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National Clinical Practice Guideline

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

irspen Irish Society for Clinical Nutrition & Metabolism

Endorsed by the Irish Society for Clinical Nutrition & Metabolism

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1.0 Introduction

The availability of parenteral nutrition (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 provide PN safely, 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 (IV) 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 improve evidence-based safe prescribing, administration, and monitoring of 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. It is 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 Summary and Key Recommendations

The Use of Parenteral Nutrition in Neonatal and Paediatric Units in Ireland

The availability of parenteral nutrition (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. In order to provide PN safely, 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 and rigorous monitoring of the patient's electrolytes and response to treatment. 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.

The PN guideline on 'The Use of Parenteral Nutrition in Neonatal and Paediatric Units in Ireland' incorporates the 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.

This short document supports the guideline, with recommendations, an accompanying algorithm, and some frequently asked questions.

Recommendations:

1. We recommend that healthcare professionals refer to the guideline 'The Use of Parenteral Nutrition in neonatal and Paediatric Units in Ireland' for guidance on the use of PN.
2. We recommend that all healthcare professionals should have education on PN relevant to their setting prior to undertaking practice in this area.
3. We recommend that care should be centralised to tertiary and regional centres should an infant or child require PN.
4. We recommend that multidisciplinary team input (e.g. Dietitian, Pharmacy, Medical, Advanced Nurse Practitioner) is desirable when ordering PN.
5. We recommend that PN is used where it is not possible to meet nutritional requirements via the enteral route, often due to intestinal immaturity or intestinal failure.
6. We recommend that standardised PN (SPN) should generally be used over individualised PN (IPN) in most patients, including very low birth weight infants. IPN should generally be used when the nutritional requirements cannot be met by SPN preparations.
7. We recommend that biochemistry, fluid balance and allowance should be assessed to determine first whether a SPN preparation is suitable; if additional intravenous solutions are required to provide additional volume, carbohydrates, or electrolytes; or if IPN is required.

8. We recommend that once indicated, PN should be commenced as soon as possible following confirmation of line placement.
9. We recommend using a central line for the administration of PN, however a peripheral line can be used. A central line recommended if the glucose concentration is more than 12.5%.
10. We recommend the use of care bundles for central line insertion and that the aseptic non-touch technique is used to insert and access lines.
11. We recommend that 2 nurses are required to prepare PN – one to assist and confirm the checks while the other prepares and connects the infusions.
12. We recommend that the PN preparation is held to light and visually inspected prior to use; if any visible particles are seen the bag should not be used, and returned to Pharmacy.
13. We recommend that each PN preparation bag is connected to the correct line and filter and set at the correct infusion rate (set, check, and verify infusion rates). Check infusion from patient – to pump – to bag.
14. We recommend that differently coloured bags and lines should be used to help make the distinction in the preparation of aqueous and lipid preparations.
15. We recommend that the line used for PN should not be interrupted if possible.
16. We recommend that line sites are inspected regularly when using PN and monitored for swelling, and it is ensured that dressing is dry and intact.
17. We recommend that when infection is suspected in a patient with an indwelling catheter, a blood culture should be obtained and empiric antibiotic therapy commenced for catheter related blood stream infection.
18. We recommend that infants receiving PN should be monitored, with particular attention to daily fluid balance, weight, glucose, and lab monitoring. Lab monitoring requirement may differ depending on the clinical situation.
19. We recommend that PN should be continued until adequate nutritional intake from enteral nutrition is tolerated, i.e. generally until 75% of nutritional requirement (120ml/kg/day enteral feeds in preterm infants) is tolerated enterally. For SPN, the lipid and aqueous preparation, filters, and infusion administration sets can be left in-situ for up to 48-hours.
20. We recommend that each unit should audit their use of PN annually, including monitoring the incidence of central line infection.

3.0 Algorithms

Use of parenteral nutrition (PN)

PN provides nutrients via the intravenous (parenteral) route

Indications

1. Preterm infants < 32 weeks or < 1.5kg
2. Intestinal failure
3. Post-gastrointestinal tract (GIT) surgery, congenital GIT defects
4. Necrotising enterocolitis
5. See guideline for further details e.g. relative indications

Initiation of PN

1. PN type: Standardised PN (SPN) should generally be used over individualised PN (IPN) in most paediatric and neonatal patients
2. Biochemistry, fluid balance and allowance should be assessed to determine first whether a SPN preparation is suitable for a patient's needs; if additional IV solutions are required to provide additional volume, CHO, or electrolytes; or if IPN is required.
3. PN volume: Consider other fluids patient is receiving, optimising the provision of nutrition within the available volume
4. In preterm infants, start asap following confirmation of line

Administration of PN

Checks required before commencing PN (by two nurses)

1. PN preparation labels
2. PN order against the label on each preparation
3. Verify: Expiry date; Batch number; Patient/preparation name; Volume, duration, infusion route, and infusion rate; and composition
4. Remove outer cover, hold to light and visually inspect preparation
    a. Aqueous – pale straw/yellow coloured clear solution
    b. Lipid – uniformly opaque creamy white emulsion
    c. If any visible particles, do not use and return to Pharmacy

Preparation

1. Prime lipid preparation and connect light-protected infusion set
2. Prime aqueous infusion and connect and prime (0.2 micron filter)
3. Check identifiers and confirm correct patient, medication, and correct form immediately before connection, correctly coloured lines and bag cover
4. 'Scrub the Hub' with alcohol/chlorhexidine wipe and allow to dry
5. Set, check and verify infusion rates (independent checks by both nurses)
6. L is for LIPID
    a. **Label lipid:** Label infusion lines and infusion pumps
    b. **Lipid filter:** Lipid through 1.2 micron Light blue filter
    c. **Lipid pump lowest:** Lipid pump lower on space station
    d. **Lipid bag and rate last**
    e. **Lipid rate lower:** Lipid rate is lower than aqueous infusion rate
    f. **Lights on:** Always have Lights on when setting/checking rates

Advancement

1. Continue PN until adequate nutritional intake from enteral nutrition is tolerated, ~ 75% is tolerated (120ml/kg/day feeds in infants)

Lab monitoring

1. Monitoring requirements may differ depending on clinical situation
2. Recommend daily fluid balance, weight, glucose
3. Daily electrolytes during critical illness, less frequent when stable
4. From day 3, assess triglyceride level 24-48 hours after each increase of lipid until recommended lipid intake tolerated. Consider cautious increase of lipids in infants with insulin resistance/hyperglycaemia

Use of parenteral nutrition (PN) *(continued)*

Please refer to PN guideline for further details, including lab monitoring suggestions

PN will require a prescription

MDT input from Dietitian and Pharmacy is desirable

Forms of PN
– SPN: pre-prepared with fixed composition; longer shelf life; kept as stock; fixed amount of nutrients incl. electrolytes
– IPN: specific order for individual patient

Constituents may include
– Fluid (water)
– Energy
– Protein (amino acids/nitrogen)
– Carbohydrate
– Lipid (fat)
– Electrolytes
– Vitamins
– Trace elements +/-iron
– Acetate +/-
– Carnitine +/-

Complications
– Infection
– Catheter-related complications
– Biochemical imbalances
– Refeeding syndrome
– Hepatobiliary comp

SPN: 48-hour hang time

Infusion route and lines

Central line recommended but peripheral line can be used (Glucose conc. > 12.5% via central line)

Upper limit osmolarity of preparations:
– Central 1200 mOsm/L
– Peripheral 800mOsm/L

Care bundles for central line insertion

Aseptic non-touch technique (ANTT) used to insert and access lines

Check catheter tip position after insertion and on subsequent films

Ideally line used for PN should not be interrupted

Ensure PN bag is connected to correct line and filter and set at correct infusion rate

Check infusion from patient – to pump – to bag

Use distinctly coloured bags
– Blue: Aqueous
– Red: Lipids

Use distinctly coloured lines

Monitor for swelling, ensure dressing dry and intact; inspect sites 6-hrly for central and hrly for peripheral lines

4.0 Roles and Responsibilities

1. To appropriately implement these guidelines each hospital's local neonatal/paediatric governance group should review and approve their use. This will help to ensure that the inpatient care of neonates/children admitted to their facility is optimised irrespective of location. All healthcare professionals should have education on PN relevant to their setting prior to undertaking practice in this area. We recommend that care should be centralised to tertiary and regional centres should an infant or child require PN.

5.0 Clinical Guideline

Information and recommendations in the following sections are supplemented with additional detail in the accompanying appendices.

5.1 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, e.g., 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).

Examples of Indications for Parenteral Nutrition

Absolute Indications	• Functional immaturity of GIT, 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-GIT surgery • Necrotising enterocolitis (NEC) • Congenital GIT defects, e.g., gastroschisis, intestinal atresia

Relative Indications	• Preterm infants ≥32 weeks gestation or ≥1.5 kg, or term infants or children who are not expected to receive adequate enteral intake (i.e. ≥75% of nutritional requirements) within approximately 3-5 days. • Severe intrauterine growth restriction (IUGR) with associated absent or reduced end diastolic flow. • Intractable diarrhoea or vomiting • Chemotherapy-induced GIT failure • Inflammatory bowel disease • Malabsorption syndromes • Acute pancreatitis

5.2 Forms of Parenteral Nutrition

5.2.1 PN preparations are available in different forms:

- **Aqueous or '2-in-1' preparations**, which contain amino acids (AAs), carbohydrate (CHO), electrolytes ± water-soluble vitamins ± trace elements. An aqueous preparation is generally infused simultaneously with a lipid preparation.
- **Lipid preparations**, which contain lipid ± fat-soluble vitamins ± water-soluble vitamins. A lipid preparation is generally infused simultaneously with an aqueous preparation.
- **'All-in-one' or '3-in-1' preparations**, which combine both the aqueous and lipid preparations in a single product, and contain AAs, CHO, lipid ± electrolytes ± vitamins ± trace elements.

PN preparations are available as either Standardised PN (SPN) or Individualised PN (IPN).

5.2.2 Standardised PN (SPN)

- SPN is pre-prepared with a fixed composition.
- SPN preparations have a longer shelf life and can be kept as stock on wards allowing PN to be started without delay.
- SPN contains fixed amounts of nutrients including electrolytes. Refer to product information for details of currently available SPN preparations (Appendix A)
- If additional electrolytes are required, they may be provided by other sources, e.g., additional IV solutions. If it is not possible to meet requirements with SPN ± other sources/additional IV solutions, IPN may be required.

5.2.3 Individualised PN (IPN)

- IPN is prepared based on individual requirements, ordered specifically for an individual patient. IPN allows for the provision of levels of nutrients that cannot be provided by SPN.
- The composition of IPN may be limited by the volume available and other factors – refer to the Compounding Facility for details.

5.2.4 Indication for use of PN types

SPN should generally be used over IPN in most paediatric and neonatal patients, including VLBW preterm infants (NICE 2022). IPN should generally be used when the nutritional requirements cannot be met by the available range of SPN preparations.

Current SPN preparations for paediatric patients may not always meet full requirements for vitamins and trace elements, e.g., SPN preparations currently available for patient >2.5 kg may not contain micronutrients, and where micronutrients are present, full requirements may not be met (See Appendix A for further details of currently available SPN for paediatric populations). Check available formulations against requirements and order IPN where necessary, especially if patient is expected not to tolerate enteral nutrition for more than 3-4 days. Further information on SPN versus IPN is provided in ESPGHAN/ESPEN/ESPR guidelines (Riskin A *et al.*, 2018).

5.3 Constituents of Parenteral Nutrition

PN preparations contain some or all the following constituents:

5.3.1 Fluid (Water)

- Water is an essential carrier for nutrients and metabolites and it comprises a major part of human body mass at any age.
- Total fluid requirements include maintenance requirements and requirements for growth.
- Water and electrolyte requirements per kilogram are very high after birth and decrease with age until adulthood.
- Preterm infants can have high insensible losses via their skin.

Refer to ESPGHAN guidelines on paediatric PN fluid and electrolytes (Jochum *et al.*, 2018), and Appendix B for further information on PN fluid intakes.

5.3.2 Energy

- Energy is required for maintenance requirements and new tissue synthesis (i.e., growth).
- Requirements may be increased in the presence of metabolic stress, fever or sepsis, correction of faltering growth, and other clinical conditions.
- Parenteral energy requirements are generally less than enteral requirements as there is no energy lost in the stools.
- Total parenteral energy requirements of stable patients can be calculated from resting energy requirements (estimated from Schofield's equations) with adding constants for physical activity, catch up growth and disease factors.
- The terms 'non-protein energy (NPE)' expressed as kilocalories (kcal) or 'non-protein calories (NPC)' are used to describe energy coming from CHO and lipid only. NPE/NPC excludes energy from protein.
- Aim to provide adequate CHO and lipid to meet energy requirements to ensure proper utilisation of protein for tissue growth.
- The protein energy ratio should always be optimised. 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.

Refer to ESPGHAN guidelines on paediatric PN energy (Joosten *et al.*, 2018), Appendix B and Appendix H for further information on PN energy requirements.

5.3.3 Protein/Amino Acids/Nitrogen

- Proteins are the major structural and functional components of all cells in the body and are made up of chains of amino acids (AAs).
- AAs are the source of nitrogen (N_2) in PN.
- Infants and children need AAs in their PN to repair tissue and to grow.
- Certain AAs are not fully metabolised by neonates. For this reason, it is important for neonatal PN to use an AA product that is primarily designed for this patient group.
- It is important that AAs are used for tissue maintenance and growth and not as a source of energy.
- Non-protein energy to amino acid ratio (NPE:AA) describes the relationship between the NPE and AA content and may be used to assess whether AA intake is sufficient to meet requirements.
- The AA content of the currently available AA product and the AA to N_2 conversion values are outlined in Appendix C.

Refer to ESPGHAN guidelines on paediatric PN AA (van Goudoever *et al.*, 2018), product information and Appendix B for further information on PN AA requirements.

5.3.4 Carbohydrate

- Carbohydrate (CHO) is the main source of energy in PN.
- Glucose/anhydrous dextrose is the preferred IV 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.
- It is recommended that approximately 60-75% of NPE comes from CHO.
- Each gram of anhydrous dextrose contains 3.4 kcal/g (rounded to 4 kcal in clinical practice, Mesotten *et al.*, 2018). Refer to product information for details on currently available PN anhydrous dextrose products.
- CHO 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 CHO/glucose provision for infants. Refer to 'Glucose Infusion Rate Conversion' Appendix D. Infants born preterm, especially if evidence of growth restriction, are at risk of hypoglycaemia after birth.
- CHO should be increased gradually as tolerated in a stepwise manner over 2 to 3 days to reach target intakes, taking account of CHO provided from other sources, e.g., other infusions or medications containing CHO, or affecting CHO metabolism, e.g., steroids.
- During acute illness (e.g., sepsis, infection), CHO intake may need to be reduced – guided by blood glucose levels.

Refer to ESPGHAN guidelines on paediatric PN CHO (Mesotten *et al.*, 2018) and Appendix B for further information on PN CHO requirements.

5.3.5 Lipid (Fat)

- Lipid provided as an IV lipid emulsion (ILE) should be an integral part of PN, whether PN is the sole source of nutrition or supplementary to EN (Lapillone *et al.*, 2018).
- ILE is used as a non-CHO source of energy, to provide a source of essential fatty acids (EFAs) and as a means of delivering fat-soluble vitamins.
- It is recommended that approximately 25-40% of NPE comes from lipid when PN is the sole source of nutrition.
- The ESPGHAN recommendation is for use of a composite ILE with or without fish oils (Lapillone *et al.*, 2018); however, benefits of fish oil have been suggested although further high-quality trials to provide data of sufficient validity and applicability to inform practice are required (Kapoor *et al.*, 2019; Cleminson *et al.*, 2021).
- Based on a review of the literature, Ireland has decided to use a lipid product that contains fish oils.
- The lipid product currently in use in Ireland is SMOFlipid® and this contains fish oils. ILE containing a single lipid source, such as pure soya bean oil ILE (e.g., Intralipid®), should no longer be used routinely.
- Infants who are prone to insulin resistance, e.g., those who are growth restricted, may be at higher risk of hypertriglyceridaemia, requiring cautious advancement of PN lipid (van Kempen, *et al.*, 2006).
- The energy provided per gram of lipid in PN depends on the lipid preparation used. Check product information for details.
- To prevent EFA deficiency (EFAD), a minimum linoleic acid intake of 0.25 g/kg/day is recommended for preterm infants; or 0.1 g/kg/day for term infants and older children (Lapillonne *et al.*, 2018).
- SMOFlipid® 20% – 1 g /kg/day corresponds to 5 ml/kg/daySMOFlipid® contains 35 mg/ml (range 28-50 mg/ml) linoleic acid (omega-6) and 4.5 mg/ml (range 3-7 mg/ml) α-linolenic acid (omega-3).

Refer ESPGHAN guidelines on paediatric PN Lipids (Lapillonne *et al.*, 2018) and Appendix B for further information on PN lipid requirements.

5.3.6 Acetate

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), for infants at high risk (e.g., large patent ductus arteriosus (PDA), weight loss >15%, ELBW).

The ability to add acetate is dependent on the amount of sodium and potassium prescribed, as acetate is provided as either sodium acetate or potassium acetate.

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) if necessary.

Some SPN preparations include acetate, otherwise acetate may be ordered in IPN and increased as needed to maintain acid/base balance.

Refer to Appendix B for further information on acetate intakes during PN.

5.3.7 Electrolytes

The main electrolytes included in PN are:

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

- Electrolyte balance depends on clinical circumstances such as fluid restriction, dehydration or excessive water losses, fluid overload as well as intake.
- In ELBW and VLBW infants, according to ESPGHAN (Jochum *et al.*, 2018), Na and K may be included from birth when giving the recommended high AA and energy supply if urine output is established and considering the potential for the development of non-oliguric hyperkalaemia. SPN preparations currently used for these patients in the first 24-48 hours contain electrolytes but at low levels.
- Consider other sources of electrolytes such as IV fluids and medications when ordering PN.
- Adequate Ca, P, Mg, together with vitamin D is essential for bone mineralisation, to support linear growth and to protect against rickets fractures.

Refer to ESPGHAN guidelines on paediatric PN fluid and electrolytes (Jochum *et al.*, *et al.*, 2018) and Appendix B for further information on PN electrolyte requirements.

5.3.8 Trace Elements and Iron

- There is a range of preparations available to add trace elements to PN. Details of the preparations currently available and their recommended doses are outlined in Appendix A.
- 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 EN.
- If a trace element preparation is held or the dose reduced on an ongoing basis, consider individual supplementation with zinc and selenium.
- Iron is not routinely added to PN preparations or commercially available trace element preparations.
- If iron supplementation is required, it should be given enterally rather than parenterally, if tolerated (Domellöf *et al.*, 2018).
- 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 has commenced. Infants and children receiving PN >3 weeks, who cannot maintain adequate iron status using enteral iron supplements, should receive parenteral iron supplementation. If indicated, and assuming no enteral iron supplementation, ESPGHAN advises parenteral iron supplementation at a dose of 200-250 microgram/kg/day in preterm infants and 50-100 microgram/kg/day up to a maximum dose of 5 mg/day in infants and children.
- Individual trace element and iron requirements may vary based on factors such as age, weight, duration of PN and underlying diseases.

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

For further information, including precautions and special warnings for the use of trace elements and iron in PN, refer to ESPGHAN guidelines on PN iron and trace elements (Domellöf *et al.*, 2018) and to the manufacturer of trace mineral and iron preparations and the PN Compounding Facility.

Refer to Appendices A and B for guidance on trace element and iron intakes during PN.

5.3.9 Vitamins

- Both water-soluble and fat-soluble vitamins are added to PN.
- Water-soluble vitamins are the B group of vitamins and vitamin C; and fat-soluble vitamins are vitamins A, D, E and K.
- Water-soluble vitamins can be added to either the aqueous or lipid preparation; fat-soluble vitamins can be added to the lipid (or 3-in-1) preparation only. In Ireland at present, all vitamins are generally added to the lipid preparation, unless when providing lipid-free IPN, in which case water-soluble vitamins are added to the aqueous preparation only.
- Details of the preparations currently available to add vitamins to PN and their recommended doses, are outlined in Appendix A.
- Commercially available products may not always meet specific vitamin requirements (Bronsky *et al.*, 2018).

For further information, refer to ESPGHAN guidelines on PN vitamins (Bronsky *et al.*, 2018), the manufacturer of vitamin preparations and the PN Compounding Facility.

Refer to Appendix A and B for guidance on vitamin intakes during PN.

5.3.10 Carnitine

- 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). At present, carnitine is not available from the PN Compounding Facility and must therefore be supplemented separately to the PN.

For further information on recommenced doses etc., refer to ESPGHAN guidelines on paediatric PN lipid (Lapillonne *et al.*, 2018).

5.4 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/EN (Brennan *et al.*, 2018).

Recommended intakes for preterm infants and the goals that should be reached for optimal growth are summarised in Appendix B.

For children who are catabolic or unwell, requirements vary and research suggests that actual energy requirements are less than previously thought (Shaw, 2020).

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.

5.5 Ordering and Prescribing Parenteral Nutrition

5.5.1 Order Form/Prescription

- Typed electronic order forms/prescriptions should be used when ordering PN when possible, according to local practice (Riskin *et al.*, 2018).

5.5.2 PN Type

- It should be determined daily if PN is required, and whether SPN or IPN is needed. Refer to section 5.2 for overview of SPN and IPN and indications for each type.
- Biochemistry, fluid balance and allowance should be carefully assessed to determine first whether a SPN preparation is suitable for a patient's needs; if additional IV solutions are required to provide additional volume, CHO, or electrolytes; or if IPN is required.
- Where SPN is not suitable, IPN should be ordered.

5.5.3 PN Volume

- It is important that the appropriate volume of PN is ordered, considering other fluids that a patient may be receiving, to optimise the provision of nutrition within the available volume.
- 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.

5.5.4 Ordering and Prescribing PN

- PN can be ordered by a consultant, non-consultant hospital doctor (NCHD), registered dietitian, pharmacist or registered advanced nurse practitioner (RANP). However, for administration 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 and require a prescription.
- PN orders should be double-checked by a suitable second person (dietitian or pharmacist) before sending to the Compounding Facility
- For **SPN**, order the volume of each SPN preparation, i.e., aqueous and lipid or 3-in-1, to be provided (mL/kg/day). This volume determines the intake of each nutrient that will be provided by the SPN preparations.

- For **IPN**, order the amount of each ingredient on an order form that is sent to the Compounding Facility. The order form should include the following details:

Relevant patient details

- ✓ Patient hospital number
- ✓ Patient name
- ✓ Patient date of birth
- ✓ Patient location (ward)
- ✓ Working weight/dosing weight (kg)

PN order details

- ✓ Date of PN order
- ✓ Date of PN infusion
- ✓ Day of PN

PN infusion details and presentation

- ✓ Type (IPN)
- ✓ Central or peripheral access (if glucose concentration is greater than 12.5%, a central venous access device (CVAD) must be used)
- ✓ Duration of PN infusion (hours)
- ✓ Whether '2-in-1' (i.e., separate aqueous and lipid preparations) or '3-in-1' (i.e., aqueous and lipid preparations combined) PN

PN volume and nutrient intakes

- ✓ PN volume (mL/kg/day)
- ✓ 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, preparation name and dose (mL/kg/day)
- ✓ Fat-soluble vitamins, preparation name and dose (mL/kg/day or mL/day)
- ✓ Trace elements, preparation name and dose (mL/kg/day or mL/day)
- ✓ Other requirements (as necessary), e.g., acetate (mmol/kg/day)

Calculations based on intakes ordered

- ✓ Glucose concentration (%)
- ✓ Infusion rates for both aqueous and lipid or 3-in-1 preparations (mL/hour)

- IPN orders should be sent to the Compounding Facility by the agreed cut-off time, noting that this may be earlier on bank holidays or at weekends where this service exists, to ensure a same day service, i.e., that IPN is compounded and delivered later the same day that it is ordered.
- **Note**, the amount of the various constituents will change depending on the volume of PN provided, for example 90 mL/kg of a PN preparation will provide more sodium than 70 mL/kg of the same preparation. Therefore, if the infusion rate is changed from that documented, the nutrients provided should be recalculated based on the new infusion rate.

5.6 Delivery and Storage of Parenteral Nutrition

5.6.1 PN Delivery

- PN preparations are delivered directly by the Compounding Facility to the hospital.
- IPN is generally delivered on the same day it is ordered, usually in the evening.
- SPN is generally ordered in advance for delivery within 1-2 working days.

5.6.2 PN Storage

- All PN should be stored in a designated refrigerator at 2 to 8°C.
- The expiry date/shelf life of each PN preparation should be noted and adhered to. The expiry date of all PN preparations should be checked regularly and stock should be rotated so that preparations with the shortest expiry date are used first.
- The shelf life for SPN is usually longer (generally 45-90 days from day of compounding) than that for IPN, which is generally 7 days from day of compounding. However, IPN should be used on the date it is ordered for. The exact shelf life of SPN preparations depends on product – check with Compounding Facility for details.

5.7 Administration of Parenteral Nutrition

- PN preparations must be removed from the fridge in advance, approximately one hour prior to commencing the infusion. This allows it to come to a suitable temperature for infusion.

5.7.1 Infusion route

- PN can be infused via a peripheral or central venous access device (CVAD).
- It is recommended that CVADs are used for PN (Puntis *et al.*, 2018; Ainsworth *et al.*, 2007). However, considerations also include the access available, the concentration of the preparations to be infused and the duration of use, e.g., peripheral access is for short-term use only.
- A glucose concentration greater than 12.5% should not be infused via a peripheral line (Puntis *et al.*, 2018).
- The addition of electrolytes and minerals further increases the osmolarity of the preparation, with potential for tissue damage if infiltration or extravasation occurs.
- The following upper limits for the osmolarity of preparations according to the route of infusion, have been suggested (Carnielli *et al.*,2021), (Boullata JI *et al.*, 2014):
    - Peripheral: 900 mOsm/L.
    - Central: 1200 mOsm/L.

5.7.2 Infection prevention and control

Infection is one of the most common and potentially fatal complications of CVADs and PIV cannula (Puntis *et al.*, 2018). Infection rates in paediatric patients vary depending on the underlying condition, with the highest rates being reported in children receiving PN for GI dysfunction (Dudeck *et al.*, 2013).

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.
- ✓ No manipulation or additions should be made to PN.

- All IV cannulas/venous catheters must be inserted using strict aseptic non-touch technique (ANTT®). Proper care of the site, all connections and tubing are essential to reduce the risk of infection.
- Ideally, the venous cannula/catheter 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).
- The requirement for a CVAD/peripheral cannula should be reviewed daily and the line/cannula removed promptly if no longer required or if concerned upon inspection.
- Currently SPN infusions (aqueous and lipid) and administration sets can be left in situ for up to 48 hours or as per local policy, but IPN infusions and administration sets should be changed every 24 hours (Puntis *et al.*, 2018).
- Effective prevention of catheter-related infections requires strict adherence to antiseptic techniques.
- CVADs must be dressed using a transparent dressing to cover insertion site.
- The dressing must be changed when visibly soiled, damp or loose.
- Infusions sets must be primed using an aseptic non-touch technique, protecting key parts.
- ANTT® must also be used to access the catheter and the hub cleaned with 70% alcohol or 70% alcohol and chlorhexidine wipes to reduce contamination.
- If a PN preparation/infusion is disconnected from an IV cannula/CVAD it must be discarded; PN preparations/lines should not be reconnected to the same or other sites.

5.7.3 Monitoring for infiltration/extravasation, infection

- Infiltration/extravasation is a risk with any intravascular device, with a particularly high risk associated with peripheral cannulas/catheters.Signs of infiltration/extravasation include swelling of the area affected.
- Central 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.
- The insertion sites of IV cannulas should be inspected regularly for signs of infiltration/extravasation or infection and to ensure the dressing remains dry and intact. Also check for swelling in the limb and the area where the tip is located and not just at the insertion site.
  - ✓ For peripheral cannulas, inspect at least hourly.
  - ✓ For CVADs, inspect at least every 6 hours.

5.7.4 Dressings

- A transparent dressing should be used to secure the IV cannula/catheter and should remain in place.
- Routine dressing changes are not recommended to avoid damaging the skin, the catheter itself or dislodging the catheter.
- If the dressing is wet or no longer occlusive, it must be changed using a sterile technique.

5.7.5 Infusion pumps

- PN preparations/infusions 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).
- The pump should have free-flow prevention if inadvertently opened during use and have lockable settings (Puntis *et al.*, 2018).
- The pump must be inspected hourly to ensure the correct rate of infusion is set and to monitor volume infused.

5.7.6 Medications and other infusions

- Mixing of medication with PN administration lines should be avoided unless validated by the manufacturer.
- 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).
- If there is no information available regarding compatibility, the medication should be infused separately from the PN.

5.7.7 Infusion sets/lines, light protection, filters, and hang-times

Caution

Take particular care to ensure each PN preparation is connected to the correct line and filter and is set at the correct infusion rate.

When using separate aqueous and lipid preparations, especially when both are provided in bags, extra vigilance is required to clearly distinguish each bag from each other, when setting the infusion rate and doing hourly checks.

A tool 'L is for lipid' has been developed to help (Appendix E).

- PN preparations (aqueous, lipid, 3-in-1 bags), lines and filters 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, NICE 2022).
- PN preparations may contain particulate matter and biochemical interactions can result in chemical precipitations in addition to the risk of bacterial contamination.
- It is recommended that all PN preparations are administered via an infusion set containing a terminal filter (Puntis *et al.*, 2018).
- The current PN infusion set contains filter membranes with pore sizes of 1.2 microns (lipid line) and 0.2 microns (aqueous line).

  - ✓ For 3-in-1 preparations a 1.2-to-1.5-micron filter is recommended (ASPEN 2004, Puntis *et al.*, 2018, ASPEN 2021). The filter should be as close as possible to the catheter hub (Worthington *et al.*, 2021).
  - ✓ For aqueous preparations, place the filter below the Y site where the aqueous and lipid preparations co-infuse (Worthington *et al.*, 2021).

- For SPN, the lipid preparation, the aqueous preparation, filters, and infusion administration sets 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, Chirinian & Shah 2012, Puntis *et al.*, 2018, Guenter *et al.*, 2018, NICE 2022, Worthington *et al.*, 2021), however refer to your local hospital guidelines for hanging times for IV solutions. Filters are generally changed when the preparations are changed, i.e., every 48 hours however they can become clogged and may require to be changed more frequently observing strict ANTT®.
- Please consider the total SPN bag volume as this will dictate if there is sufficient volume to run for a hang time of 48 hours. E.g. For a 2 kg infant on cSPN2 at 120 mL/kg/day, the 400 mL bag would empty prior to 48 hours.
- For IPN, the lipid preparation and infusion set with filters can only be left in-situ for up to 24 hours, while the aqueous preparation and infusion set can be left in-situ for up to 48 hours. The shorter hang-time for IPN lipid is due to insufficient stability data currently. A lipid line, separate to the aqueous line with a 1.2 micron filter is required, allowing for the individualised lipid preparation and line be changed after 24 hours without the need to remove the aqueous part of the infusion set.

5.7.8 Administration of Parenteral Nutrition

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

- PN preparation labels.
- PN order (for IPN, also check the Delivery Sheet provided by the Compounding Facility) against the label on each PN preparation to be infused, i.e., aqueous, lipid or 3-in-1 preparations, and verify the following:
  - ✓ Expiry date – ensure the preparations are still in date by the time the infusion will be stopped. For IPN, also check the date of infusion.
  - ✓ Batch number
  - ✓ Patient/preparation name. For IPN: ensure correct patient name, date of birth and hospital number; For SPN, ensure correct preparation name.
  - ✓ Volume of each PN preparation to be infused and duration, the infusion route (central/peripheral) and infusion rate (mL/hour).
  - ✓ Composition, including the quantity of each constituent ordered and the percentage glucose, matches the PN order/prescription.

- Remove the outer cover and visually inspect each preparation/bag, gently shake to dislodge any particles that may have formed and hold up to the light at a slight angle to inspect.
  - ✓ Aqueous preparation: This is a pale straw/yellow coloured clear solution. If the solution is cloudy or has visible crystals/particles, do not use, and return it to Pharmacy.
  - ✓ Lipid and 3-in-1 preparations: Should be uniformly opaque creamy white emulsion with no visible particles. If not, do not use and return it to Pharmacy.

- If there is concern about any aspect of the PN preparations, do not use and notify or return to Pharmacy.
- Both nurses must sign the PN prescription sheet/electronic patient record to verify if the checks are correct, before commencing infusion.

5.7.9 Procedure

Preparation

- Ensure there is adequate light to clearly see the pumps and perform all checks.
- Follow a strict aseptic non-touch technique (ANTT®).

Aseptic Non-Touch Technique (ANTT®)

- Research studies have shown that adoption of rigorous aseptic technique markedly reduce the incidence of line infections. To ensure high standards of asepsis, ANTT® is recommended (ASAP, 2015).
- Two nurses are required, one to assist and confirm the checks while the other prepares and connects the infusions.
- The number of key parts involved determines the choice of surgical or standard ANTT®. The points below describe the recommended process for Surgical ANTT®.

- Both nurses decontaminate their hands and then check the PN prescription, remove the PN preparations from the fridge, check the expiry date on each preparation and allow to come to room temperature (takes approximately I hour or more depending on volume).
- Prepare supplies (including labels), then both nurses decontaminate their hands again.
- Clean trolley with disinfection wipes.
- Prepare sterile field using sterile drape.
- Decontaminate hands.
- Don hat, sterile gown (Aly *et al.*, 2005) and sterile gloves.
- Observing Surgical ANTT®, one nurse prepares the infusions while a second nurse assists with the process as described below. Always protect key parts and “scrub the hub” for 30 secs with alcohol/ Chlorhexidine wipes. Allow to dry for 15 secs.
- Connect the PN preparations to the appropriate light-protected infusion sets, filters (refer to section 5.7.7 for more details), label and cover.

The following section describes the process when separate aqueous and lipid preparations are used. Please refer to local hospital guidelines. See Appendix E for some hints and tips to improve safety for lipid infusions.

- First prime the **lipid preparation** by connecting to a light-protected infusion set (Worthington *et al.*, 2021).
- Then connect this line to the **lipid** limb (PN infusion Kit/Octopus® or similar) with a 1.2-micron filter and prime the full length of the infusion set *before* priming the aqueous preparation (Does not apply to 3-in-1 preparations).
- Immediately close the roller clamp on the infusion line.
- Check the line carefully to ensure no air present.

- Cover the lipid preparation with the opaque bag supplied (currently red in colour), and apply label indicating the type of preparation (e.g., SPN lipid, IPN lipid), the date and time the infusion commences and the date and time to change the infusion. A brightly coloured "LIPID" label may also be used to identify the infusion preparation.
- Place Yellow or similar brightly coloured label clearly marked "LIPID" on the lipid administration set above and immediately proximal to the infusion pump. Place a second similar "LIPID" label proximal to the patient end of the infusion.
- Next, prime the **aqueous infusion** by connecting a separate light-protected infusion line to the aqueous bag and carefully expel all air.
- Connect this line to the **aqueous** limb of PN set (as above) with the 0.2-micron filter and prime. Close the roller clamp on the infusion line. Check the line to ensure no air present.
- Cover the aqueous preparation with the opaque bag supplied (currently silver/blue in colour), and apply label indicating the type of preparation (e.g., IPN aqueous/SPN aqueous preparation name), the date and time the infusion commences and the date and time to change the infusion.

Commencing Infusion

CAUTION

There is a high risk of errors occurring during this stage of the process so it is important that due care is taken.

Avoid interruptions and perform safety checks as described.

A standardised process such as the one described below can reduce the risk of serious errors/omissions occurring at this point. Refer to Appendix F *L is for Lipid*

- Check the patient's identity with the prescription and PN label, in line with national medication administration guidelines, to confirm correct patient, correct medication, and correct form immediately before connecting to the venous access device.
- 'Scrub the Hub' for 30 seconds with alcohol/chlorhexidine wipe 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).
- Remove discontinued infusions from the infusion pump(s) and dispose as per hospital policy.

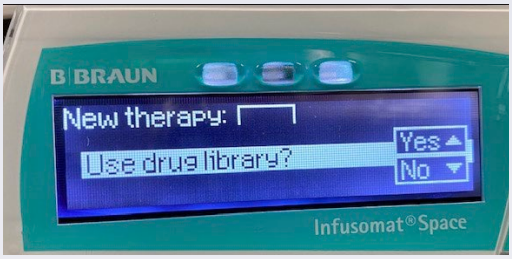
Setting infusion rate

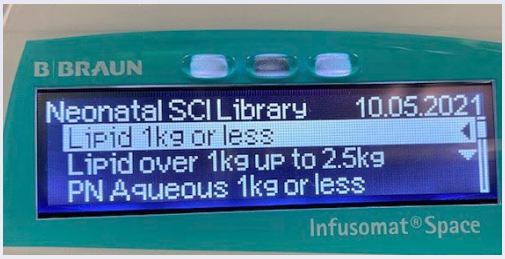
- **Carefully connect each infusion set to the corresponding infusion pump(s) and set the infusion rates.** A 3-in-1 preparation will require a single infusion pump. Where preparations other than a 3-in-1 preparation are used, the following process applies.
- **FIRST:** Load the Aqueous infusion. Carefully set the required infusion rate and volume. **Both** nurses must **independently check and verify settings** are set as prescribed.
- **SECOND:** Load the Lipid infusion. Select the correct dosing weight band if using programmed pumps with the National Drug Library (see section 5.7.10 below for process) and enter the infusion rate. For pumps without the National Drug Library set the prescribed infusion rate. **Both** nurses must **independently check and verify settings** as prescribed.
- Check all the connections are tight.
- Connect the new infusions to the intravenous cannula or catheter avoiding contamination of key parts by using sterile gauze to hold the outer surface of the connections.
- Remove gloves and decontaminate hands.
- Commence infusion at the prescribed rate (both staff to check and verify infusion rate as correct).

- Unclamp all infusion lines and start infusions.
- Sign the medication administration in the infant's medical record/drug Kardex/prescription sheet as per local guidelines.
- In the patient's health care record for each separate PN preparation/infusion, document the infusion rate (mL/hour) and volume infused hourly (includes hourly volume and running total), as well as any changes to the infusion rate which may occur.
- The infusion pumps must be secured on infusion stand/equipment pole and whenever possible run off mains electricity. Keep Lipid pump lowest on the stand to distinguish it from the Aqueous pump (see Appendix E).
- **Remember to take extreme care to ensure that aqueous and lipid preparations/infusions are clearly distinguished from each other, connected to the appropriate infusion sets, and set at the prescribed infusion rate for each. Ensure in line with your own hospital pump system.**

5.7.10 Programming the infusion pump for Lipid preparations using the National Drug Library

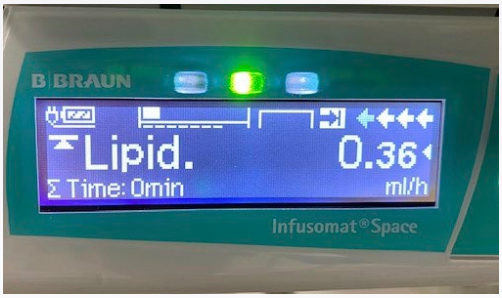
- Select "Use drug library – Yes". Select the appropriate patient profile and lipid infusion weight band.





- Programme the required flow rate and volume to be infused (VTBI) for 24 hours. Dose Guard applies weight-based limits to the flow rate (as per figures below).

- Ensure that the infusion screen displays "Lipid"



For aqueous preparations select solution label, i.e., PN/TPN.

5.7.11 Enteral nutrition during PN

Aim to provide even minimal enteral feeds (oral/via gastric tube) while providing PN if not contraindicated (Shaw, 2020). The absence of EN is associated with PN-associated liver disease (PNALD), see 'Hepatobiliary Complications' section 5.11.5. EN can also have a trophic effect on the GIT.

5.8 Cycling Parenteral Nutrition

Intermittent administration or 'cycling' of PN may help with partial or complete weaning off PN, enable compatible medications to be delivered through a single IV site, and allow a stable patient to have more freedom during the day for other activities (Shaw, 2020); it may also reduce the risk of cholestasis (especially in long term patients). Cycling of PN is not routine in short term PN but may be considered if long-term PN or if cholestasis.

5.8.1 Considerations when cycling PN

- Ensure that the patient is medically stable.
- Introduce in a controlled, step-wise fashion by reducing the infusion time by 1-2 hours each day of each PN preparation (i.e., both aqueous and lipid preparations simultaneously and in proportion to each other or 3-in-1 preparations) as tolerated, generally down to a minimum of 12 hours infusion per day. This depends on the individual as some infants, especially those who are preterm or VLBW, may not tolerate extended periods without a supply of glucose (Shaw, 2020).
- Consider maximum PN recommended infusion rates (see Appendix B which provides details of the maximum rate of individual nutrients where relevant).
- Monitor blood glucose and lipid tolerance throughout the process.
- During the final hour of infusion, reduce the infusion rate of CHO containing infusions to approximately half of the previous rate to prevent rebound hypoglycaemia. This applies to 2-in-1 preparations (containing AAs and CHO) and 3-in-1 preparations (containing AAs, CHO, and lipid). Lipid infusions do not require step-down infusion.

5.9 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 (EN). PN composition will vary depending on the PN individual order or preparation used, and in most cases the nutritional content of the PN will not be equivalent to the same volume of EN, i.e., 1 mL of PN is not the same as 1 mL of EN.

The process followed when transitioning from PN to EN, may differ according to the patient group and local practice.

5.9.1 Preterm Infants

- In preterm infants, once EN volumes are increased beyond trophic/minimal amounts (≥40 mL/kg/day) and are clinically tolerated, their contribution to nutritional intake should be considered when calculating PN requirements (Brennan *et al.*, 2018).
- As the EN volumes increase, PN volumes should be reduced accordingly without compromising nutritional intake. (See table below).
- Both the lipid infusion and aqueous PN infusion should be continued until the infant tolerates at least 120 mL/kg/day EN (Brennan *et al.*, 2018).

- The total fluid volume provided from PN and EN may be increased if required to meet fluid and nutrient requirements, according to local guidelines and once there are no contraindications. Additional fluids may be provided if required (e.g., glucose or saline, depending on the individual patient's need/tolerance).
- The 'Protocol for Standardised Parenteral Nutrition for Preterm Infants©', developed by Dr Ann-Marie Brennan, (Cork University Maternity Hospital and University College Cork, Copyright UCC, 2018) incorporates guidance on the transition from SPN to EN. Please refer to this protocol which is available locally for further details.

Table: Suggested titration of parenteral lipid according to EN volume 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

5.9.2 Term Infants and Children

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

- There should be a gradual transition from PN once a clinical decision has been made to commence EN.
- Full PN volumes should continue until at least 25% of nutritional requirements are met from EN.
- When reducing PN, ensure that aqueous and lipid infusions are reduced in correct proportion to each other or as per local guidance.

5.10 Monitoring of Parenteral Nutrition

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

5.10.1 Anthropometry

- Anthropometry (weight, length/height, head circumference) should be assessed regularly as a measure of growth.
- Measurements should be plotted on an appropriate growth chart for each patient and serial trends assessed.

5.10.2 Fluid Balance

- Fluid balance, including input and output from all sources, must be monitored daily and provision of fluid and electrolytes adjusted as required.
- Weight should be monitored as clinically indicated when assessing fluid balance

5.10.3 Biochemistry

- Biochemistry should be assessed as required, with caution to avoid unnecessary blood sampling and to use the minimum blood volumes required. Once established on PN, the need for regular biochemistry generally reduces. The recommended biochemical monitoring is detailed in Appendix H. Guidance on the management of biochemical complications is outlined in section 5.11.3.

Further guidance on monitoring during PN for preterm infants is provided by ESPGHAN (Puntis J *et al.*, 2018) and by Carnielli VP *et al.*, 2021 (specific to preterm infants).

5.11 Complications of Parenteral Nutrition

5.11.1 Infectious Complications: Management of suspected CRBSI

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

- Any decision to stop PN should be discussed with a senior clinician.A blood culture should be obtained.
- 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.
- The choice of antibiotics should be based on local antimicrobial guidelines. Antibiotics should be changed to narrow spectrum once the infective organism has been identified (Puntis *et al.*, 2018; Hartman *et al.*, 2018). The duration of antibiotics is guided by the identified organism.
- 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).
- Peripheral intravenous cannula should be removed if there is clinical evidence that it is infected (HCAI, 2014)
- CVAD infection should be managed in conjunction with the local Infection Prevention and Control team and national best practice guidelines (HCAI, 2014).

5.11.2 Catheter-related Complications

- 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).
- 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.
- 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.

5.11.3 Biochemical Imbalances

Biochemical imbalances may occur when receiving PN. Therefore, it is important to monitor biochemistry with appropriate frequency, (see Appendix F for recommended frequency) and to use age-appropriate reference ranges.

- Biochemical imbalances may be associated with negative clinical outcomes and should be avoided where possible. For accurate interpretation of results, consider the site used to obtain sample, e.g., avoid limb with PN/electrolyte/CHO infusion as sample may reflect content of PN infusion.
- When an imbalance is identified, aim to identify, and correct the cause. For example, check that the PN has been infused correctly, e.g., correct infusion rate, functioning catheter; and that the sample has not been taken from the line containing that nutrient, e.g., CHO, lipid, Na, etc. Sometimes intakes will need to be adjusted. Refer to local policies for further management

Amino Acid Imbalance

- Insufficient provision of AAs in PN can inhibit protein synthesis and limit growth.
- Low plasma urea levels, especially in preterm infants, may indicate inadequate AA provision.
- A rising serum urea level or rising serum ammonia level may indicate excess provision or poor tolerance of AAs.
- Steroids cause a reduction in growth by increasing protein breakdown and can contribute to a rise in plasma urea levels. AA tolerance should be monitored in neonates receiving steroids, and AA intake reduced according to tolerance.

Glucose Imbalance

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. Accuracy of point of care (POC) devices to measure blood glucose is still of concern. Therefore, if blood glucose measurements are outside the normal range on a POC device (including blood gas analyser), consideration should be given to confirming the results with a laboratory glucose measurement.

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

Hyperglycaemia

- Glucose intake beyond individual tolerance may be responsible for hyperglycaemia.
- Blood glucose levels greater than 8 mmol/L should be avoided in paediatric and neonatal ICU patients as it is associated with increased morbidity and mortality (Mesotten *et al.*, 2018).
- If blood glucose level is above 10 mmol/L and/or marked glycosuria, consider decreasing the glucose infusion rate (GIR) stepwise, for example by 1-2 mg/kg/minute (1.5-3 g/kg/day) taking care to avoid intakes below minimum recommended intakes (Mesotten *et al.*, 2018). See Appendix B for further guidance.
- If blood glucose level remains >10 mmol/L and/or marked glycosuria, consider insulin therapy, starting with a continuous low dose infusion. Restrict the use of insulin to conditions where reasonable adaptation of the GIR fails to control the hyperglycaemia (Mesotten *et al.*, 2018).
- All cases should be considered individually and monitor closely, taking care to avoid hypoglycaemia.

Refer to local policies for further management

Hypoglycaemia

- Repetitive and/or prolonged blood glucose levels of ≤2.5 mmol/L should be avoided (Mesotten *et al.*, 2018).
- Hypoglycaemia can be precipitated by significant reduction or discontinuation of glucose infusions.
- Check urine for ketones 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.

Refer to local policies for further guidance.

Lipid Imbalance

- Refer to Appendices F for recommended monitoring during parenteral nutrition and Appendix G for guidance and management of parenteral lipid intake according to triglyceride level.

Electrolyte imbalances

In all instances of electrolyte imbalances (hyper/hypo), consider all sources that contribute to intake. Management includes reducing or increasing intake from all sources, and to ensure correction at an acceptable rate. Refer to local policies for further guidance.

Sodium Imbalance

- Sodium balance depends on clinical circumstances such as fluid restriction, dehydration, or excessive water losses, as well as sodium intake.
- Large variation in serum sodium concentration in the very preterm neonate is an independent risk factor for poor neuro-motor outcome at two years and should be avoided (Baraton *et al.*, 2009).

Hyponatraemia

- Hyponatraemia is generally defined as a serum sodium level 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.
- In clinical practice a correction rate in the range of 8-12 mmol/L in 24 hours is acceptable (Somers *et al.* 2022).

Hypernatraemia

- Hypernatremia is generally defined as a serum sodium level >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, EN, medications and other infusions.
- A rapid correction of hypernatraemia may induce cerebral oedema, seizures, and neurological injury. In clinical practice, a reduction rate in the range of 8-12 mmol/L in 24 hours is recommended (Jochum *et al.*, 2018).

Refer to local policies for further guidance.

Potassium Imbalance

Hypokalaemia

- Hypokalaemia is generally defined as a serum potassium level of <3.5 mmol/L. It is rarely a cause for concern until the serum potassium level is <3 mmol/L. Hypokalaemia can result from chronic diuretic use and un-replaced GI losses, e.g., persistent gastric tube drainage, 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, supplementary IV fluids, 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 (2020).

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 >6.5 mmol/L or if ECG changes have developed.
- If a non-haemolysed potassium level is >5.5, potassium intake should be reduced or stopped and refer to local policy as necessary, including indications for cardiac monitoring.

Refer to local policies for further guidance.

Calcium Imbalance

Ionised serum calcium level, rather than total serum calcium level, correlate better with calcium functions such as cardiac contractility in infants.

Corrected calcium is a good indicator of serum calcium in term neonates, older children, and adults.

Hypercalcaemia

- Hypercalcaemia is generally defined as a serum calcium level >2.75 mmol/L or an ionised calcium level >1.25 mmol/L (Rodd *et al.*, 1999) or >1.45 mmol/L in preterm infants (Hsu and Levine, 2004).
- Hypercalcaemia may be associated with a low serum phosphate level, therefore ensure optimisation of phosphate level.
- Avoid decreasing calcium below recommended intake.

Hypocalcaemia

- Hypocalcaemia is generally defined as a serum calcium level <1.75 mmol/L or an ionised calcium level <0.9-1 mmol/L in preterm infants (Hsu and Levine, 2004) and is more common than hypercalcaemia.
- Early onset hypocalcaemia may occur within the first 3 days from birth in preterm infants born to mothers with unstable diabetes or in infants who experienced perinatal asphyxia.
- Additional calcium should be provided if calcium levels are low, and management in keeping with local policy.
- Late-onset hypocalcaemia can develop after the first week from birth 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.

Refer to local policies for further guidance.

Phosphate Imbalance

The reference range for serum phosphate levels varies according to age, therefore ensure age-appropriate reference range.

Hypophosphataemia

- In the presence of a low phosphate intake, the kidney retains phosphate and excretion in the urine reduces. Therefore, assessment of urine phosphate can be useful. See Senterre *et al.*, (2015) for further information.
- Phosphate deficiency may result in hypercalcaemia and hypercalciuria. Prolonged deficiency of phosphate may result in bone demineralisation and rickets.
- Extreme hypophosphataemia can be precipitated by nutritional restitution (refeeding syndrome – see section 5.11.4) and can result in muscle paralysis, cardiac dysfunction, and respiratory failure.
- When correcting phosphate imbalance, ensure adequate calcium and vitamin D intake.

Refer to local policies for further guidance.

Magnesium Imbalance

Hypermagnesaemia

- Hypermagnesaemia generally occurs when serum magnesium level is >1.25 mmol/L.
- 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).
- Most other cases occur in severe renal failure where magnesium intake has been excessive. In such cases, reduce magnesium intake, e.g., reduce/stop magnesium containing infusions or supplements, and commence cardiac monitoring (watch for 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.

Hypomagnesaemia

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

Refer to local policies for further guidance.

5.11.4 Refeeding Syndrome

- Refeeding syndrome is a potentially fatal complication observed in severely malnourished children, or infants with severe intrauterine growth restriction (IUGR) commencing PN after birth (Mihatsch *et al.*, 2018). Appropriate and early identification will help to avoid refeeding syndrome when commencing nutrition support.
- Refeeding syndrome is characterised by acute electrolyte imbalances, most notable hypophosphataemia, hypokalaemia, hypomagnesaemia, and hypoglycaemia.
- Refeeding syndrome may result in red cell dysfunction, rhabdomyolosis, respiratory failure and sudden death.
- To reduce the risk of refeeding syndrome please correct deficits slowly and refer to local policies for further guidance.

5.11.5 Complications in Long-term Parenteral Nutrition

Metabolic Bone Disease

- 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.
- Regular measurements of serum calcium, phosphorus, alkaline phosphatase, parathyroid hormone, and vitamin D concentrations are advised (Santerre *et al.*, 2015). Particular attention should be given to the calcium: phosphorus ratio supplied in prescribed PN (Chinoy *et al.*, 2019).
- Regular assessment of bone mineralisation should be undertaken in children on long-term or home PN.

Hepatobiliary Complications

- Although the pathogenesis of PN-associated liver disease (PNALD) is unknown, hepatobiliary complications of PN are in most cases moderate and reversible.
- Patients receiving long-term PN are at high risk of developing PNALD.
  - ✓ Risk factors for PNALD include:
  - ✓ Absence of EN 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 GIT-related which may cause liver injury.
  - ✓ Prematurity is a known risk factor especially if NEC or sepsis occurs.
  - ✓ Excessive or inadequate AA supply.
  - ✓ Excessive CHO intake and/or continuous PN infusion leading to hyperinsulinism and subsequently to steatosis.

Prevention and treatment of cholestasis

- Reduce risk factors where possible.
- Introduce EN as soon as possible, even if only minimal amount.
- Try to cycle PN as soon as clinically possible.
- Consider possible intestinal bacterial overgrowth. Contact Gastroenterology team for advice.
- 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 109/L, high prothrombin time, low albumin) or signs of hepatic fibrosis.

6.0 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 with neonatal and paediatric units.
- Distribution to other interested parties and professional bodies.
- The guideline development group has agreed that this guideline will be reviewed on a 3-yearly basis. Periodic update may be required should new pertinent evidence become available.

6.1 Education and Training

All healthcare professionals should have education on PN relevant to their setting prior to undertaking practice in this area.

6.2 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.

6.2.1 Each unit should audit their use of PN annually. See Appendix I for a sample audit template.

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

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

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8.0 Qualifying Statement

This guideline has been prepared to promote and facilitate standardisation and consistency of practice, using a multidisciplinary approach. The guideline development and revision process considered current available evidence and best practice, however advice may change as new evidence emerges or practice evolves. 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.

This guideline does 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.
- 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.

9.0 Appendices

Appendix A: Composition of Parenteral Nutrition Products

1. PN Trace Elements Preparations

The composition of the current range of preparations avaxilable to add trace elements to PN are outlined below. Please note that the range may change in future.

Peditrace®		
Trace element	**Composition per 1 mL**	
Copper	20 micrograms	(0.315 micromol)
Fluoride	57 micrograms	(3 micromol)
Iodine	1 microgram	(7.88 nanomol)
Iron	0 microgram	(0 micromol)
Manganese	1 microgram	(18.2 nanomol)
Selenium	2 micrograms	(25.3 nanomol)
Zinc	250 micrograms	(3.82 micromol)
Suitability	Infants and Children up to 40 kg	
Dose	Children ≤ 15 kg: 1 mL/kg/day up to maximum 15 mL/day Children 15-40 kg: 15 mL/day total dose	
Manufacturer	Fresenius-Kabi	

Additrace®		
Trace element	**Composition per 10 mL**	
Chromium	10 micrograms	(0.2 micromol)
Copper	1.3 mg	(20 micromol)
Fluoride	0.95 mg	(50 micromol)
Iodine	0.13 mg	(1 micromol))
Iron	1.1 mg	(20 micromol)
Manganese	0.27 mg	(5 micromol)
Molybdenum	19 micrograms	(0.2 micromol)
Selenium	32 micrograms	(0.4 micromol)
Zinc	6.5 mg	(100 micromol)
Suitability	Children and Adults >40 kg	
Dose	10 mL/day	
Manufacturer	Fresenius-Kabi	

Junyelt®		
Trace Element	**Composition per 1 mL**	
Copper	20 micrograms	(0.315 micromol)
Iodine	1 microgram	(0.0079 micromol)
Iron	0 microgram	(0 micromol)
Manganese	0.5 microgram	(0.0091 micromol)
Selenium	2 micrograms	(0.0253 micromol)
Zinc	100 micrograms	(1.53 micromol)
Suitability	Infants and Children	
Dose	1 mL/kg/day up to maximum 20 mL/day	
Manufacturer	Baxter Healthcare	

Junyelt also contains 1.16 microgram (0.0506 micromol) sodium and 0.31 micrograms (0.008 micromol) potassium per mL

- Individual trace element requirements may vary based on factors such as age, weight, duration of PN and underlying diseases.
- Pay particular attention when providing trace elements to patients on long-term PN, patients with renal or liver disease or impairment,reduced bile excretion, cholestatic liver disease, markedly reduced urine excretion, hyperthyroidism, or if altered requirements anticipated.
- During medium to long-term PN, ensure dose meets individual nutrient requirement. It may be necessary to adapt the dose with the use of additional preparations containing individual nutrients.
- Refer to company information regarding special warnings and precautions for use of trace elements in PN.
- For further information and guidance refer to company information and ESPGHAN/ESPEN/ESPR 2018 (Domellöf *et al.*, 2018).

2. PN Vitamin Preparations

The composition of the current range of preparations available to add water-soluble vitamins to PN are outlined below. Please note that the range may change in future.

Solivito® N	
Vitamin	**Composition per 1 mL**
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 micrograms
Folic Acid (B_9)	40 micrograms
Cobalamin (B_{12})	0.5 microgram
Ascorbic Acid (C)	10 mg
Suitability	Infants, children, adults Can be added to aqueous or lipid PN preparations
Dose	1 mL/kg/day up to maximum 10 mL/day Children 15-40 kg: 15 mL/day total dose
Manufacturer	Fresenius-Kabi

The composition of the current range of preparations available to add fat-soluble vitamins to PN are outlined below. Please note that the range may change in future.

Vitlipid® N Infant		
Vitamin	**Composition per 1 mL**	
Vitamin A (Retinol)	69 micrograms	(230 IU)
Vitamin D (Ergocalciferol)	1 microgram	(40 IU)
Vitamin E (α tocopherol)	0.64 mg	(0.7 IU)
Vitamin K (Phytomenadione)	20 micrograms	
Suitability	Infants and children up to age 11 years Can only be added to a lipid containing PN preparation	
Dose	Infants ≤2.5 kg: 4 mL/kg/day >2.5 kg: 10 mL/day total dose	
Manufacturer	Fresenius-Kabi	

Vitlipid® N Adult		
Vitamin	**Composition per 10 mL**	
Vitamin A (Retinol)	990 micrograms	(3300 IU)
Vitamin D (Ergocalciferol)	5 micrograms	(200 IU)
Vitamin E (α tocopherol)	9.1 mg	(10 IU)
Vitamin K (Phytomenadione)	150 micrograms	
Suitability	Children >11 years and adults Can only be added to a lipid containing PN preparation	
Dose	10 mL/day total dose	
Manufacturer	Fresenius-Kabi	

3. Volume of Parenteral Nutrition Constituents

Constituent	Volume	Quantity of Nutrient Provided
Aminoven® 25	6.7 mL	1 g amino acids (0.17g nitrogen)
Primene® 10%	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®	5 mL	1 g lipid (0.05 mmol phosphate)
30% NaCl	1 mL	5 mmol sodium + 5 mmol chloride
23.5% NaCl	1 mL	4.02 mmol sodium + 4.02 mmol chloride
15% KCl	1 mL	2 mmol potassium + 2 mmol chloride
22% KCl	1 mL	3 mmol potassium + 3 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
49.3% magnesium sulphate	1 mL	2 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 (0.2 micromol)

4. Standardised Aqueous Preparations for Preterm Infants

The composition of the current range of standardised aqueous preparations for preterm infants are outlined below. Please note the ranges may change in future.

cSPN1 Aqueous Solution *cSPN1 is designed to be specifically used in conjunction with the 'Protocol for Standardised Parenteral Nutrition for Preterm Infants'**													
Vol	**Energy**	**NPE**	**Protein**	**AA**	**Glucose**	**Na**	**K**	**Ca**	**P**	**Mg**	**Cl**	**Zn**	**Acetate**
mL	**kcal**	**kcal**	**g**	**g**	**g**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mcg**	**mmoL**
100	54	38	3.47	3.9	9.5	1	1	1	1	0.13	0.74	327	0.5

** Protocol is available at local hospital level*
NPE = Non-protein energy

Contains zinc: 327 micrograms (5 micromol)/100 mL.
Contains **no** additional trace elements (other than zinc) and no vitamins.

Indications: Preterm infants requiring standardised reduced electrolyte PN on day 1 and 2 from birth. Provide together with SPN lipid preparation.

Osmolarity: 900 mOsmol/L.

Infusion route: Peripheral or Central.

Miniumum and Maximum Volumes:
The Recommended cSPN1 Aqueous Solution starting volume is 65 mL/kg/d. The maximum recommended dose of cSPN1 is 90 mL/kg/d. cSPN1 Aqueous Solution is suitable for use for the first 48 hr from birth. Extra volume is provided by PN lipid preparation/infusion. If additional volume required, options include dextrose +/- electrolytes or saline.

Product details: 400 mL bag. Manufactured by Baxter.

Shelf life: 60 days from day of compounding.

Hanging time: 48 hours at room temperature.

cSPN2 Aqueous Solution *cSPN2 is designed to be specifically used in conjunction with the 'Protocol for Standardised Parenteral Nutrition for Preterm Infants'**														
Vol	**Energy**	**NPE**	**Protein**	**AA**	**Glucose**	**Na**	**K**	**Ca**	**P**	**Mg**	**Cl**	**Zn**	**Junyelt®**	**Acetate**
mL	**kcal**	**kcal**	**g**	**g**	**g**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mmoL**	**mcg**	**mL**	**mmoL**
100	51	38	3	3.33	9.38	3	1.38	1.4	1.5	0.19	0.63	325	0.8	1.38

* *Protocol is available at local hospital level*
NPE = Non-protein energy

Contains zinc: 325 micrograms (5 micromol)/100 mL.
Contains **no** vitamins.

Indications: Preterm infants requiring standardised maintenance PN from day 3+ from birth.
Provide together with SPN lipid preparation.
Use of cSPN2 on day 2 (before 48 hrs). It is acceptable to start cSPN2 from 24 hrs if considered clinically appropriate for the individual and once the infant is passing urine due to trace element content. Aim for a target intake of 90 mL/kg/d and a max of 105 mL/kg/d of cPSN2 on day 2 if given.

Osmolarity: 900 mOsmol/L.

Infusion route: Peripheral or Central.

Maximum volume:
The maximum recommended dose of cSPN2 Aqueous Solution is 120 mL/kg/d. cSPN2 Aqueous Solution is suitable for use from 48 hours onwards after birth. Extra volume is provided by PN lipid preparation/infusion. If additional volume required, options include dextrose ± electrolytes or saline.

Product details: 400 mL bag. Manufactured by Baxter.

Shelf life: 60 days from day of compounding.

Hanging time: 48 hours at room temperature.

5. Standardised Lipid Preparations for Preterm Infants/Infants <2.5 kg

The composition of the current range of standardised lipid preparations for preterm infants/infants <2.5 kg are outlined below. Refer to CHI for details of the current range of standardised preparations for other infants and children. Please note this range may change in future.

SMOFlipid® with Vitamins				
Vol	**Energy**	**Lipid**	**Solivito® N**	**Vitlipid® N**
mL	**kcal**	**g**	**mL**	**mL**
100	168	16.7	5.6	22.2

SMOFlipid® with Vitamins is suitable for use with the 'Protocol for Standardised Parenteral Nutrition for Preterm Infants – protocol available at local hospital level
Data Source: Fresenius Kabi

Indications: Preterm infants/infants <2.5 kg requiring standardised PN lipid.
Provide together with SPN aqueous preparation.

Osmolarity: 283 mOsm/L.

Infusion route: Peripheral or Central.

Max volume: 24 mL/kg/day (4 g/kg/day lipid) – note this volume provides more than the standard doses of vitamins.
Standard volume = 18 mL/kg/day (3 g/kg/day lipid) which provides the standard doses of vitamins for infants up to 2.5 kg.

Product details: 108 mL bag (contains SMOFlipid® 78 mL + Vitlipid® N 24 mL + Solivito®N 6 mL and provides 180 kcals).
Manufactured by Fresenius Kabi.

6. CHI Standardised PN Preparations for Neonatal and Paediatric Patients

CHI Standardised PN Solutions

Standardised Aqueous PN Solutions for Under 10kg (Composition per 100mls)

Standardised PN Solution Name	Vol	Energy	AA	Glucose	Na	K	Ca	P	Mg	Peditrace Trace Elements	Junyelt Trace Elements	Acetate
	mL	kcal	g	g	mmol	mmol	mmol	mmol	mmol	mL	mL	mmol
cSPN2	100	51	3,3	9,4	3	1,4	1,4	1,5	0,19	N/A	0,8	1,4
Under 2.5kg Central standard PN bag	100	74	3,5	15	4	2,2	1,5	1,3	0,2	1	N/A	1
Under 10kg Peripheral standard PN bag	100	49	2,3	10	3	2	0,6	0,6	0,12	0,8	N/A	N/A
Under 10kg Central standard PN bag	100	68	3	14	3	2	0,8	0,8	0,2	1	N/A	N/A
Under 10kg Highly Concentrated Central standard PN bag	100	87	3,3	18,3	5	3,3	1,33	1,33	0,33	1	N/A	N/A

Standardised 3-In-1 PN Solutions for Over 10kg Patients (Composition per 100mls)

Standardised PN Solution Name	Vol	Energy	AA	Glucose	Na	K	Ca	P	Mg	Peditrace	Solivito	Lipid	Vitlipid
	mL	kcal	g	g	mmol	mmol	mmol	mmol	mmol	mL	mL	g	mL
10 to 40kg All-In-One standard bag	100	93	2,8	12	4,5	3	0,3	0,35	0,15	1	0,67	3,3	0,65
Over 40kg All-In-One standard bag	100	102	3,6	12	6	4	0,4	0,5	0,2	0.5*	0,67	4	0,5

** The trace element preparation is Addaven in Over 40kg All-In-One standard bag.*

Standardised PN Lipid Solutions for Under 10kg (Composition per Bag)

Standardised PN Lipid Solution Name	Weight	Bag Vol	SMOF Lipid (20%)	Lipid	Solivito	Vitlipid	P	Energy
	kg	mL	mL	g	mL	mL	mmol	kcal
SMOF Lipid and Vitamins	≤2.5	108	78	18	6	24	1,53	182
Lipid B	2.5-10	125	104	22,2	7	14	1,77	222

Developed by the DIETETIC and PHARMACY Departments, Children's Health Ireland
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Appendix B
Recommended Parenteral Nutrition Intakes and Requirements

Notes

- In the following tables, estimated PN requirements are presented according to 'day of PN' however, individual patient requirements may vary and should be considered.
- Estimated requirements apply when PN is the main source of nutrition. When starting PN after previously tolerating feeds or PN, it may be acceptable to start at or advance more quickly to maintenance doses of nutrients. Ongoing monitoring is required.
- Achieving recommended intakes may be restricted by fluid volume available for PN, the stability of preparations and the maximum concentration of ingredients in the IV line.
- Estimated requirements are generally based on recommendations from ESPGHAN/ESPEN/ESPR/CSPEN, 2018, ESPGHAN, 2021 (Moltu SJ *et al.* 2021), Carnielli VP *et al.* in Koletzko B *et al.*, 2021 and NICE, 2020.
- Tables of recommended intakes are based on the range of PN products currently in use – these may change in future.

Table 1: Recommenced intakes for Preterm Infants

TABLE 1: Preterm Infants	Daily Requirements	Comments
Fluid (mL/kg/day)	**<1 kg** **Day 1 from birth:** 80-90 **Day 2 from birth:** 100-110 **Day 3 from birth:** 120-140 **Day 4 from birth:** 140-160 **Day 5 from birth:** 160-180 **After initial weight loss/during stable growth:** 140-160 **1-1.5 kg** **Day 1 from birth:** 70-90 **Day 2 from birth:** 90-110 **Day 3 from birth:** 110-130 **Day 4 from birth:**130-150 **Day 5 from birth:** 160-180 **After initial weight loss/during stable growth:** 140-160	The needs of individual patients may deviate markedly. Adjust according to individual requirement, taking account of weight, urine output, fluid balance, clinical status, and other fluid intake. Fluids may need to be restricted during critical illness and PN volume reduced accordingly

Table 1: Recommenced intakes for Preterm Infants *(continued)*

TABLE 1: Preterm Infants	Daily Requirements	Comments
Fluid (mL/kg/day)	**>1.5 kg** **Day 1 from birth:** 60-80 **Day 2 from birth:** 80-100 **Day 3 from birth:** 100-120 **Day 4 from birth:**120-140 **Day 5 from birth:** 140-160 **After initial weight loss/during stable growth:** 140-160	The needs of individual patients may deviate markedly. Adjust according to individual requirement, taking account of weight, urine output, fluid balance, clinical status, and other fluid intake. Fluids may need to be restricted during critical illness and PN volume reduced accordingly
Energy (kcal/kg/day)	**Day 1 from birth:** 45-55 **Day 2 onwards:** Increase step-wise as tolerated to 90-120 after initial postnatal weight loss and during recovery and stable growth Requirements may be reduced during critical illness as follows: *Early acute phase 40-55 kcal/kg/day* *Late acute phase 60-80 kcal/kg/day*	Adjust according to metabolic capacity and growth. Energy is provided by AA, CHO, and lipid. The energy value depends on the source (see Appendix C for further details), but in clinical practice the following are generally used: 4 kcal/g AA; 4 kcal/g CHO; 10 kcal/g lipid.
Amino Acids (AA) (g/kg/day)	**Day 1:** ≥1.5 **Day 2 onwards:** 2.5-3.5 (Accompanied by >65 NPE kcal/kg/day) *Requirements may be reduced during critical illness as follows:* *Early acute phase 1-2 g/kg/day* *Late acute phase 2 -3 g/kg/day*	Minimum 1.5 g/kg/day required to achieve N_2 balance on day 1. 2.5g/kg/day from day 2 onwards accompanied by NPE >65kcal/kg/day Maximum 4 g/kg/day. Utilisation of AA depends on sufficient energy intake: aim to provide 30-40 kcal/g AA [25 kcal NPE] /g AA].
Carbohydrate (CHO) (g/kg/day) **[Glucose Infusion Rate (GIR)** (mg/kg/minute)]	**Day 1:** 5.8-11.5 [GIR 4-8] **Day 2 onwards:** 11.5-14.4 [GIR 8-10] Increase stepwise over 2-3 days *Requirements may be reduced during critical illness as follows:* *Early acute phase 5-8 (10) g/kg/day* *Late acute phase 7-10 (12) g/kg/d*	Minimum 5.8 g/kg/day [GIR 4 mg/kg/minute]. Maximum 17.3 g/kg/day [GIR 12 mg/kg/minute]. Maximum IV CHO concentrations: Peripheral ≤12.5% Central ≤25%. In hyperglycaemia, reduce GIR stepwise to a minimum of 4 mg/kg/minute.
Lipid (g/kg/day)	**Day 1:** 1-2 **Day 2:** 2-3 **Day 3:** 3 **Day 4 5:** 3-4 *Requirements may be reduced during critical illness as follows:* *Early acute phase 1-2 g/kg/day* *Late acute phase 2-3 g/kg/day*	≥2 g/kg/day safe from day 1. Maximum 4 g/kg/day [0.17 g/kg/hour infusion rate]. If EN volume ≥60 mL/kg/day, reduce lipid dose to 2 g/kg/day.

Table 1: Recommenced intakes for Preterm Infants *(continued)*

TABLE 1: Preterm Infants	Daily Requirements	Comments
Sodium (Na) (mmol/kg/day)	**≤1.5 kg** **Day 1-2:** 0-2 (3) **Day 3:** 0-5 **Day 4-5:** 2-5 (7) **Stable Growth:** 3-5 (7) **>1.5 kg** **Day 1-2:** 0-2 (3) **Day 3:** 0-3 **Day 4-5:** 2-5 **Stable Growth:** 3-5	In practice, requirements may be higher, ensure close monitoring. Take account of additional Na from other sources, e.g. other IV fluids, flushes, EN.
Potassium (K) (mmol/kg/day)	**Day 1-3:** 0-3 **Day 4:** 2-3 **Stable Growth <1.5 kg:** 2-5 **Stable Growth >1.5 kg:** 1-3	Maximum IV K concentrations: Peripheral: ≤4 mmol/100 mL Central: ≤8 mmol/100 mL.
Calcium (Ca) (mmol/kg/day)	**Day 1-3:** 0.8-2 **Day 4 and beyond:** 1.6-3.5	
Phosphate (P) (mmol/kg/day)	**Day 1-3:** 1-2 **Day 4 and beyond:** 1.6-3.5	
Magnesium (Mg) (mmol/kg/day)	**Day 1-3:** -0.2 **Day 4 and beyond:** 0.2-0.3	Serum Mg may be elevated temporarily during initial postnatal days, secondary to maternal Mg therapy.
Trace Elements: Peditrace® (mL/kg/day)	1 up to maximum 10 mL/day total dose provided adequate urinary output	Contraindicated in patients with renal insufficiency (urine output <1 mL/kg/hour) and/or hepatic dysfunction.
Water-Soluble Vitamins: Solivito® N (mL/kg/day)	1 up to maximum 10 mL/day total dose	
Fat-Soluble Vitamins: Vitlipid® N Infant (mL/kg/day)	1-4 up to maximum 10 mL/day total dose	
Acetate (mmol/kg/day)	1-2 Adjust/increase as required to achieve/maintain acid-base balance	Acetate is provided as either Na or K acetate and may be used as an alternative to Na or K chloride to manage acid/base balance.

For preterm infants ≥2.5 kg, it may be appropriate to consider estimated requirements for term infants (table 2) and adapt individually according to clinical judgement.

Table 2: Estimated Parenteral Nutritional Requirements for Term Infants 0-1 years

TABLE 2: Term Infants 0-1 Year*	Daily Requirements	Comments
Fluid (mL/kg/day)	**Day 1 from birth:** 40-60 **Day 2 from birth:** 50-70 **Day 3 from birth:** 60-80 **Day 4 from birth:** 60-100 **Day 5 from birth:** 100-140 **After initial postnatal weight loss and during stable growth:** 140-160 **Beyond neonatal period (>1 month):** 120-150	The needs of individual patients may deviate markedly. Adjust according to individual requirement, taking account of weight, urine output, fluid balance, clinical status, and other fluid intake. Fluids may need to be restricted during critical illness and PN volume reduced accordingly
Energy (kcal/kg/day)	**Day 1:** 45-50 **After initial postnatal weight loss:** 60-65 **During stable growth:** 75-85 *Requirements may be reduced during critical illness as follows:* *Early acute phase 15-40 kcal/kg/day;* *Late acute phase 45-70 kcal/kg/d* *Generally, applies to infants <28 days.*	Adjust according to metabolic capacity and growth. Energy is provided by AA, CHO, and lipid. The energy value depends on the source (see PN Macronutrients – Appendix C for further details) but in clinical practice the following are generally used: 4 kcal/g AA; 4 kcal/g CHO; 10 kcal/g lipid.
Amino Acids (AA) (g/kg/day)	**Day 1:** Min 1.5/Max 3 **Day 2:** 2-3 **Day 3 onwards:** 2-3 *Requirements may be reduced during critical illness as follows:* *Early acute phase 0 (- 1) g/kg/day;* *Late acute phase 1.5-2.5 g/kg/day* *Generally, applies to infants <28 days*	Minimum 1.5 g/kg/day. Maximum 3 g/kg/day. PN and EN combined should not provide >4.5 g AA/kg/day. Aim to provide 30-40 kcal/g AA.
Carbohydrate (CHO) (g/kg/day) **[Glucose Infusion Rate (GIR)** (mg/kg/minute)]	**<28 days** **Day 1:** 3.6-7.2 [GIR 2.5-5] **Day 2 onwards:** 7.2-14.4 [GIR 5-10] Increase gradually over 2-3 days **>28 days-10 kg** **Day 1 of PN:** 2.9-5.8 [GIR 2-4] increase step wise to 8.6-14 [GIR 6-10] **during stable growth** *Requirements may be reduced during critical illness as follows:* *Early acute phase 4-7 (10) g/kg/day;* *Late acute phase 6-10 g/kg/day;* *Generally, applies to infants <28 days*	Minimum 3.6 g/kg/day [GIR 2.5 mg/kg/minute]. Maximum 17.3 g/kg/day [GIR 12 mg/kg/minute]. Maximum IV CHO concentrations: Peripheral ≤12.5% Central ≤25%. In hyperglycaemia, reduce GIR stepwise to a minimum of 3.6 mg/kg/minute.

Table 2: Estimated Parenteral Nutritional Requirements for Term Infants 0-1 years *(continued)*

TABLE 2: Term Infants 0-1 Year*	Daily Requirements	Comments
Lipid (g/kg/day)	**Day 1:** 1 **Day 2:** 2 **Day 3 onwards:** 3 Up to maximum 4 g/kg/day *Requirements may be reduced during critical illness as follows:* *Early acute phase 0-7 (10 g/kg/day;* *Late acute phase 6-10 g/kg/day;* *Generally, applies to infants <28 days*	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 [0.17 g/kg/hour infusion rate]. Monitor serum lipid tolerance (triglyceride/lipaemia index) closely.
Sodium (Na) (mmol/kg/day)	**Day 1-3:** 0-2 **Day 4-5:** 1-3 **Stable Growth:** 2-3	In practice requirements may be higher, ensure close monitoring. Take account of additional Na from other sources, e.g. other IV fluids, flushes, EN intake.
Potassium (K) (mmol/kg/day)	**Day 1-3:** 0-3 **Day 4-5:** 2-3 **Stable Growth:** 1.5-3	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 low serum Ca, 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 low serum P, 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/hour) 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: Estimated Parenteral Nutritional Requirements for Term Infants 0-1 years *(continued)*

TABLE 2: Term Infants 0-1 Year*	Daily Requirements	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.

* *For term infants <2.5 kg, it may be appropriate to also consider estimated requirements for preterm infants (table 1) and adapt individually according to clinical judgement.*

Table 3: Estimated Parenteral Nutritional Requirements for Children 1-12 years

TABLE 3 Children 1-12 Years	Daily Requirements	Comments
Fluid (mL)	**1st 10 kg:** 100 mL/kg/day **2nd 10 kg:** 50 mL/kg/day **Every kg thereafter:** 20 mL/kg/day up to max 2000 mL/day for females; 2500 mL/day for males	Maintenance fluid requirements (mL/kg body weight/day) for children >10 kg is estimated using the Holliday Segar method (Holliday *et al.*, 1957). PN is normally administered in ≤100% maintenance fluid requirements, however PN volume may be more or less than this depending on nutritional requirements, clinical condition, other infusions etc.
Energy (kcal/kg/day)	**1-7 years** **Acute phase:** 40-45 **Stable Phase:** 55-60 **Recovery phase:** 65-75 **7-12 years** **Acute phase:** 30-40 **Stable phase:** 40-55 **Recovery phase:** 55-65	Individual requirements may differ markedly due to heterogeneity of patients, e.g., the upper end of these energy requirements can hugely overestimate energy needs in a child who is likely bed-bound. Total parenteral energy requirements of stable patient can be calculated from resting energy requirements with adding constants for physical activity, catch up growth and disease factors. Energy requirements for PN in children are unlikely to exceed Estimated Average Requirements (EAR) for age (SACN, 2011). Refer to Appendix H for details. Energy is provided by AA, CHO, and lipid. The energy value depends on the source (see Appendix C for further details) but in clinical practice the following are generally used: 4 kcal/g AA; 4 kcal/g CHO; 10 kcal/g lipid.

Table 3: Estimated Parenteral Nutritional Requirements for Children 1-12 years *(continued)*

TABLE 3 Children 1-12 Years	Daily Requirements	Comments
Amino Acids (AA) (g/kg/day)	**1-3 years** 1-2.5 **3-12 years** 1-2	Aim to provide 30-40 kcal energy/g AA.
Carbohydrate (CHO) (g/kg/day) **[Glucose Infusion Rate (GIR)** (mg/kg/minute)]	**11-30 kg** **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] **31-45 kg** **Acute Phase:** 1.4-2.2 [GIR 1.5-2.5] **Stable Phase:** 2.2-4.3 [GIR 1.5-3] **Recovery Phase:** 4.3-5.8 [GIR 3-4]	Maximum IV CHO concentrations: Peripheral ≤12.5% Central ≤25%.
Lipid (g/kg/day)	**Day 1:** 1 **Day 2:** 2 **Day 3 onwards:** 2-3	Maximum lipid intake is 3 g/kg/day and is rarely required; this depends on clinical condition and energy requirements. Maximum lipid infusion rate 0.125 g/kg/hour.
Sodium (Na) (mmol/kg/day)	1-3	Usually start on 3 mmol/kg/day if serum Na level within normal range. Take account of additional Na from other sources, e.g. other IV fluids, flushes, EN intake.
Potassium (K) (mmol/kg/day)	1-3	Provide K as soon as adequate urine output. If serum k level within normal range: start 2.5 mmol/kg (<15 kg) or 2 mmol/kg (>15 kg). Maximum IV K concentrations: Peripheral: ≤4 mmol/100 mL Central: ≤8 mmol/100 mL.
Calcium (Ca) (mmol/kg/day)	0.25-0.4	If low serum Ca, Ca content of PN may need to be increased. Refer to BNF for Children.
Phosphate (P) (mmol/kg/day)	0.2-0.7	If low serum low, P content of PN may need to be increased. Refer to BNF for Children.
Magnesium (Mg) (mmol/kg/day)	0.1	

Table 3: Estimated Parenteral Nutritional Requirements for Children 1-12 years *(continued)*

TABLE 3 Children 1-12 Years	Daily Requirements	Comments
Trace Elements: **15-40 kg:** **Peditrace®** **>40 kg:** **Additrace®** (mL)	**<15 kg: 1 mL/kg/day** Peditrace: 15mL/day total dose **15-40 kg** Peditrace: 15mL/day total dose **>40 kg** Additrace: 0.2mL/kg/day Up to 10 mL/day total dose	Contraindicated in patients with renal insufficiency (urine output <1 mL/kg/hour) and/or hepatic dysfunction. If trace elements held/reduced on an ongoing basis, consider additional Zn and Se.
Water-Soluble Vitamins: **Solivito® N** (mL)	1 mL/kg/day up to maximum 10 mL/day total dose	
Fat-Soluble Vitamins: **≤11 years:** **Vitlipid® N Infant** (mL) **>11 years:** **Vitlipid® N Adult) (mL)**	10 mL/day total dose	Maximum dose 10 mL/day for Vitlipid® N and Vitlipid® N Adult

Table 4: Estimated Parenteral Nutritional Requirements for Adolescents 13-18 years

TABLE 4: Adolescents 13-18 Years	Daily Requirements	Comments
Fluid (mL)	**1st 10 kg:** 100 mL/kg/day **2nd 10 kg:** 50 mL/kg/day **Every kg thereafter:** 20 mL/kg/day up to max 2000 mL/day for females; 2500 mL/day for males	Maintenance fluid requirements (mL/kg body weight/day) for children >10 kg is estimated using the Holliday Segar method (Holliday *et al.*, 1957). PN is normally administered in ≤100% maintenance fluid requirements, however PN volume may be more or less than this depending on nutritional requirements, clinical condition, other infusions etc.

Table 4: Estimated Parenteral Nutritional Requirements for Adolescents 13-18 years *(continued)*

TABLE 4: Adolescents 13-18 Years	Daily Requirements	Comments
Energy (kcal/kg/day)	**Early Acute phase:** 20-30 **Late Acute/Stable phase:** 25-40 **Recovery phase:** 30-55	Individual requirements may differ markedly due to heterogeneity of patients, e.g., the upper end of these energy requirements can hugely overestimate energy needs in a child who is likely bed-bound. Individual assessment is recommended considering resting energy expenditure, physical activity, growth, and disease states. Energy requirements for PN in children are unlikely to exceed Estimated Average Requirements (EAR) for age (SACN, 2011) due to the absence of diet induced thermogenesis and reduced activity, and estimated resting energy requirements (REE) should be considered. Refer to Appendix H for further details. Energy is provided by AA, CHO, and lipid. The energy value depends on the source(see Appendix C) but in clinical practice the following are generally used: 4 kcal/g AA; 4 kcal/g CHO; 10 kcal/g lipid.
Amino Acids (AA) (g/kg/day)	1-2 depending on clinical condition and requirements	Aim to provide 30-40 kcal/g AA.
Carbohydrate (CHO) (g/kg/day) **[Glucose Infusion Rate (GIR)** (mg/kg/minute)]	**Body Weight: 31-45 kg** **Acute Phase:** 1.4-2.2 [GIR 1-1.5] **Stable Phase:** 2.2-4.3 [GIR 1.5-3] **Recovery Phase:** 4.3-5.8 [GIR 3-4] **>45 kg** **Acute Phase:** 0.7-1.4 [GIR 0.5-1] **Stable Phase:** 1.4-2.9[GIR 1-2] **Recovery Phase:** 2.9-4.3 [GIR 2-3]	Maximum IV CHO concentrations: Peripheral ≤12.5% Central ≤25%.
Lipid (g/kg/day)	**Day 1:** 1 **Day 2:** 2 **Day 3 onwards:** 2-3	Maximum 3 g/kg/day and is rarely required; this depends on clinical condition and energy requirements.

Table 4: Estimated Parenteral Nutritional Requirements for Adolescents 13-18 years *(continued)*

TABLE 4: Adolescents 13-18 Years	Daily Requirements	Comments
Sodium (Na) (mmol/kg/day)	1-3	If serum Na level within normal range, usually start on 3 mmol/kg/day. Take account of additional Na from other sources, e.g. other IV fluids, flushes, enteral intake.
Potassium (K) (mmol/kg/day)	1-3	Provide K as soon as adequate urine output. In practice if serum K level within normal range, start on 2 mmol/kg/day.
Calcium (Ca) (mmol/kg/day)	0.25-0.4	If serum Ca level is low, PN Ca may need to be increased. Refer to BNF for Children.
Phosphate (P) (mmol/kg/day)	0.2-0.7	If serum P level low, PN P may need to be increased. Refer to BNF for Children.
Magnesium (Mg) (mmol/kg/day)	0.1	
Trace Elements: **15-40 kg:** **Peditrace®** **>40 kg:** **Additrace®** (mL)	**15-40 kg** **Peditrace:** 15 mL/day total dose **>40 kg** **Additrace:** 0.2 mL/kg/day up to 10 mL/day total dose	Contraindicated in patients with renal insufficiency (urine output <1 mL/kg/hour) and/or hepatic dysfunction. If trace elements held/reduced on an ongoing basis, consider additional Zn and Se.
Water-Soluble Vitamins: **Solivito® N** (mL/day)	10 mL/day total dose	
Fat-Soluble Vitamins: **Vitlipid® N Adult** (mL/day)	10 mL/day total dose	

Appendix C: Parenteral Nutrition 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 CHO = 3.4 kcal – rounded to 4 kcal in clinical practice	
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® 10% Suitable ≤10 kg	1 g AA = 4 kcal	AA g divided by 6.67 = N_2 g
	Synthamin 17EF® Suitable >10 kg	1 g AA = 4 kcal	AA divided by 6.06 = N_2 g
	Vaminolact®	1 g AA = 3.7 kcal – rounded to 4 kcal in clinical practice	AA g divided by 7.02 = N_2 g

Appendix D: **Glucose Infusion Rate Calculation**

To calculate the Glucose Infusion Rate (GIR), first determine the CHO intake.
The CHO intake can be calculated based on the CHO concentration of the fluid.

Carbohydrate concentration = grams of CHO per 100 mL.
This may also be expressed as a percentage (%)
e.g., 12.5 g CHO per 100 mL = 12.5% CHO concentration.

Carbohydrate intake (g/kg/day) = CHO concentration (g/100 mL) x daily fluid intake (mL/kg/day) ÷ 100
e.g., 12.5% CHO (12.5 g CHO per 100 mL) x 150 mL/kg/day fluid intake ÷ 100 = 18.75 g/kg/day.

Carbohydrate intake expressed as glucose infusion rate
(GIR) = CHO (glucose) intake (g/kg/day) ÷ 24 (hours) ÷ 60 (minutes) x 1000 mg/kg/minute
e.g., 18.75 g/kg/day ÷ 24 (hours) ÷ 60 (minutes) x 1000 = 13 mg/kg/minute.
GIRs may also be calculated by dividing CHO intake (g/kg/day) by 1.44

Example:

CHO concentration of fluid: **12.5** %
Daily fluid intake: **150** mL/kg

CHO concentration (%)
= **12.5** grams of glucose per 100 mL

CHO intake (g/kg/day)
= CHO concentration (**12.5** g/100 mL) **x** daily fluid intake (**150** mL/kg/day) **÷ 100 = 18.75** g/kg/day

CHO intake expressed as glucose infusion rate (GIR) (mg/kg/minute)
= CHO intake (**18.75** g/kg/day) **÷ 24** (hours) **÷ 60** (minutes) **x 1000 = 13** mg/kg/minute

Appendix E:
L is for LIPID Tool

Remember the L's of Lipid Administration

Avoiding infusion rate errors with Parenteral Nutrition

*****Lipid Bag is Red*****

Label	Infusion lines, bags and pumps should be labelled.
Light blue filter	Prime and administer Lipid through the 1.2 micron light blue filter provided. Remember: Lipid bag is **red.**
Lipid pump Lower	The lower pump is used to deliver Lipid infusion; the Aqueous pump sits above it.
Lipid bag on Left	Hang the Lipid bag on the left hand side of the infusion stand; the Aqueous bag hangs on the right.
Library Limits	Program PN infusions via drug library to ensure safe rate limits are in place
Lipid rate set Last	Set Aqueous rate first & Lipid rate last
Lipid rate Is Less	Lipid is always infused at a lower rate than Aqueous
Lights on	Turn the room lights on (or the pump light up) to set/check PN pump rates
Look!	Look at your infusions and get your pump rates second checked before pressing start. **PN Aqueous** = pale yellow, translucent, Higher Rate **PN Lipid** = off-white, non-translucent., Lower Rate

Appendix F: **Recommended Monitoring during Parenteral Nutrition**

- This is a guideline only. Monitoring requirements may differ depending on the infant/child and the clinical situation. Refer to local policies and guidelines.
- Monitoring may be required more frequently if clinically indicated and/or if PN intake changes.
- Avoid unnecessary blood sampling. Assess blood levels only as required.
- 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 generally not replace serum monitoring until patient is stable on PN. POCT measurements outside the normal range must be confirmed with laboratory samples
- Blood glucose measurements should preferably be performed on blood gas analysers or as per local guidelines (Mesotten *et al.*, 2018).
- Avoid taking blood sample from line or limb where IV cannula is sited that contains the ingredient being measured, e.g., glucose or sodium, as this may interfere with the result.
- Each unit should identify the individual(s) responsible for reviewing biochemistry results and taking appropriate action when results are abnormal.
- Low serum albumin levels do not tend to correlate with nutritional status.
- Electrolyte levels may reflect hydration status/hydration status may affect electrolyte levels.
- Assessment of urine electrolytes is useful to determine urine losses, e.g., if persistent hyponatremia.
- 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.
- If long-term PN or if renal failure, hepatic disease or pre-existing imbalances, monitoring of trace elements (including zinc, selenium, manganese, copper) is required.

Suggested Frequency of Monitoring during PN

	First Week/During Critical Illness					When Stable			
	Daily	Day 1	Day 2	Day 3-4	Day 5-7	Daily	Weekly	Fort-nightly	Monthly
Infusion site	hourly					✓			
Fluid balance	✓					✓			
Weight	✓						✓		
Urinary glucose	✓								
Urinary sodium, calcium, phosphate					✓		✓		
Blood glucose	✓					✓			
Electrolytes: Na, K, Cl*		✓	✓	✓	✓		✓		
Urea, Creatinine			✓		✓		✓		
Calcium			✓		✓		✓		
Phosphate, Magnesium			✓		✓		✓		
Triglyceride/Lipaemia Index^				✓			✓		
LFTs, Alk Phos, Protein, Albumin					✓		✓		
Bilirubin				✓				✓	
Full Blood Count					✓			✓	✓
Iron studies**									✓**
Ferritin – if receiving IV iron							✓		
Trace elements: Cu, Mn, Se, Zn†									✓†
Vitamins A, D, E									✓‡
Vitamins B_1, B_2, B_6, C, B_{12} and Folate‡									✓‡
Growth (weight, OFC, length)		✓					✓		

* During critical illness – more frequent monitoring may be required. Daily electrolytes during severe illness and on alternate days when stable is advised (Carnielli *et al.*, 2021).

^ Assess TG 24-48 hours after each increase of 1 g/kg/day lipid until recommended lipid intake tolerated. When recommended lipid intake tolerated and stable, assess TG once weekly. Please refer to table (appendix G) for further guidance

** Iron studies – Iron, TIBC, transferrin, transferrin saturations and ferritin 4-6 weekly.

† Copper, Manganese Selenium and Zinc after 1 month; then 6 monthly for Aluminium, Cobalt, Copper, Manganese, Selenium and Zinc

‡ All vitamins (fat-soluble and water-soluble) after 1 month; then 3 monthly for vitamins A, D, E, B_1, B_2, B_6, C, B_{12}; and 4-6 weekly for folate.

Appendix G: Recommended Adjustment of PN Lipid According to Triglyceride Level

- While there is limited evidence to guide action based on triglyceride (TG) levels, the following recommendations may be used in practice. Please refer to local guidelines for further management.
- 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.
- If TG level is above the limits, lowering not stopping lipid dose is generally recommended. In exceptional cases lipid infusion may need to be discontinued temporarily.
- Some centres may monitor Lipaemia Index as an alternative to TG in line with local policy (see below).

Table 6: Suggested PN Lipid Monitoring and Adjustment

Parenteral Nutrition Lipid Intake Based on Triglyceride (TG) Level	
TG Level	**Recommended PN Lipid Intake**
Infants: <3 mmol/L (<265 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
Children: ≤4.5 mmol/L (≤400 mg/dL)	– When recommended lipid intake tolerated, assess TG once weekly
3-3.9 mmol/L (265-350 mg/dL)*	– Reduce lipid by 1 g/kg/day and repeat TG after 24 hours – Repeat TG <3: increase lipid by 0.5 g/kg/day – Repeat TG ≥3: maintain current (reduced) lipid dose
>3.9-4.5 mmol/L (350-400 mg/dL)*	– Reduce lipid by 2 g/kg/day and repeat TG after 24 hours – Repeat TG <3: increase lipid by 0.5 g/kg/day – Repeat TG ≥3: maintain current (reduced) lipid dose
Children: >4.5mmol/L (>400 mg/dL)	– If TG above the limits, lowering not stopping lipid dose is generally recommended. – In exceptional cases lipid infusion may need to be discontinued temporarily.

* Applies to preterm infants – from Carnielli VP *et al.*, 2021 in Koletzko B *et al.*, 2021

Parenteral Nutrition Lipid Intake Based on Lipaemia Index (LI) Level	
LI Level	**Recommended PN Lipid Intake**
<1 g/L	Advance lipid intake as normal
1-1.5 g/L	Halve the lipid intake and repeat LI after 24 hours or when next appropriate
>1.5 g/L	Discontinue lipid for 24 hours, then restart at a lower dose and repeat the LI after a further 24 hours

Appendix H: Paediatric Energy Requirements

1. Average Energy Requirements for Paediatrics (SACN, 2011)

	Male			Female		
Age	**Weight[a]**	**Kcal/day[b]**	**Kcal/kg/day[b]**	**Weight[a]**	**Kcal/day[b]**	**Kcal/kg/day[b]**
Breastfed						
1-2 months	5.0	526	96	4.7	478	96
3-4 months	6.7	574	96	6.1	526	96
5-6 months	7.7	598	72	7.1	550	72
7-12 months	9.0	694	72	8.3	646	72
Formula-Fed						
1-2 months	5.0	598	120	4.7	550	120
3-4 months	6.7	622	96	6.1	598	96
5-6 months	7.7	646	96	7.1	622	96
7-12 months	9.0	742	72	8.3	670	72
Mixed feeding or Unknown						
1-2 months	5.0	574	120	4.7	502	120
3-4 months	6.7	598	96	6.1	550	96
5-6 months	7.7	622	72	7.1	574	72
7-12 months	9.0	718	72	8.3	646	72
1 year	9.6	765	80	9.0	717	80
2 years	12.2	1004	82	11.5	932	81
3 years	14.4	1171	81	13.9	1076	77
4 years	16.3	1386	85	16.0	1291	81
5 years	18.6	1482	80	18.2	1362	75
6 years	21.0	1577	75	21.0	1482	71
7 years	23.0	1649	72	23.0	1530	67
8 years	26.0	1745	67	26.0	1625	63
9 years	29.0	1840	63	29.0	1721	59
10 years	31.5	2032	65	32.0	1936	61
11 years	34.5	2127	62	35.9	2032	57
12 years	38.0	2247	59	40.0	2103	53
13 years	43.0	2414	56	46.0	2223	48
14 years	49.0	2629	54	51.0	2342	46
15 years	55.5	2820	51	53.0	2390	45
16 years	60.2	2964	49	55.3	2414	44
17 years	64.0	3083	48	57.0	2462	43
18 years	66.2	3155	48	57.2	2462	43

[a] Median weight from thw UK-WHO growth charts ages 0-4 years and the UK 1990 reference for children aged >4 years.

[b] Energy requirements are based on the average energy required for people of a healthy weight who are moderately active (at PAL of 1.4 for 1-3 year olds; 1.58 for 3-10 year olds and 1.75 for 10-18 year olds). Estimated energy requirements will be greater in more active people, and lower in those that are more sedentary.

2. Schofield equations for calculating Resting Energy Expenditure (Schofield, 1995)

Age	Male	Female
0-3 years	59.511 x weight (kg) – 30.4	58.316 x weight (kg) – 31.1
3-10 years	22.705 x weight (kg) + 504.3	20.315 x weight (kg) + 485.9
10-18 years	17.686 x weight (kg) + 658.2	13.384 x weight (kg) + 692.6

Note: Tables above (1 and 2) do not apply to babies born preterm.

Appendix I: **Summary**

Example of PN requirements for 1 kg baby (<2.5kg)

	Units	Starting values	Target values (when stable growth achieved)
Amino acids (AA)	g/kg/24h	≥1.5	3.5 (max 4)
Carbohydrate CHO GIR (mg/kg/min)	g/kg/24h mg/kg/min	5.8-11.5 (4-8)	11.5-14.4 (8-10)
Lipid	g/kg/24h	1-2	3-4
Sodium	mmol/kg/24h	0-2 (3)	3-5 (7)
Potassium	mmol/kg/24h	0-3	2-5
Calcium	mmol/kg/24h	0.8-2	1.6-3.5
Phosphate	mmol/kg/24h	1-2	1.6-3.5
Magnesium	mmol/kg/24h	0.2	0.3
Trace elements: **Peditrace IPN, Junyelt SPN**	mL/kg/24h	1	1
Fat soluble vitamins Vitlipid N infant	mL/kg/24h	4	4
Water soluble vitamin Solivito N	mL/kg/24h	1	1
Acetate	mmol/kg/24h	1-2	1-2
TFI recommendations	mL/kg/24	70-90	140-160

Please note above recommendations are a guide only. Please refer to PN guideline for further details.

1. Aim to ↑ stepwise to achieve targets, taking into account fluid and electrolyte intake from other sources.
2. Aim to provide target PN volumes – consider modifying infusions to ensure adequate PN running.
3. If single electrolyte/glucose disturbance, consider additional IV supplementation e.g. saline, dextrose.
4. Refer to local protocols for use of Standardised PN. In instances of multiple electrolyte disturbances or severe metabolic acidosis or if target PN volumes cannot be met, consider individualised PN.

	Physiology
Pre-diuretic phase	↓ urine output ↓ urinary excretion of Na & K ↑ insensible water losses
Diuretic phase	↑ urine output ↑ Na & K excretion Hypernatremia (water loss > Na loss) Weight loss
Post-diuretic phase	Urinary water and electrolyte excretion ↓

If hyponatremia

- Too much fluid?
- Water gain/poor UO?
- Sodium losses?
- Inadequate sodium intake?

If hypernatremia

- Is fluid intake enough?
- Is there sodium in other sources?

Review

- Age of baby
- Weight
- TFI
- Balance
- UO
- Sodium intake
- Consider losses

NB Infant TFI, can adjust IPN volume within 10% of prescribed volume

If infant dry, may need to advance TFI by 10-20ml/kg/day

If infant overloaded, may need to reduce TFI by 10-20ml/kg/day

Lipid infusion based on triglyceride level	
≤3 mmol/L	Advance lipid intake as normal Assess TG 24-48 hours after each increase
>3 mmol/L	Reduce lipid intake to dose previously tolerated Recheck TG after 24 hours

Appendix J: Sample Parenteral Nutrition 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	Insert number

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

How many patients received PN for each of the following durations?	1-2 days	3-7 days	8-10 days	11-21 days	>21 days

How many of each of the following types of PN preparations were used?	Neonatal Standard Aqueous Preparation	Paediatric Standard Aqueous Preparation	Standard Lipid Preparation	Individualised 2-in-1 Preparation	Individualised 3-in-1 Preparation

How many patients received SPN and IPN in each of the following categories?	Preterm Infants <2.5 kg	Term Infants 0-1 year	Children 1-12 years	Adolescents 13-18 years
SPN				
IPN				
Total				

How many of each of the following types of PN preparations were wasted, *i.e., ordered but expired before use or were no longer suitable or required for the patient?*	Preterm Infants <2.5 kg	Term Infants 0-1 year	Children 1-12 years	Adolescents 13-18 years
SPN				
IPN				
Total				

Number of catheter-related sepsis that occurred in patients receiving PN?	0	1-3	4-6	7-9	10+

Number 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 over the last 12 months

What number of each category of staff received education in relation to PN, *e.g., review of national guideline, attendance at PN education session?*	Total number of staff in each category	Number who received education in relation to PN
Consultant		
Registrar		
Senior House Officer		
Intern		
Clinical Nurse Manager 1-3		
Registered Advanced Nurse Practitioner		
Clinical Nurse Specialist		
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 the indication for PN and 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 (Yes/No)	Time PN commenced post-birth in neonates (Age in hours)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

For a sample of ten patients who have received IPN within the last month (or all patients if <10 patients in total), please review the indication for IPN, and if IPN was used for the appropriate indication.

Patient	Indication for PN	Appropriate (Yes/No)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Please record issues relating to PN delivery and the frequency over the last 1 month/1 year

Issue relating to PN delivery	Occurrence (Yes/No)	Frequency/Quantity
Late delivery of IPN		
Non delivery of IPN		
Late delivery of SPN		
Non delivery of SPN		
SPN products delivered with shorter than expected shelf life?		
Other – please specify		

Number of PN-related errors in the last month/year	Administration Errors	Prescribing Errors	Other (Include details)
	Month Year	Month Year	

Appendix K: Acknowledgements and Approval

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

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Appendix L: Glossary of Terms, Abbreviations and Definitions

AA	Amino Acid
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
CHI	Children's Health Ireland
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
IPN	Individualised Parenteral Nutrition
IU	International Units

IUGR	Intra-Uterine Growth Restriction
IV	Intravenous
Kcal	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
VTBI	Volume To Be Infused

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 and functioning). PN usually comprises of both aqueous and lipid preparations. Aqueous preparations may also be referred to as 'solutions', while the lipid preparations may be referred to as 'emulsions'; for the purpose of this guideline, both are generally referred to as preparations.
Enteral Nutrition (EN)	For the purpose of this guideline, the term 'enteral' refers to nutrition that is provided directly to the GIT, 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)
Critical Illness	Any life-threatening condition induced by sepsis, major surgery, or other insults associated with tissue injuries, such as severe trauma, hypoxia-ischaemia, severe cardiorespiratory compromise, or any other acute illness requiring intensive care. During critical illness, it is prudent to adapt nutritional care according to the phases of metabolic stress response. This approach would help avoid inappropriate nutrition, especially overfeeding in the early phase and under feeding during recovery (Moltu *et al.*, 2021). Three phases are described: early acute, late acute and recovery. The phases described below can occur earlier in preterm infants or neonates with less illness severity; or can be delayed in neonates with severe injury insults. Assess the phase of illness every 24 hours and adapt nutritional support accordingly.

Early Acute Phase of Critical Illness	This phase describes the acute metabolic response in critical illness. The response is proportional to the degree of illness severity and duration. Despite reduced energy needs, there is an increased risk of hyperglycaemia due to reduced glucose uptake. This phase usually ends when clinical symptoms stabilise and acute cardio-respiratory support can be reduced. The duration is variable but generally starts within 6 hours from the onset of critical illness and lasts 1-2 days (Moltu *et al.*, 2021).
Late Acute Phase of Critical Illness	Depending on illness severity, this phase generally corresponds to days 3-7 from the onset of illness (Moltu *et al.*, 2021).
Recovery Phase of Critical Illness	Intensive cardiorespiratory care is typically no longer required (generally >7days). Previously referred to as the stable phase. In children, when the child is mobilising, it is called the recovery phase (Mesotten *et al.*, 2018).
Parenteral (PN) Phase of Nutrition Support	Phase during which infant is fully dependent on PN for nutrition, i.e., enteral nutrition intake is not considered and estimated requirements are based on PN recommendations and PN intakes only (Brennan *et al.*, 2018).
Transition (TN) Phase of Nutrition Support	Phase when enteral nutrition is increasing and replacing PN. During this phase, estimated requirements are based on both PN and EN recommendations and PN and EN intakes combined (Brennan *et al.*, 2018).
Enteral Nutrition (EN) Phase of Nutrition Support	Phase during which the infant is fully established on milk feeds and estimated requirements are based on EN recommendations and EN intakes only (Brennan *et al.*, 2018).

It is important to adapt nutritional care according to the metabolic stress response during the different phases of critical illness, e.g., to avoid over-nutrition during the early (catabolic) phase and under-nutrition during recovery. For further details on the different phases of critical illness and the nutritional management, refer to 'Nutritional Management of the critically ill neonate: A position paper of the ESPGHAN Committee on Nutrition' (Moltu SJ *et al.*, 2021).