; Ainsworth *et al,* 2007).

4.7.1.2 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

4.7.1.3 A glucose concentration greater than 12.5% should not be infused via a peripheral line (Puntis *et al*, 2018).

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

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

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

4.7.3 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; Puntis *et al*., 2018; Kolaček *et al*, 2018).

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

4.7.3.2 If co-infusion is unavoidable through the same line, medication stability and compatibility with the PN must be established and verified before administration (Mirtallo *et al*, 2004; Puntis *et al*, 2018).

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

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

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

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

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

4.7.5.1 The infusion should be inspected hourly to monitor the volume infused.
4.7.5.2 The insertion site of a peripheral cannula should be inspected hourly for signs of extravasation.
4.7.5.3 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.
4.7.5.4 Check for swelling in the limb and the area where the tip is located and not just at the insertion site.
4.7.5.5 Catheter tip position should be checked after insertion and on subsequent chest x-rays (upper limb insertion) to ensure the line has not moved and the position remains satisfactory.

4.7.6 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 (Puntis *et al.*, 2018).

4.7.6.1 The pump should have free flow prevention if inadvertently opened during use and have lockable settings (Puntis *et al.*, 2018)

4.7.7 PN solutions (**solution, syringe and lines**) should be protected from light to prevent peroxidation and degradation of light sensitive vitamins (Mirtallo *et al.*, 2004, Chessex *et al.*, 2017, Lapillonne *et al.*, 2018, Puntis *et al.*, 2018, Hartman *et al.,* 2018).

4.7.7.1 Lipid may be supplied in a bag or a syringe. When using lipid solutions provided in a bag, extra care is required to distinguish it from the aqueous solution which is also provided in a bag.

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

4.7.8.1 It is recommended that all PN solutions are administered via an infusion set containing a terminal filter (Puntis *et al.*, 2018).
4.7.8.2 A 1.2 to 1.5 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).

4.7.8.3 The lipid solution and infusion line should be changed every 24 hours, and the aqueous PN solution and the rest of the infusion set can be left in-situ for up to 48 hours with confirmed stability from the manufacturer (HSE 2014, Fox *et al.*, 1999, O'Grady *et al.*, 2011, Puntis *et al.*, 2018)

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

4.7.9 Nursing Administration of Parenteral Nutrition

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

4.7.9.1.1 Delivery sheet and solution labels.

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

- IPN: Correct patient name, date of birth and hospital number and
    - Date of infusion
- SPN: Correct solution name
- IPN and SPN:
    - Expiry date
    - Batch number
- Volume of each PN solution (i.e. the aqueous solution and the lipid solution) to be infused over 24 hours, infusion route (central/peripheral) and rate (ml/hour)
- Composition, including the 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
- Aqueous solution: This is a pale straw / yellow coloured clear solution – if the solution is cloudy or has visible crystals / particles do not use it and return it to Pharmacy
- Lipid solution: This should be uniformly opaque with no visible particles. If not, do not use and return to Pharmacy.

4.7.9.1.3 Both nurses must sign the PN prescription sheet/electronic patient record to verify the checks if correct, before commencing infusion.

4.7.9.2 Adoption of rigorous aseptic technique has been shown to markedly reduce incidence of line infections. To ensure high standards of asepsis ANTT® is recommended (THE-ASAP 2015). Two nurses are required: one will assist while the other prepares and connects the infusion. The choice of surgical or standard ANTT® is determined by the number of key parts involved. The following section describes the process for surgical ANTT®.

4.7.9.3 Recommended procedure for administration via a CVAD and peripheral lines:

4.7.9.3.1 Prepare supplies, then both nurses decontaminate their hands.

4.7.9.3.2 Clean trolley with disinfection wipes.

4.7.9.3.3 Prepare sterile field using sterile drape.

4.7.9.3.4 Decontaminate hands.

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

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

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

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

4.7.9.3.8 '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, Puntis *et al.*, 2018).

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

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

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

4.7.9.3.12 Document infusion rate and volume of each PN solution infused hourly (includes hourly volume and running total), as well and changes to the infusion rate which may occur.

4.7.9.3.13 Ensure PN infusions are light protected.

4.7.9.3.14 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.

4.8 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 routine in preterm infants receiving PN short-term but may be considered if long-term PN or if cholestasis.

4.8.1 Considerations when cycling PN:

4.8.1.1 Ensure that the patient is medically stable.

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

4.8.1.3 Consider maximum PN recommended infusion rates. (Puntis *et al.*, 2018).

4.8.1.4 Monitor blood glucose and lipid tolerance throughout the process.

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

4.9 Transitioning from Parenteral Nutrition to Enteral Nutrition

Optimum provision of nutrition and normal glucose levels should be maintained when transitioning (moving) from parenteral to enteral nutrition (oral/tube feeds/diet).

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

4.9.2 Preterm Infants

In preterm infants, once enteral nutrition volumes are increased beyond trophic / minimal amounts (>30 ml/kg/day) and are clinically considered to be tolerated, their contribution to nutritional intake should be considered when calculating PN requirements (Brennan *et al.*, 2018).

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

4.9.2.2 The lipid infusion should be reduced with advancing enteral nutrition to ensure maximum lipid tolerance is not exceeded (see table below for suggested weaning of PN during transition to enteral nutrition in preterm infants).

4.9.2.3 Both the lipid infusion and aqueous PN infusion should be continued until the infant tolerates at least 120 ml/kg/day enteral nutrition (Brennan *et al.*, 2018).

4.9.2.4 The total fluid volume provided from parenteral and enteral nutrition may be increased above 150 ml/kg/day if required to meet fluid and nutrient requirements once there are no contraindications.

Suggested Transition of Parenteral Lipid in Preterm Infants

Volume of Enteral Nutrition	Parenteral Lipid Provision
≤ 50 ml/kg/day	3 g/kg/day
≥ 60 ml/kg/day	2 g/kg/day

4.9.3 Older Children

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

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

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

4.9.3.3 When reducing PN, ensure that aqueous and lipid solutions are reduced in correct proportion to each other or as per local guidance.

4.10 Monitoring of Parenteral Nutrition

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

4.10.2 Anthropometry should be checked regularly as a measure of growth**.**

4.10.2.1 Weight should be monitored as clinically indicated. After the initial postnatal nadir of weight loss, aiming for a weight gain of 17-20 g/kg per day in VLBW infants is recommended to prevent dropping across weight centiles i.e. growth failure (Joosten et al., 2018).

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

4.10.2.3 Measurements should be plotted on the appropriate growth charts for each patient and serial trends assessed.

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

4.10.4 The recommended biochemical monitoring is detailed in Appendix 2. Guidance on the management of biochemical complications is detailed in Section 6.11.

4.11 Complications of Parenteral Nutrition

4.11.1 Infectious Complications

4.11.1.1 Infection is one of the most common and potentially fatal complications of CVADs (Puntis *et al.*, 2018).

4.11.1.2 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).

4.11.1.3 Prevention of catheter-related infection (see also 6.7.9.3):

4.11.1.3.1 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

4.11.1.3.2 PN should be prepared in a suitable aseptic environment.

4.11.1.3.3 Aqueous (AA, CHO) infusion sets can be left in situ for up to 48 hours, but lipid sets should be changed every 24 hours (Puntis *et al.*, 2018).

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

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

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

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

4.11.1.3.8 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.

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

4.11.1.4 Management of suspected catheter-related infection:

4.11.1.4.1 Infection should be suspected in any patient with a CVAD that develops fever (temperature >38°C), metabolic acidosis, thrombocytopenia or glucose instability (Puntis *et a.l*, 2018; Hartman *et al.*, 2018).
In preterm infants with temperature instability (hypothermia/pyrexia) infection should be suspected.

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

4.11.1.4.3 Empirical antibiotic therapy for catheter related blood stream infection (CRBSI) should usually include coverage for Gram-positive coagulase-negative or -positive staphylococci and Gram-negative bacilli. Broad spectrum antibiotics should be commenced promptly.

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

4.11.1.4.4 Antibiotics should be changed to narrow spectrum once the infective organism has been identified (Puntis *et al*, 2018; Hartman *et al*, 2018).

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

4.11.1.4.5 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)

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

4.11.2 Catheter-related Complications

4.11.2.1 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 (Puntis *et al.*, 2018).

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

4.11.2.2.1 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.

4.11.3 Biochemical Imbalances

Biochemical imbalances may occur when receiving PN. It is important to monitor biochemistry with appropriate frequency, (see Appendix 2 Recommended Monitoring) and to use age appropriate reference ranges. When imbalances occur, adjust intakes accordingly.

4.11.3.1 Amino Acid Imbalance

4.11.3.1.1 Insufficient provision of AAs in PN can inhibit protein synthesis and limit growth (Shaw and Lawson, 2007).

4.11.3.1.2 Low plasma urea levels, especially in preterm infants, may indicate inadequate AA provision.

4.11.3.1.3 A rising plasma urea level or rising serum ammonia level may indicate excess provision or poor tolerance of AAs.

4.11.3.1.4 Steroids cause a reduction in growth by increasing protein breakdown and can contribute to a rise in plasma urea levels.

4.11.3.1.5 AA tolerance should be monitored in neonates receiving steroids, and AA intake reduced according to tolerance.

4.11.3.2 Glucose Imbalance

4.11.3.2.1 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.

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

4.11.3.2.3 Hyperglycaemia:

- Glucose intake beyond individual tolerance may be responsible for hyperglycaemia.
- Hyperglycaemia greater than 8 mmol/L should be avoided in paediatric and neonatal ICU (NICU) patients as it is associated with increased morbidity and mortality (Mesotten *et al.*, 2018).
- Paediatric ICU (PICU) patients with repetitive blood glucose levels greater than 10 mmol/L should be treated with a continuous insulin infusion.
- If blood glucose level above 10mmol/L and/or marked glycosuria consider decreasing glucose infusion rate (GIR) by 1 - 2 mg/kg/minute (1.5 - 3 g/kg/day) to a minimum of 4 mg/kg/minute (5.8 g/kg/day). All cases should be considered individually.
- In NICU patient's insulin therapy at a low starting dose should commence when repeated blood glucose levels are greater than 10 mmol/L despite reasonable adaptation of GIR (Mesotten *et al.*, 2018). Avoid hypoglycaemia.
- The use of insulin should be restricted to conditions where reasonable adaptation of GIR does not control marked hyperglycaemia.

4.11.3.2.4 Hypoglycaemia:

- Repetitive and/or prolonged blood glucose levels of ≤2.5 mmol/L should be avoided.
- Hypoglycaemia 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.

4.11.3.3 Lipid Imbalance

4.11.3.3.1 Refer to Appendix 2 'Recommended Lipid/Triglyceride monitoring' for guidance and management of abnormal values.

4.11.3.4 Sodium Imbalance

4.11.3.4.1 Sodium balance depends on clinical circumstances such as fluid restriction, dehydration or excessive water losses as well as sodium intake.

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

4.11.3.4.3 Hyponatraemia:

- Hyponatraemia is generally defined as a serum sodium level less than 135 mmol/L. Symptoms are likely with serum sodium levels <125 mmol/L or with a rapid fall in levels.
- Routine studies in the 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) of hyponatraemia.
- Rapid correction of hyponatraemia, especially in patients with chronic hyponatraemia can lead to osmotic demyelination syndrome and should be avoided.
- The maximum recommended rate of sodium correction is 8 mmol/L per day.

4.11.3.4.4 Hypernatraemia:

- Hypernatremia is generally defined as serum sodium levels >145 mmol/L (Jochum *et al.,* 2018).
- Mild hypernatremia (Na 145 - 149 mmol/L) is relatively common and not generally associated with problems, however risk increases with an increase in serum sodium levels above this range.
- Severe symptoms may occur at sodium levels > 160 mmol/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 sodium intake.
- Identify and correct causes of hypernatremia.
- A rapid correction of hypernatraemia may induce cerebral oedema, seizures and neurological injury. A reduction rate of 10 - 15 mmol/L/24 h is recommended (Jochum *et al.*, 2018).

4.11.3.5 Potassium Imbalance

4.11.3.5.1 Hypokalaemia:

- Hypokalaemia is generally defined as a serum potassium level of less than 3.5 mmol/L. It is rarely a cause for concern until the serum potassium level is less than 3mmol/L. Hypokalaemia can result from chronic diuretic use and unreplaced electrolyte loss from nasogastric drainage or other GI losses, e.g. persistent loose stools or stoma output.
- Electrocardiographic (ECG) manifestations of hypokalaemia include a flattened T wave, prolongation of the QT interval, or the appearance of U waves.
- Correct hypokalaemia slowly by increasing potassium 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 unit, the risks and benefits of such an infusion need to be assessed by the treating consultant.

4.11.3.5.2 Hyperkalaemia:

- Hyperkalaemia is generally defined as a serum potassium level of >6 mmol/L measured in a non-haemolysed specimen (Jochum *et al*, 2018).
- Hyperkalaemia is of more concern than hypokalaemia, especially when serum potassium levels exceed 6.5mmol/L or if ECG 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 a non-haemolysed potassium level is >5.5 mmol/L, potassium supplementation should be reduced or stopped and the patient should be placed on cardiac monitoring.
- If asymptomatic and with normal electrocardiogram (ECG) and serum potassium <6 mmol/L, consider if treatment is necessary; salbutamol can be used.
- If potassium levels >6 mmol/L in an asymptomatic child with normal ECG, consider salbutamol, insulin/glucose IV and correct metabolic acidosis if present.

- If potassium level >7 mmol/L or changes in ECG are present or patient is clinically unstable, seek appropriate clinical advice; dialysis may be indicated. Calcium gluconate IV and sodium bicarbonate is indicated.

4.11.3.6 Calcium Imbalance

4.11.3.6.1 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.

4.11.3.6.2 Hypercalcaemia:

- Hypercalcaemia is generally defined as a total serum calcium concentration of higher than 2.75 mmol/L or an ionised calcium concentration of higher than 1.25 mmol/L (Rodd *et al*, 1999) or higher than 1.45 mmol/L in preterm infants (Hsu and Levine, 2004).
- Ensure optimisation of phosphate levels. Avoid decreasing calcium below recommended intake. See Appendix 1.

4.11.3.6.3 Hypocalcaemia:

- Hypocalcaemia is generally defined as a total serum calcium concentration of less than 1.75 mmol/L or an ionised calcium concentration of less than 1 mmol/L or 0.9 mmol/L in preterm infants (Hsu and Levine, 2004).
- Hypocalcaemia is more common than hypercalcaemia.
- 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 1.62 mmol/L or if the ionised level is less than 0.8 - 0.9 mmol/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. Treat according to local guidelines.

4.11.3.7 Phosphate Imbalance

4.11.3.7.1 Hypophosphataemia:

- Ensure age-appropriate reference range.
- In the presence of a low phosphate intake the kidney retains phosphate and it disappears from the urine.
- Phosphate deficiency may result in hypercalcaemia and hypercalciuria.
- Deficiency of phosphate results in bone demineralisation and rickets.
- Extreme hypophosphataemia can be precipitated by nutritional restitution (refeeding syndrome – see Section 6.11.3.9) and can result in muscle paralysis, cardiac dysfunction and respiratory failure. Ensure adequate calcium and vitamin D intake.

4.11.3.7.2 Hyperphosphataemia:

- Ensure age-appropriate reference range.
- Excess phosphate intake may lead to hyperphosphataemia, hypocalcaemia and secondary hyperparathyroidism.

4.11.3.8 Magnesium Imbalance

4.11.3.8.1 Hypermagnesaemia generally occurs when serum magnesium concentration is greater than 1.25 mmol/L. Most cases occur (other than preterm infants in the first days of life, see below) 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, intraventricular conduction delay).
- If the patient is symptomatic (evidence of arrhythmias, wide QRS complex, systemic hypotension, loss of deep tendon reflexes), seek appropriate clinical advice.

4.11.3.8.2 Serum magnesium levels in preterm infants 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).

4.11.3.8.3 Hypomagnesaemia is generally defined as a serum magnesium level ≤0.65mmol/L. Hypomagnesaemia can lead to neuromuscular manifestations, electrocardiographic abnormalities or arrhythmias, and/or metabolic manifestations including hypokalaemia and hypocalcaemia.

4.11.3.9 Refeeding Syndrome

4.11.3.9.1 Refeeding syndrome is a potentially fatal complication observed in severely malnourished children, or preterm infants with severe intrauterine growth restriction (IUGR) commencing PN after birth (Mihatsch *et al.,* 2018). Appropriate and early identification will help to prevent refeeding syndrome when commencing nutrition support.

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

4.11.3.9.3 Refeeding syndrome may result in red cell dysfunction, rhabdomyolosis, respiratory failure and sudden death.

4.11.3.9.4 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 20 kcals/kg/day, with gradual increase in provision over the first week of refeeding until the patient is metabolically stable.
- Patients may be at risk of thiamine deficiency, therefore supplementation with thiamine and a multivitamin is essential (Mehanna *et al*., 2009).

4.11.4 Complications in Long-term Parenteral Nutrition

4.11.4.1 Metabolic Bone Disease

4.11.4.1.1 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.

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

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

4.11.4.2 Hepatobiliary Complications

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

4.11.4.2.2 Patients requiring long-term PN are at high risk of developing PNALD.

4.11.4.2.3 Risk factors include:

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

4.11.4.2.4 Prevention and treatment of cholestasis:

- 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 6.8).
- 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 a continuous rise of transaminases, conjugated bilirubin and alkaline phosphatase. Seek input from Gastroenterology specialist.
- Refer early to the Gastroenterology specialist if signs of impairment of liver synthetic function (platelets <100 x 10^9/L, high prothrombin time, low albumin) or signs of hepatic fibrosis.

5.0 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.

5.1 Education and Training

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

5.2 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.

5.2.1 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. See Appendix 3 for national audit template.

5.2.2 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.

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

6.0 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.

- BRENNAN AM, FENTON S, MURPHY BP, KIELY ME. (2018) Transition Phase Nutrition Recommendations: A missing link in the nutrition management of preterm infants. J Parenter Enteral Nutr. 42(2):343-351

- BRENNAN AM, KIELY ME, FENTON S, MURPHY BP. (2018) Standardised Parenteral Nutrition for the Transition Phase in Preterm Infants: A Bag That Fits. Nutrients. 2018 Feb 2, 10(2): E170.

- BRITISH ASSOCIATION OF PERINATAL MEDICINE (2016) The Provision of Parenteral Nutrition within Neonatal Services – A Framework for Practice.

- CAIRNS P., STALKER D.J. Carnitine supplementation of parenterally fed neonates. Cochrane Database Syst Rev. 2000 ;(4):CD000950

- 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. J Parenter Enteral Nutr 2017; 41:378-383).

- 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.

- DOMELLÖF M, SZITANYI P, SIMCHOWITZ V, FRANZ A, MIMOUNI F, THE ESPGHAN/ ESPEN/ ESPR/ CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Iron and trace minerals, Clinical Nutrition 2018: 37, 2354-2359.

- 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.

- FOSTER J.P., RICHARDS R., SHOWELL M.G., JONES I.J. (2015) Intravenous in-line filters for preventing morbidity and mortality in neonates. Cochrane Database of Systematic Reviews, 2015:8:CD005248A.

- 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.

- HARTMAN C., SHAMIR R., SIMCHOWITZ V., LOHNER S., CAI W., DECSI T., THE ESPGHAN/ ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018). ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Complications. Clinical Nutrition 37, 2418 - 2429

- 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.

- JOCHUM F., MOLTU S.J., SENTERRE T., NOMAYO A., GOULET O., IACOBELLI S., THE ESPGHAN/ ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018). ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Fluid and Electrolytes. Clinical Nutrition 37, 2344-2353.

- JOOSTEN K., EMBLETON N., YAN W., SENTERRE T., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION(2018) ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Energy. Clinical Nutrition 37, 2309-2314.

- 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.

- KERMORVANT-DUCHEMIN E, LACTOBELLI S, ELENI-DIT-TROLLI S, BONSANTE F, KERMORVANT C, SARFATI G, GOUYON J-B, LAPILLONE A. Early Chloride intake does not parallel that of sodium in extremely-low-birth-weight infants and may impair neonatal outcomes. J Ped Gastro and Nutr 2012 54(5):613-619

- KOLAČEK S., PUNTIS J.W.L., HOSJSAK I., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION. ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition; Venous access. Clinical Nutrition 37:2379-2391.

- 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.

- LAPILLONE A., FIDLER MIS N., GOULET O., VAN DEN AKKER C.H.P., WU J., KOLETZKO B., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018). ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Lipids Clinical Nutrition 37, 2324-2336.

- LOCKMAN, L.L., HEITMILLER E.S., ASCENZI, J.A., BERKOWITZ I. (2011) Scrub the Hub! Catheter Needleless Port Decontamination. Anesthesiology, 114(4) 958

- 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.

- MESOTTEN D., JOOSTEN K., VAN KEMPEN A., VERBRUGGEN S., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018) ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Carbohydrates. Clinical Nutrition 38:1-7.

- MIHATCH W., FEWTRELL M., GOULET O., MOLGAARD C., PICAUD J.C., SENTERRE T., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018) ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition:Calcium, phosphorus and magnesium. Clinical Nutrition 37, 2360-2365.

- 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.

- 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.

- PUNTIS J.W.L., HOJSAK I., KSIAZYK J., THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTERAL NUTRITION (2018) ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parentral nutrition: Organisational aspects. Clinical Nutrition, 37, 2392-2400.

- REPORT OF THE PAEDIATRIC CHIEF PHARMACISTS GROUP (2011) Improving practice and reducing risk in the provision of parenteral nutrition for neonates and children (**http://www.rpharms.com**)

- RISKIN A., PICAUD J.C., SHAMIR R. THE ESPGHAN/ESPEN/ESPR/CSPEN WORKING GROUP ON PEDIATRIC PARENTRAL NUTRITION (2018) ESPGHAN/ESPEN/ESPR/CSPEN guidelines on pediatric parenteral nutrition: Standard versus individualized parenteral nutrition. Clinical Nutrition 37, 2409-2417.

- RODD C. AND GOODYER P. (1999) Hypercalcemia of the new-born: 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. Available at **www.gov.uk**

- 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 (http://www.ncepod.org.uk).

- TORONTO SICK KIDS NUTRITION TEAM (2007) Guidelines for the Administration of Enteral and Parenteral Nutrition in Paediatrics (3rd) (**https://www.sickkids.org**)

- THE ASSOCIATION FOR SAFE ASEPTIC PRACTICE (2015) The ANTT Clinical Practice Framework for all invasive Clinical Procedures from Surgery to Community Care. The-ASAP. (www.antt.org).

- 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.

- VAN GOUDOEVER J.B., CARNELLI V., DARMAUN D., SANTZ DE PIPAON M. (2018) the ESPGHAN/ESPEN/ESPR/CSPEN working group on pediatric parenteral nutrition: Amino acids. Clinical Nutrition 37, 2315-2323.

7.0 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 guideline 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.

8.0 Appendices

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

In the following tables, estimated PN requirements are presented according to 'day of PN'; however, individual patient requirements may vary and should be considered. Ongoing monitoring is required

Estimated Fluid Requirements

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

Recommended parenteral fluid intake during the first days of life in neonates (Phase I of adaptation) (ml/kg body weight/day) (Jochum *et al*, 2018):

	Days following birth				
	1st day	2nd day	3rd day	4th day	5th day
Term neonate	40 - 60	50 - 70	60 - 80	60 - 100	100 - 140
Preterm neonate >1500 g	60 - 80	80 - 100	100 - 120	120 - 140	140 - 160
Preterm neonate 1000 - 1500 g	70 - 90	90 - 110	110 - 130	130 - 150	160 - 180
Preterm neonate <1000 g	80 - 100	100 - 120	120 - 140	140 - 160	160 - 180

Recommended parenteral fluid intakes (ml/kg body weight/day) for neonates during the intermediate phase (Phase II) and during the first month of life with stable growth (Phase III) (Jochum *et al*, 2018):

	Intermediate phase (Phase II)	First month of life with stable growth (phase III)
Term neonate	140 – 170	140 - 160
Preterm neonate >1500 g	140 – 160	140 - 160
Preterm neonate ≤1500 g	140 – 160	140 - 160

Recommended parenteral fluid intakes (ml/kg body weight/day) for infants and children beyond the neonatal period (Jochum *et al*, 2018):

	1m to <1 yr	1 - 2 years	3 - 5 years	6 - 12 years	13 - 18 years
Fluid (ml/kg/d)	120 - 150	80 - 120	80 - 100	60 - 80	50 - 70

Estimated Parenteral Nutritional Requirements for Preterm Infants <2.5 kg

TABLE 1: PRETERM INFANTS <2.5 kg	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Total Energy (kcals/kg/day)	45 - 55	90-120	90 - 120	90 - 120	30 – 40 kcal total energy per gram of amino acid
Non-protein Energy (kcal/kg/day)		>65	>65	>65	
Amino Acids (AA) (g/kg/day)	≥1.5	2.5 - 3.5			Minimum 1.5 g/kg/day achieve nitrogen balance Maximum 4.0 g/kg/day
Carbohydrate(CHO) g/kg/day	5.8 - 11.5	11.5 – 14.4			Minimum 5.8 g/kg/day (GIR 4 mg/kg/minute). Maximum 17.3 g/kg/day (GIR 12 mg/kg/minute).
Glucose Infusion Rate (GIR) (mg/kg/min)	4 - 8	8-10 Increase stepwise over 2 to 3 days			In hyperglycaemia, reduce GIR by stepwise by 2 mg/kg/min to a minimum of 4 mg/kg/min. Maximum IV CHO concentrations: Peripheral ≤12.5% Central ≤25%
Lipid (g/kg/day)	1 -2	2 - 3	3	3 - 4	≥2 g/kg/day safe from day 1. Maximum 4g/kg/day (0.17 g/kg/hour)
Sodium (Na) (mmol/kg/day)	0-2 (3)	0 - 2 (3)	<u>≤1.5kg</u> 0-5 <u>>1.5kg</u> 0-3	<u>≤1.5kg</u> 2-5(7) <u>>1.5kg</u> 2-5	In practice, requirements may be higher, ensure close monitoring. Take account of additional Na from other sources, e.g. other IV fluids, flushes, enteral intake.

TABLE 1: PRETERM INFANTS <2.5 kg	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Potassium (K) (mmol/kg/day)	0 - 3			2 - 3	Peripheral: ≤4 mmol/100 mL Central: ≤8 mmol/100 mL
Calcium (Ca) (mmol/kg/day)	0.8 - 2			1.6 - 3.5	Achieving ≥2.5 mmol/kg/day Ca may be restricted by stability of PN solution.
Phosphate (P) (mmol/kg/day)	1 - 2			1.6 - 3.5	Achieving ≥2.5 mmol/kg/day P may be restricted by stability of PN solution.
Magnesium (Mg) (mmol/kg/day)	0.1 - 0.2			0.2 - 0.3	SerumMg may be elevated temporarily, secondary to maternal Mg therapy.
Trace Elements: Peditrace® (ml/kg/day)	1 provided there is adequate urinary output				Maximum 15 ml/day total dose. Contraindicated in patients with renal insufficiency (urine output <1ml/kg/hour) and/or hepatic dysfunction.
Fat Soluble Vitamins Vitlipid®N Infant (ml/kg/day)	1-4				Maximum 10 mL/day total dose.
Water Soluble Vitamins: Solivito® N (ml/kg/day)	1				Maximum 10 ml/day total dose.
Acetate (mmol/kg)	1 - 2				Acetate is provided as either sodium or potassium acetate and may be used as an alternative to sodium or potassium chloride to manage acid/base balance. The dose of acetate may be increased as required to maintain acid-base balance.

Estimated Parenteral Nutritional Requirements for Term Infants 0-1 years

TABLE 2: TERM INFANTS 0 – 1 YEAR	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Energy (kcals/kg/day)	Acute phase: 45 - 50 Stable phase 60-65 Recovery phase: 75 - 85				Aim to provide 30-40 kcal per gram amino acid
Amino Acids (AA) (g/kg/day) Vaminolact - convert to Nitrogen equivalent by dividing AA (g) by 7.02 Aminoven – convert to Nitrogen equivalent by dividing AA (g) by 5.88	Min 1.5 Max 3	2 - 3	2- 3	2 - 3	Minimum 1.5 g/kg/day Maximum 3g/kg/day PN + enteral nutrition combined should not provide >4.5 g AAs/kg/day
Carbohydrate (CHO) (g/kg/day) **Glucose Infusion Rate** (GIR) (mg/kg/minute)	**Term newborn <28 days** **Day 1:** 3.6-7.2 (GIR 2.5-5) **From Day 2 onwards:** 7.2-14.4 (GIR 5-10) Increase gradually over 2-3 days **>28 days – 10 kg** **Acute phase:** 2.9-5.8 (GIR 2-4) **Stable phase:** 5.8-8.6 (GIR 4-6) **Recovery phase:** 8.6-14.4 (GIR 6-10)				Min 3.6g/kg/day (GIR 2.5) Max 17.3g/kg/day (GIR 12) In hyperglycaemia, reduce GIR by stepwise by 2 mg/kg/min to a minimum of 4 mg/kg/min Maximum IV CHO: Peripheral access ≤12.5% Central access up to 25%

TABLE 2: TERM INFANTS 0 – 1 YEAR	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Lipid (g/kg/day)	1	2	3	3	Maximum 4 g/kg/day (0.17 g/kg/hour infusion rate). If lipid intake 3 g/kg/day for one week and weight gain poor, lipid intake can be increased to a maximum of 4 g/kg/day. Monitor serum triglyceride levels closely.
Sodium (Na) (mmol/kg/day)	0 - 2	0 - 2	0 - 2	1 - 3	In practice requirements may be higher, ensure close monitoring.
Potassium (K) (mmol/kg/day)	0 - 3	0 - 3	0 - 3	2 - 3	Maximum IV K concentrations Peripheral: ≤4 mmol/100 mL Central: ≤8 mmol/100 mL
Calcium (Ca) (mmol/kg/day)	**0 - 6 months** 0.8 - 1.5 **7 - 12 months** 0.5				If serum Ca levels low, Ca content of PN may need to be increased. Refer to BNF for Children.
Phosphate (P) (mmol/kg/day)	**0 - 6 months** 0.7 - 1.3 **7 - 12 months** 0.5				If serum P levels low, P content of PN may need to be increased. Refer to BNF for Children.
Magnesium (Mg) (mmol/kg/day)	**0 - 6 months** 0.1 - 0.2 **7 - 12 months** 0.15				
Trace Elements: Peditrace® (ml)	1 ml/kg/day up to a maximum 15 ml/day total dose				Contraindicated in patients with renal insufficiency (urine output <1 ml/kg/hr) and/or hepatic dysfunction.
Water-Soluble Vitamins: Solivito® N (ml)	1 ml/kg/day up to a maximum 10 ml/day total dose				

TABLE 2: TERM INFANTS 0 – 1 YEAR	Day 1 of PN	Day 2 of PN	Day 3 of PN	Day 4 of PN and beyond	Comments
Fat-Soluble Vitamins: Vitlipid® N Infant (ml)	4 ml/kg/day up to a maximum 10 ml/day total dose				Consider reducing dose to 2 ml/kg/day if infant very fluid restricted and additional volume required to meet minimum AA and CHO 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)	**1 - 7 years:** Acute phase: 40–45 Stable Phase: 55-60 Recovery phase: 75-85 **7 - 12 years:** Acute phase: 30-40 Stable phase: 40-55 Recovery phase: 55-65				
Amino Acids (AA) (g/kg/day) Convert to Nitrogen equivalent by dividing amino acid (g) by 7.02 for Vaminolact® in <10 kg patient or by 5.8 for Aminioven® in >10 kg patient	**1 – 3 years** 1-2.5 **3-12 years** 1-2				21 - 35 non- protein kcals required per gram of amino acids

<table>
<tr><th>TABLE 3:
CHILDREN
1 – 12 YEARS</th><th>Day 1 of PN</th><th>Day 2 of PN</th><th>Day 3 of PN</th><th>Day 4 of PN and beyond</th><th>Comments</th></tr>
<tr><td>Carbohydrate (CHO)
(g/kg/day)

Glucose Infusion Rate
(GIR)
(mg/kg/min)</td><td colspan="4"><u>11-30kg</u>
Acute Phase:
2.2-3.6
(GIR 1.5-2.5)
Stable Phase:
2.8 – 5.8
(GIR 2 – 4)
Recovery Phase:
4.3 – 8.6
(GIR 3 – 6)

<u>31 – 45 kg</u>
Acute Phase:
1.4 – 2.2.
(GIR 1.5 – 2.5)

Stable Phase:
2.8 – 5.8
(GIR 2 – 4)

Recovery Phase:
4.3 – 5.8
(GIR 3 – 4)</td><td>Maximum CHO concentrations:
Peripheral ≤12.5%
Central ≤25%</td></tr>
<tr><td>Lipid (g/kg/day)

Infusion rate 0.08-0.13g/kg/hr</td><td>1</td><td>2</td><td>2 - 3</td><td>2 - 3</td><td>Maximum lipid intake is 3 g/kg and is rarely required; this depends on clinical condition and energy requirements.</td></tr>
<tr><td>Sodium (Na)
(mmol/kg/day)</td><td colspan="4">1 - 3</td><td>Children usually started on 3 mmol/kg if serum Na
levels are within normal range</td></tr>
<tr><td>Potassium (K)
(mmol/kg/day)</td><td colspan="4">1 - 3</td><td>K to be added provided that there is adequate
diuresis. Children usually started on 2 mmol/kg/day if serum K levels are within normal range, if weight between 10-15kg start on 2.5mmol/kg/day.</td></tr>
<tr><td>Calcium (Ca)
(mmol/kg/day)</td><td colspan="4">0.25 - 0.4</td><td>If serum Ca levels low, Ca content of PN may need to be increased. Refer to BNF for Children.</td></tr>
</table>

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
Phosphate (P) (mmol/kg/day)	0.2 – 0.7				If serum P levels low, P content of PN may need to be increased. Refer to BNF for Children.
Magnesium (Mg) (mmol/kg/day)	0.1				
Trace Elements: Peditrace® (ml)	1 ml/kg, up to maximum of 15 ml/day total dose				Contraindicated in patients with renal insufficiency (urine output <1 ml/kg/hr) and/or hepatic dysfunction Additional Zn and Se can be added to PN if Peditrace held or reduced on an ongoing basis.
Water Soluble Vitamins: Solivito® N (ml)	1 ml/kg/day Maximum 10ml/day total dose				
Fat Soluble Vitamins: Up to 11 years: Vitlipid® N (Infant)(ml) **Over 11 years: Vitlipid® N Adult) (ml)**	10 ml/day total dose				

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)	**Acute phase:** 20-30 **Stable phase:** 25-40 **Recovery phase:** 30-55				
Amino Acids (AA) (g/kg/day) 1 g amino acids (Aminioven®) = 3.6 kcals	1 – 2 depending on clinical condition and requirements				21 - 35 non- protein kcals required per gram of AA

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
Carbohydrate (CHO) (g/kg/day) **Glucose Infusion Rate (GIR) (mg/kg/min)**	<u>Acute Phase</u> 31 – 45 kg 1.4 - 2.2 (GIR 1~~.0~~ – 1.5) <u>>45 kg</u> 0.7-1.4 (GIR 0.5 - 1~~.0~~) <u>Stable Phase</u> 31 – 45 kg 2.2 - 4.3 (GIR 1.5 - 3~~.0~~) >45 kg 1.4 - 2.8 (GIR 1 - 2) <u>Recovery Phase</u> 31 – 45 kg 4.3 - 5.8 (GIR 3 - 4) >45 kg 2.8 - 4.3 (GIR 2-3)				Maximum CHO: Peripheral: ≤12.5% Central ≤25%
Lipid (g/kg/day) 1g lipid = 10 kcals	1	2	2 - 3	2 - 3	Maximum 3g/kg/day
Sodium (Na) (mmol/kg/day)	1 - 3				Children usually started on 3 mmol/kg if serum Na levels are within normal range
Potassium (K) (mmol/kg/day)	1 - 3				Provide K as soon as adequate urinary output. In practice, commence on 2 mmol/kg/day if serum K levels within normal range

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
Calcium (Ca) (mmol/kg/day)	0.25 - 0.4				If serum Ca levels low, Ca content of PN may need to be increased. Refer to BNF for Children.
Phosphate (P) (mmol/kg/day)	0.2 – 0.7				If serum P levels low, P content of PN may need to be increased. Refer to BNF for Children.
Magnesium (Mg) (mmol/kg/day)	0.1				
Trace Elements: 15-40kg: Peditrace® **Additrace® if >40 kg (ml)**	**15-40kg** Peditrace: 15 ml/day total dose **>40kg** Additrace: 0.2 ml/kg/day up to				Contraindicated in patients with renal insufficiency (urine output <1 ml/kg/hr) and/or hepatic dysfunction
Water Soluble Vitamins: Solivito® N (ml/day)	10 ml/day total dose				
Fat Soluble Vitamins: Vitlipid® NAdult (ml/day)	10 ml/day total dose				

Volume of PN Solution Constituents

Constituent	Volume	Quantity of Nutrient Provided
Aminoven® 25	6.7 mL	1 g amino acids (0.17g nitrogen)
Primene®	10 mL	1 g amino acids (0.15 g nitrogen)
Synthamin 17EF®	10 mL	1 g amino acids (0.165 g nitrogen)
Vaminolact®	15.3 mL	1 g amino acids (0.14g nitrogen)
50% glucose/dextrose	2 mL	1 g carbohydrate
SMOFLipid® 20%	5 mL	1 g lipid
30% NaCl	1 mL	5 mmol sodium + 5 mmol chloride
15% KCl	1 mL	2 mmol potassium + 2 mmol chloride
10% calcium gluconate	1 mL	0.226 mmol calcium
21.6% sodium glycerophosphate	1 mL	1 mmol phosphate + 2 mmol sodium
10% magnesium sulphate	1 mL	0.4 mmol magnesium
30% sodium acetate	1 mL	2.2 mmol acetate + 2.2 mmol sodium
Zinc sulphate	1 mL	50 micromol zinc
Sodium selenite	1 mL	200 nanomol selenium

PN Macronutrients - Energy value per gram and Amino Acid to Nitrogen conversion values

Nutrient	Source	Energy value	Amino Acid to Nitrogen Conversion Value
Carbohydrate (CHO)	**Anhydrous Glucose**	**1 g Glucose = 3.4 kcal**	**-**
Lipid	**SMOFlipid®**	**1 g Lipid = 10 kcal**	**-**
Amino Acid (AA)	**Aminoven®25**	**1 g AA = 4 kcal**	**AA g divided by 5.84 = N_2 g**
	Primene®	**1 g AA = 4 kcal**	**AA g divided by 6.67 = N_2 g**
	Synthamin 17EF®	**1 g AA = 4 kcal**	**AA divided by 6.06 = N_2 g**
	Vaminolact®	**1 g AA = 3.7 kcal**	**AA g divided by 7.02 = N_2 g**

Appendix 2 Recommended Monitoring in Parenteral Nutrition

- 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 intake changes.
- Stable patients 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 patient is stable on PN.
- Each unit should identify the individual(s) responsible for reviewing biochemistry results and taking appropriate action when results are abnormal.
- Blood glucose measurements should preferably be performed on blood gas analysers. (Mesotten *et al*, 2018)
- Low serum albumin levels do not tend to correlate with nutritional status.
- Electrolyte levels may reflect hydration status.
- Urinary electrolytes may be monitored in certain circumstances, e.g. persistent hyponatremia to determine urinary losses.
- If patient commences parenteral/IV iron, monitor iron status closely - check ferritin levels weekly and monitor patient closely for any signs of adverse reaction during iron infusion.
- Close monitoring of trace elements (including zinc, selenium, manganese, copper) is required with long-term PN or if renal failure, hepatic disease or pre-existing imbalances.

	First Week					When Stable			
	Every Day	Day 1	Day 2	Day 3 - 4	Day 5 - 7	Every Day	Once Weekly	Fortnightly	Monthly PN
Infusion site – assess hourly	✓					✓			
Fluid balance	✓					✓			
Weight	✓						✓		
Urinary glucose	✓								
Blood glucose	✓					✓			
Electrolytes (Na, K, Cl)		✓	✓	✓	✓		✓		
Urea, Creatinine			✓		✓		✓		
Calcium			✓	✓	✓		✓		
Phosphate, Magnesium			✓		✓		✓		
Triglyceride				✓	✓		✓		
LFTs, Alk Phos, Protein, Albumin					✓			✓	
Bilirubin				✓				✓	
Full Blood Count								✓	✓
Ferritin							✓		✓
Trace elements: Zn, Cu, Mn, Se									✓
Vitamins A, D, E									✓
Growth (weight, OFC, length)		✓					✓		
Urinary sodium and phosphate					✓		✓		

Recommended Lipid / Triglyceride Monitoring Guideline

- While there is limited evidence to guide action based on triglyceride (TG) levels, the following guidelines may be used in practice.
- TG levels may need to be monitored more frequently in patients receiving high lipid or high glucose doses or with sepsis, malnourishment, catabolism, severe unexplained thrombocytopenia or in extremely low birth weight infants, and the lipid doses adjusted as necessary.
- TG and bilirubin levels should be monitored in patients 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.
- Some centres may monitor lipaemic index as an alternative to TG in line with local policy.

Suggested Triglyceride Monitoring

IV Lipid Intake Based on Triglyceride Level	
TG Level	**Recommended PN Lipid Intake**
Infants: ≤3 mmol/L (≤265 mg/dL) **Children:** ≤4.5 mmol/l (≤400 mg/dL)	Advance lipid intake as normal - Assess TG 24 - 48 hours after each increase of 1 g/kg/day lipid until recommended lipid intake tolerated - When recommended lipid intake tolerated, assess TG once weekly
Infants: >3 mmol/L (>265 mg/dL) **Children: >4.5mmol/l** (>400 mg/dL)	- Reduce lipid intake to dose previously tolerated / associated with normal TG level - Recheck TG after 24 hours If plasma TG levels are above the limits, lowering not stopping the dosage is generally recommended. In exceptional cases lipid infusion may need to be discontinued temporarily

Appendix 3 PN Audit Template

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

How many patients received standardised PN (SPN)?	0	1-4	5 - 10	11 - 20	21 - 30	>30
How many patients received Individualised PN (IPN)?	0	1-4	5 - 10	11 - 20	21 - 30	>30

How many patients received PN for each of the following:	1 – 2 days	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:

Individualised		**Starter sodium free**	
Preterm with electrolytes		**Term with electrolytes**	
SMOFVits 100 ml bag		**SMOFLipid® 100 ml bottle**	
SPN1		**SPN2**	
27 ml Lipid Syringe with Vitamins		**40 ml 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:

Individualised		**Starter sodium free**	
Preterm with electrolytes		**Term with electrolytes**	
SMOFVits 100 ml bag		**SMOFLipid® 100 ml bottle**	
SPN1		**SPN2**	
27 ml Lipid Syringe with Vitamins		**40 ml Lipid Syringe with Vitamins**	

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 occurred 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:

	Total Number	**Number Trained**
Consultant		
Registrar		
Senior House Officer		
Intern		
CNM 1-3		
RANP		
CNS		
Staff Nurse		
Dietitian		
Pharmacist		

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 the appropriate indication. In neonates, please also record the time between birth and PN commencement:

Patient	**Indication for PN**	**Appropriate (Y/N)**	**Time PN 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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Ms. Claire Browne
Dr. Alina Zidaru
Dr. Mary Flanagan
Ms. Siobhan Horkan

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Appendix 5 Approval

Approved by Parenteral Nutrition Expert Group	August 2016
Approved by Neonatal Clinical Advisory Group	September 2016
Approved by HSE CSPD Senior Management Team	January 2017
Revision of guideline approved by Parenteral Nutrition Expert Group	December 2019
Revision of guideline approved by Neonatal Clinical Advisory Group	January 2020
Revision of guideline approved by National Clinical Advisor & Group Lead	September 2020
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