Neonatal Parenteral and Enteral Nutrition

A Resource Guide for the Student and Novice Neonatal Nurse Practitioner

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Introduction

The neonatal nurse practitioner (NNP), in collaboration with the physician, provides medical care to a very fragile high-risk population, the sick and premature neonate. The NNP must be prepared to make lifesaving medical decisions daily. These decisions may have a lifelong impact on the fragile neonate’s quality of life. Decisions and care given should be based on the best available evidence to ensure optimal outcomes and quality of life. Nutrition may have one of the greatest impacts on long-term outcomes, particularly brain development.

This resource guide was developed to help student and novice NNPs order the most appropriate evidence-based individualized nutrition for sick or premature infants under their care. All components of nutrition, including the starting and advancing of total parenteral nutrition (TPN), feedings, and calculation of kilocalories and fluids, are addressed and explanations provided.
I. Total Parenteral Nutrition (TPN)

A. Fluid Management with TPN
Determine the infant’s fluid requirement (desired ml/kg/day).

Total fluid requirements may vary, depending on institutional guidelines, but generally full-term infants may be started on 60–80 ml/kg/day, late preterm and preterm infants who have a gestational age of 30–37 weeks may be started on 80 ml/kg/day, and very-low-birth-weight (VLBW) infants may be started on 100–120 ml/kg/day. If a humidified incubator is used on the VLBW infant, fluids may be started in the 80–100 ml/kg/day range. Humidified incubators decrease insensible water loss. Consider decreasing total fluids on asphyxiated infants and infants in renal failure.

TPN includes the parenteral nutrition (PN) fluid plus the lipid volume. In calculations for TPN, after the total fluid requirement is determined, you will need to calculate and deduct the volume of lipids, deduct any additional fluids (e.g., from an umbilical arterial catheter, a peripheral artery line, or continuous infusion medications), and then calculate the PN volume for glucose, protein, and electrolytes.

You will need to consider the percent of enteral fluids or feeds and the percent of TPN. For example, a 1.0 kg baby on 100 ml/kg/day of TPN and 25 ml/kg/day of feeds is receiving about ¾ TPN and ¼ enteral nutrition (EN). The TPN should reflect this proportion. Protein, lipids, and electrolytes should equal about ¾ of the total nutritional content.

B. Calculations for TPN
1. Intravenous Lipids
Intravenous (IV) lipids are fat-based solutions to provide fatty acids in TPN. A 20% solution of lipids is recommended for neonates (10 kilocalories [kcal]/g).

- Lipids can be difficult to clear in VLBW or extremely-low-birth-weight (ELBW) infants.
- Limited lipoprotein lipase may lead to pulmonary compromise and therefore is infused over 24 hours.
- Carnitine supplementation may enhance utilization of lipids.
- At least 0.5 gram/kg/day is required to prevent essential fatty acid (EFA) deficiency.
- Start lipids at 0.5–1.5 gram/kg/day; advance by 0.5–1 gram/kg/day to a goal of 3–4 gram/kg/day.
- Monitor triglycerides when advancing IV lipid solution in patients ≤1,500 grams or in cases of sepsis with cardiorespiratory decompensation or persistent pulmonary hypertension (PPHN), or when total bilirubin is nearing exchange levels.

To determine the proper amount of IV lipids to administer, perform these calculations:
- Determine gram/kg/day.
- Calculate gram/day.
- Convert gram/day into ml/day.
- Calculate ml/kg/day and hourly rate of administration.
Example: A 1.5 kg infant needs to receive 0.5 gram/kg/day of 20% IV lipids solution

- Determine gram/kg/day of IV lipids needed (0.5 gram/kg/day).
- Calculate gram/day of IV lipids.
  Weight of infant × desired gram/kg/day = gram/day
  1.5 kg × 0.5 = 0.75 gram/day
- Convert gram/kg into ml/kg/day.
  gram/kg/day ÷ 0.2 (20% IV lipids solution) = ml/kg/day
  0.75 ÷ 0.2 = 3.75 ml/kg/day of IV lipids
- Calculate ml/hr of IV lipids.
- ml/day ÷ 24 = ml/hr
  3.75 ÷ 24 = 0.156 ml/hr

2. Parenteral Nutrition: Carbohydrate-Protein Solution
Electrolytes will be added to the PN solution.

**Determine ml/kg/day of glucose/protein solution that is needed.**

- Deduct ml/kg/day of feeds to get IV hourly rate.
- Deduct lipids, continuous infusion medications, and hourly rate of IV arterial fluids to get hourly rate of protein glucose solution.
- Calculate ml/kg/day of protein glucose solution.

**a. Glucose (dextrose)**

**Calculate the maintenance glucose.**

Glucose infusion rate (GIR) = milligram/kilogram/minute (mg/kg/min).

- Start with GIR 4–6 mg/kg/min in parenteral nutrition (PN), advance by 1–2 mg/kg/min to goal of 12 mg/kg/min.
- Initial intravenous (IV) fluids usually provide GIR of 5–5.5 mg/kg/min.
- Advance conservatively with patients <1,000 gram.
- For hyperglycemia (glucose >150 ml/dL), decrease GIR by about 20%. It is not advisable to go below a GIR of 3.5–4 mg/kg/min. (A lower GIR may cause neurological injury.)

A GIR greater than or equal to 18–20 mg/kg/min increases the risk for development of lipogenesis and fatty deposits in the liver. VLBW infants may not tolerate increases in glucose concentration.

**Calculate the % dextrose from the desired GIR.**

- mg/kg/min (desired) × kg = mg glucose/min
- mg/min ÷ 1,000 (mg/gram = gram/min
- gram/min × 1.440 (min/day) = gram/day
- gram/day ÷ total ml/day × 100 = % dextrose

*Example:* For an infant who weighs 1.5 kg, use a GIR of 6 mg/kg/min with a fluid volume of 80 ml/kg/day. Calculation: 80 × 1.5 = 120 ml/day of IV fluids
Calculation of % dextrose needed from desired mg/kg/min (6 mg/kg/min)

- \( \frac{\text{mg/kg/min (desired)}}{\text{kg}} = \text{mg of glucose/min} \)
  \[ 6 \times 1.5 = 9 \text{ mg of glucose/min} \]
- \( \frac{\text{mg/min}}{1,000 \text{mg/gram}} = \text{gram of glucose/min} \)
  \[ 9 \div 1,000 = 0.009 \text{ gram of glucose/min} \]
- \( \text{gram of glucose/min} \times 1,440 \text{ (min/day)} = \text{gram of glucose/day} \)
  \[ 0.009 \times 1,440 = 12.96 \text{ gram/day} \]
- \( \text{gram/day} \div \text{ml/day} \times 80 \text{ ml/kg/day} \times 100 = \% \text{ dextrose needed} \)
  \[ 12.96 \div 120 \times 100 = 10.8\% \]

Calculate GIR from known dextrose concentration (%).

- \( \frac{\% \text{ dextrose}}{100} \times \text{ml/day} = \text{gram/day} \)
- \( \frac{\text{gram/day}}{1,440} = \text{gram/min} \)
- \( \text{gram/min} \times 1,000 = \text{mg/min} \)
- \( \frac{\text{mg/min}}{\text{kg}} = \text{mg/kg/min} \)

Example: An infant weighs 2 kg and is receiving 100 ml/kg/day of dextrose 15% solution.
Calculation: \( 100 \times 2 = 200 \text{ ml/day of dextrose 15\% IV fluids} \)

- \( 15 \div 100 \times 200 = 30 \text{ gram/day} \)
- \( 30 \div 1,440 = 0.02 \text{ gram/min} \)
- \( 0.02 \times 1,000 = 20.8 \text{ mg/min} \)
- \( 20.8 \div 2 = 10.4 \text{ mg/kg/min (GIR)} \)

b. Protein and amino acids

Start with 1.5–3.0 gram/kg/day depending on institutional guidelines, and increase 0.5–1.5 mg/kg/day to a total of 3–4 mg/kg/day, again depending on institutional guidelines.

- Goal for premature patients: 4 gram/kg/day
- No significant acidosis or abnormal blood urea nitrogen (BUN) was seen when 3–4 gram protein/kg/day was given to premature patients in the first week of life.
- Infants need more than about 80 kcal (nonprotein kcal)/kg/day for improved nitrogen balance and weight gain.
- About 22 nonprotein kcal/kg are needed for every 1 gram protein/kg in order to promote protein utilization.
- Adequate, early protein intake prevents later deficits.

Calculation of protein for PN solution:

1. Determine total gram/kg/day of protein needed.
2. \( \frac{\text{gram/kg/day} \times \text{weight (kg)}}{\text{ml/day}} = \text{gram/day} \)
3. \( \frac{\text{gram/day}}{100} = \% \text{ amino acids} \)

Example: A 3 kg infant starting TPN at 1.5 gram amino acids (AA)/kg/day is receiving 80 ml TPN fluid/kg/day. The infusion rate is 10 ml/hr, to give a total of 240 ml in 24 hours.
1. Calculate grams of AA to add to TPN:
   \[
   1.5 \text{ gram} \div 240 \text{ ml} = 0.00625 \text{ gram/ml} \\
   0.00625 \text{ gram/ml} \times 100 \text{ ml} = 0.625 \text{ grams of AA added to every 100 ml of base solution}
   \]
2. Calculate kcal delivered from protein:
   \[
   1.5 \times 4 \div 3 \text{ kg} = 2 \text{ kcal/kg/day from protein}.
   \]

c. Electrolytes (sodium, potassium, calcium, phosphorus, magnesium, trace minerals, and other additives)
Minimal electrolytes are necessary in the first days of life. Infants typically don’t need additional sodium (Na) and potassium (K) at this time.
   - Advance to standard electrolyte panel (peripheral or central).
   - Use custom panels for individual electrolyte adjustments.
     - Adjust Na by 1–2 milliequivalents (mEq)/kg/day.
     - Adjust K by 1 mEq/kg/day (or by 0.5 mEq/kg/day with renal compromise).
     - Adjust calcium (Ca) and phosphorus (P) by 0.5 mEq or mMol/kg. Try to maintain the appropriate 1.3:1 molar ratio.

Calculation of electrolytes
1. Determine amount of electrolyte needed per kg per day.
2. Determine total amount of IV fluids per day.
3. Set up a proportion and cross-multiply:
   \[
   (\text{mEq/day} \div \text{total fluids}) \times (x \div 100 \text{ ml}) = \text{amount of electrolyte in mEq or mMol to be added to base solution}.
   \]

Sodium
Sodium (Na) and potassium (K) may be given as chloride, acetate, phosphate, and lactate salts.

Normal serum values may vary, especially for the extremely premature infant, from as low as 135 mEq/l to 145 mEq/l.

Serum values, urine output, and growth must be considered in the decision about how much supplementation is needed.

To determine the amount of Na to add to a base solution, you need to determine the amount of base solution, which is commonly 100 ml or 500 ml, though it may vary by institution.

Example: A 3 kg infant is receiving 100 ml/kg/day of dextrose 10%, supplemented with 2 mEq/kg/day of Na. At 100 ml/kg/day the total IV fluids for 24 hr = 300 ml (total amount of fluid infant is to receive that day).

\[
(3 \text{ kg} \times 2 \text{ mEq/kg/day}) = 6 \text{ mEq/day} \\
= x \text{ (amount of electrolyte to be added to total volume of base solution for that day)}
\]
If calculations are figured on a base solution of 100 ml:

\[ 6 \text{ (mEq)} : 300 \text{ ml} \times x \text{ (mEq)} : 100 \text{ ml (base solution)} \]

\[ x = 2 \text{ mEq Na added to every 100 ml of base solution} \]

**Potassium**

Supplementation of potassium varies depending upon urine output, clinical condition, losses, and serum values. Requirements may vary from 1 to 2 mEq/kg/day or more.

Consider adding potassium phosphorus (PO\(_4\)) on the second day of life starting at 1 mEq/kg/day.

To calculate mEq of K to add to a base solution, use the formula for sodium given in the previous section.

*Example:* A 3 kg infant is on 100ml/kg/day of IV fluid and supplementation of 1 mEq/kg/day K:

\[ (1 \times 3 \div 300 \text{ ml}) \times 500 \text{ ml} = 5 \text{ mEq K to be added to 500 ml of solution} \]

**Calcium, Phosphorus, and Magnesium**

Recommended requirement of calcium (Ca) = 0.5–2.5 mEq/kg/day depending on serum values. Normal values may range from 8 to 11 mEq/l. Some sources cite 7–11 mEq/l as normal. Ionized calcium levels are a better indicator of physiologic calcium.

Magnesium (Mg) and PO\(_4\) must also be monitored. Serum Ca will not normalize regardless of supplementation if Mg and/or PO\(_4\) values are high or low.

Normal Mg values may range from 1.5 to 2.5 mEq/l, and PO\(_4\) values may range from 4.4 to 7.0 mEq/l.

Calculations are the same as given above for sodium and potassium.

*Example:* To give 1.5 mEq/kg/day of Ca to a 3 kg infant on 100ml/kg/day of IV fluid:

\[ (1.5 \times 3) \div 300 \text{ ml} \times 500 \text{ ml} = 7.5 \text{ mEq to be added to 500 ml of base solution} \]

Remember:

\[ 1 \text{ mEq Ca} = 20 \text{ mg elemental Ca} \]
\[ 1 \text{ mEq Mg} = 12 \text{ mg elemental Mg} \]

Recommended intake of calcium, phosphorus, and vitamin D

- **Calcium:** 20–90 mg/kg/day (1–4 mEq/kg/day)
- **Phosphorus (P):** 35–70 mg/kg/day (1–2 mMol/kg/day)
- **Vitamin D:** 400 international units (IU) daily

Molar ratio of calcium and phosphorus is 1.3–1.7:1.
Add carnitine to PN within the first week at a dose of 10 mg/kg/day in neonates of <34 weeks’ gestation receiving PN (with minimal-to-no EN). It is essential for the metabolism of long-chain fatty acids. Deficiency can develop 7–10 days after birth in neonates of <34 weeks’ gestation receiving PN (with minimal-to-no EN). Add carnitine to PN within the first week at a dose of 10–20 mg/kg/day.

Calculation of molar ratio
1. Divide mEq Ca by 2.
2. Divide mMol Ca by mMol P.
3. Ratio = mMol Ca ÷ mMol P (mMol Ca = mEq Ca ÷ 2)

Calcium and phosphorus solubility in TPN
- Trophamine has low pH.
- Addition of L-cysteine increases acidity of solution, allowing increased concentrations without precipitation.
- Ca (mEq/100 ml) + P (mMol/100 ml)
  - peripheral 2.5 (Ca cannot exceed 1 mEq/100 ml)
  - central 4 (maximum concentration of 5 with cysteine)

Trace Minerals
Copper, manganese, chromium, and zinc are trace minerals that need to be monitored in neonates with renal or hepatic dysfunction. In these infants, you will need to order the specific trace elements on a daily basis. Consider adding all trace minerals weekly or biweekly, depending on disease process.

Copper, manganese, chromium, and zinc are available as the following combination products:

<table>
<thead>
<tr>
<th></th>
<th>PTE-4</th>
<th>Peditrace</th>
<th>Neotrace*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.1 mg</td>
<td>0.1 mg</td>
<td>0.1 mg</td>
</tr>
<tr>
<td>Manganese</td>
<td>25 mcg</td>
<td>25 mcg</td>
<td>25 mcg</td>
</tr>
<tr>
<td>Chromium</td>
<td>1 mcg</td>
<td>0.85 mcg</td>
<td>0.85 mcg</td>
</tr>
<tr>
<td>Zinc</td>
<td>1 mg</td>
<td>0.5 mg</td>
<td>1.5 mg</td>
</tr>
</tbody>
</table>

Note. Neotrace is intended for neonates and therefore contains the most zinc.

- Copper and manganese—these minerals are excreted via bile, so do not give them to patients with direct bilirubin ≥2. Give copper and manganese once a week while direct bilirubin remains high.
- Chromium—chromium is excreted by the kidneys, so do not give this to patients with renal compromise (i.e., if creatinine > 1.5)
- Zinc—increased supplementation of zinc may be indicated in patients with excessive gastrointestinal losses (e.g., ileostomy); these patients may be given a maximum dose of 500 microgram/kg/day in PN.

Other Additives: Carnitine, Selenium, and Cysteine
Carnitine is a conditionally essential amino acid that is synthesized from lysine and methionine, but its biosynthesis is not fully developed in the neonate (especially infants of <34 weeks’ gestation). It is essential for the metabolism of long-chain fatty acids. Deficiency can develop 7–10 days after birth in neonates of <34 weeks’ gestation receiving PN (with minimal-to-no EN). Add carnitine to PN within the first week at a dose of 10–20 mg/kg/day.
Selenium, also a trace mineral, functions as an antioxidant against lipid peroxides. It is excreted by the kidneys; therefore the dose should be adjusted or held in patients with renal compromise. It should be added to PN within the first week.

Cysteine lowers the pH (increases the acidity) of the PN solution, thereby increasing the solubility of supplemental calcium and phosphorus. It can also act as a conditionally essential amino acid in preterm infants.
II. Calculation of Kilocalories for TPN

A. Glucose (Dextrose) Kilocalories

When TPN has been ordered, calculate the total number of kilocalories that the baby has received from TPN for the past 24 hours.

Concentration of dextrose in base solution:
- Dextrose 5% contains 5 grams of dextrose per 100 ml (0.05 gram/ml).
- Dextrose 10% contains 10 grams per 100 ml (0.1 gram/ml).
- Dextrose 12.5% contains 12.5 grams per 100 ml (0.125 gram/ml).

Calculation of dextrose kcal:
1 gram of dextrose = 3.46 kcal

*Example:* A 10% dextrose base solution contains 10 grams of dextrose in 100 ml of solution. Therefore a 10% dextrose base solution contains 34.6 kcal/100 ml or 3.46 kcal/10 ml or 0.346 kcal/ml.

**Kilocalories from Commonly Used Dextrose Base Solutions**

Total ml/day × kcal/ml of dextrose base solution = total kcal of glucose/day
- Dextrose 5% = 0.173 (0.2) kcal/ml
- Dextrose 10% = 0.346 kcal/ml
- Dextrose 15% = 0.52 kcal/ml
- Dextrose 17.5% = 0.605 kcal/ml

Calculation of glucose kcal from different dextrose base solution concentrations:
gram/100 ml of dextrose × 3.46 ÷ 100 ml = kcal/ml of dextrose base solution

*Example:* For a dextrose 12.5% solution:
gram/100 ml of dextrose × 3.46 ÷ 100 ml = kcal/ml of dextrose base solution
2.5 × 3.46 = 43.25 kcal/100 ml
43.25 ÷ 100 (ml) = 0.43 kcal/ml for dextrose 12.5% base solution

B. Protein Kilocalories

Protein gives 4 kcal/gram.
Gram/day × 4 = total protein kcal/day

C. Lipid Kilocalories

For a 20% IV lipid solution there are 2 gram/100 ml or 2 kcal/ml.
To calculate kilocalories received from lipids:
Total ml delivered × 2 kcal/ml (for 20% solutions) = total lipid kcal/day
D. Total Kilocalories

A 3 kg infant receiving 80ml/kg/day of TPN mixed in dextrose 10% solution with 1.5 gram/kg/day of protein plus 1.5 gram/kg/day of 20% lipids infusing at 0.19 ml/hr will receive the following kilocalories (total fluids are 85 ml/kg/day):

Dextrose
240 ml/day (PN solution) × 0.346k cal/ml dextrose 10% = 83 kcal/day
83 ÷ 3 = 27.6 or 28 kcal/kg/day

Protein (inclusion of protein kilocalories from TPN depends on institutional guidelines)
4.5 gram/day × 4 = 18 kcal/day
18 kcal/day ÷ 3 kg = 6 kcal/kg/day from protein

Lipids
4.56 ml × 2 = 9.12 kcal/day
9.12 kcal/day ÷ 3 kg = 3 kcal/kg/day from lipids

The total number of kilocalories in this example is 3 kcal/kg/day.

An alternate method is to calculate all the kilocalories, add them up, and then divide total kcal/day by the weight in kg.

Kilocalories (dextrose) + kilocalories (protein) + kilocalories (lipids) ÷ weight (kg) = kcal/kg/day from TPN.

83 + 18 + 9.12 110.12 ÷ 3 (kg) = 36.7 or 37 kcal/kg/day

To determine the amount of electrolyte the infant is receiving:
1. Determine the amount of electrolyte in the IV solution (usually the amount per 100 ml).
2. Determine the amount of IV fluids received over the past 24 hours:
   mEq electrolyte/IV solution ÷ 100 ml IV fluid × x ÷ the amount of IV fluids/24 hr
3. Divide x by weight to determine mEq/kg/day.
III. Additional Fluids and Electrolytes

Arterial line, bolus fluids, NaHCO₃ administration, flushes, and medications may need to be added to total fluids, especially in ELBW infants, infants with severe third-space losses, and infants with birth depression.

A. Sodium Bicarbonate

- 1 mEq = 84 mg
- 1 gram = 12 mEq Na
- 4.2% solution = 42 mg/ml = 5 mEq/10 ml

B. Saline Solutions

- Normal saline solution (NSS) = 0.154 mEq/ml
- 0.5 NSS = 0.075 mEq/ml
- 0.25 NSS = 0.037 mEq/ml
- 3% NSS = 0.5 mEq/ml

Note. Blood products such as packed red blood cells, platelets, and fresh frozen plasma are isotonic and have the same sodium content as NSS.

C. Lactated Ringers

- Na = 140 mEq/l
- K = 4 mEq/l
- Ca = 3 mEq/l
- Chloride = 109 mEq/l
- Lactate = 28 mEq/l

Example: To calculate Na/kg/day received from NSS:
Total ml received in a 24-hr interval × 0.154 ÷ weight in kg = mEq/kg/day Na
A 3 kg infant is receiving NSS at 1 ml/hr.
24 ml × 0.154 ÷ 3 kg = 1.2 mEq/kg/day Na
IV. Formula and Breast Milk

A. General Feeding Principles for the Very-Low-Birth-Weight Infant

Breast milk is best. The American Academy of Pediatrics (2005) recommends breastfeeding for the first year of life. This may present a challenge for the mother of the VLBW infant who is unable to put her baby to breast. Emotional support and education may be critical to the successful breastfeeding of the VLBW infant. Education should cover the benefits of breast milk and methods for pumping, storing, and transporting breast milk to the hospital. A lactation consultant is an excellent source of support and information for mothers. Encouraging pumping while the mother is visiting her infant, skin-to-skin care, and nonnutritive suckling by the VLBW infant are supportive nursing actions.

Feedings are started when the infant is clinically stable; it is hoped that this will occur in the first few days or first week of life. Some institutions may use gastrointestinal (GI) priming even on unstable babies until the baby is stable enough for trophic feeds to be started. The rationale for GI priming is to stimulate the gut and thus to improve or establish a more coordinated peristalsis of the premature intestine, hormone release, and GI maturation. When priming is used, a small volume (0.5–1 ml) of breast milk (preferable) or preterm formula is given by orogastric or nasogastric tube two to three times a day. GI priming is not meant to be nutritional. Initial feedings may be by bolus or continuous infusion. Initially trophic feeds of 10–20 ml/kg/day are given, depending upon institutional guidelines. Trophic feeds may be continued for several days before advancing the feeding, depending on individual clinical conditions and feeding tolerance. Advancement of feeds generally should not exceed 20 ml/kg/day in the VLBW infant (less than 1.5 kg). Larger-volume increases are associated with the development of necrotizing enterocolitis (Noerr, 2003; Spritzer et al., 1988).

Fortification adds additional protein, minerals, and kilocalories required for growth. Fortification of breast milk may vary according to institutional guidelines. Some may choose to add fortifier when the VLBW infant is tolerating half-volume feeds. The choice of adding a liquid or powder fortifier may vary as well.

Vitamins with iron are started when the infant is tolerating full enteral feeds.

B. Kilocalories in Formula

20-kcal formula contains 0.67 kcal/ml.
22-kcal formula contains 0.73 kcal/ml.
24-kcal formula contains 0.8 kcal/ml.
25-kcal formula contains 0.83 kcal/ml.
27-kcal formula contains 0.9 kcal/ml.
28-kcal formula contains 0.93 kcal/ml.
30-kcal formula contains 1.0 kcal/ml.
To calculate the total kcal received in a 24-hour interval:

1. Multiply total intake by the number of kcal/ml, depending on the formula (e.g., for 20-kcal formula, multiply by 0.68).
2. Divide this number by the infant’s weight in kilograms.

An alternative is the following calculation:

\[
\text{total ml of formula ÷ 30 (ml/oz) = oz/day} \\
\text{oz/day × kcal/oz = total kcal from enteral intake}
\]

**Example:** A 3 kg infant being fed 57 ml of 20-kcal formula every 3 hours is receiving 103 kcal/kg/day.

\[
\text{Total ml in 24 hr = 57 ml × 8 feedings = 456 ml} \\
456 × 0.68 ÷ 3 \text{ kg} = 103 \text{ kcal/kg/day}
\]

**Note.** Infants on full TPN require about 100–120 kcal/kg/day for growth, depending on the disease process. For example, infants with bronchopulmonary dysplasia may require more kilocalories. Infants on full enteral feeds require about 120–130 kcal/kg/day for growth. Again, depending on the disease process, infection, or growth restriction, infants may require more kilocalories for growth.
References


Bibliography


Practice Problems

1. Baby girl A weighs 830 grams. The IV rate is 2.2 ml/hr, and 100 ml of IV fluid contains 0.67 mEq of NaCl. Calculate the amount of sodium/kg/day that baby girl A is receiving.

2. For baby girl A, calculate the amount of sodium/kg/day when the IV rate is 3.5 ml/hr.

3. Baby boy B weighs 1.2 kg. The IV rate is 6.8 ml/hr, and the IV fluid contains the following:
   - 1.5 mEq of sodium per 100 ml
   - 1.9 mEq of potassium per 100 ml
   - 3.0 mEq of calcium per 100 ml
   - 1.2 mMol of phosphorus per 100 ml.

   Calculate the amount of sodium/kg/day, potassium/kg/day, calcium/kg/day, and phosphorus/kg/day that baby boy B is receiving.

4. For baby boy B, calculate the calcium-to-phosphorus ratio and determine whether it is adequate.

5. Baby boy C weighs 1.5 kg. Total IV fluids are to be calculated at 140 ml/kg/day. The infant is receiving central TPN. Lipids are 2 gram/kg/day. Write TPN orders (including dextrose concentration and IV rates) to give baby C a glucose infusion rate of 8 mg/kg/min.

6. For baby boy C, write orders for 4 mEq/kg of sodium, 2 mEq/kg of potassium, 3.5 mEq of calcium, and 1.5 mMol of phosphorus to be added to every 100 ml of IV base solution.

7. For baby boy C, calculate the calcium-to-phosphorus ratio.

8. Determine whether the amount of calcium and phosphorus specified in question 6 can be added to the solution.

9. On day of life (DOL) 23, baby girl D weighs 950 grams. She is currently on TPN at 120 ml/kg/day with dextrose 15%, 3 gram/kg/day of amino acids, and 3 gram/kg/day of lipids. The TPN solution contains 1.7 mEq of sodium per 100 ml and 0.83 mEq of potassium per 100 ml. Calculate the amount of lipids and PN fluids baby girl D will receive per hour.

10. Calculate the glucose infusion rate for baby girl D.

11. What is the amount of sodium and potassium per kg/day baby girl D is receiving?

12. The nurse reports that baby girl D has not passed urine since the beginning of her shift, and the total urine output recorded more than 9 hours ago was 2 ml. Calculate the urine output.

13. What is your next action for baby girl D?
14. The serum electrolytes for baby girl D are listed below.

Sodium: 128  
Chloride: 99  
Carbon dioxide: 53  
Glucose: 50  
Potassium: 6.5  
BUN: 19  
Creatinine: 1.5

What are your differential diagnoses for baby girl D?

15. On DOL 24, baby boy E weighs 1.1 kg. He is receiving TPN at 120 ml/kg/day with dextrose 12.5%, 3 gram/kg/day of amino acids, and 3 gram/kg/day of lipids.

The serum electrolytes for baby boy E this morning were as follows:

Sodium: 145  
Chloride: 105  
Carbon dioxide: 63  
Glucose: 40  
Potassium: 4.5  
BUN: 17  
Creatinine: 1.1

Write the order for lipid and PN infusion rates for baby boy E.

16. Calculate the glucose infusion rate for baby boy E.

What change would be needed to increase the glucose infusion rate by 2 mg/kg/min using the same dextrose solution for baby boy E?

17. On DOL 21, baby boy F weighs 750 grams and is receiving a total of 120 ml/kg/day of peripheral TPN with dextrose 12.5% and breast-milk enteral feeds of 4 ml every 3 hours. The TPN contains 2 mEq/kg/day of sodium and 1.5 mEq/kg/day of potassium.

Write orders for the amount of sodium and potassium to be added to every 100 ml of PN base solution for baby boy F.

18. How much of baby boy F’s total fluids in a 24-hour period are given through enteral nutrition?

19. What is the glucose infusion rate for baby boy F?
20. On DOL 22, baby boy G develops necrotizing enterocolitis. He is ordered to be given nothing by mouth (NPO) and is placed on full TPN, using the same base solution of dextrose 12.5%, 2 mEq/kg/day of sodium, and 1.5 mEq/kg/day of potassium. He was receiving breast milk of 4 ml enterally every 3 hours. When he was placed on NPO, his TPN rate of infusion was increased until new TPN orders could be written and new fluids obtained from the pharmacy.

What is the new infusion rate for administering 120 ml/kg/day to this 750-gram infant?

21. What is baby boy G’s glucose infusion rate now?

22. If this rate were maintained for 24 hours, how much sodium and potassium would baby boy G receive?

23. Baby boy G received 15 ml/kg of packed red blood cells, 45 ml/kg of fresh frozen plasma, and 15 ml/kg of platelets in a 24-hour interval. With his TPN fluid containing 2 mEq/kg/day of sodium, how much total sodium did he receive in 24 hours?

24. On DOL 23, baby boy G’s TPN fluids are restricted to 100 ml/kg/day. The new TPN ordered contains 3.4 grams of amino acids/kg/day and 3 grams of lipids/kg/day. A central line has been placed, and the dextrose concentration is 15%. Calculate his total kcal/kg/day.

25. The morning electrolytes for baby boy G were as follows:

   Sodium: 161
   Chloride: 117
   Carbon dioxide: 19
   Glucose: 160
   Potassium: 3,2
   BUN: 18
   Creatinine: 1

   What are your diagnoses for baby boy G?

26. Why is baby boy G’s sodium high? What should you do?
Answer Key

Note. Answers may be rounded to the first decimal place.

1. 0.4 mEq of sodium/kg/day
2. 0.67 mEq of sodium/kg/day
3. 2 mEq of sodium/kg/day
   2.6 mEq of potassium/kg/day
   4.1 mEq of calcium/kg/day
   1.6 mMol of phosphorus/kg/day
4. The calcium-to-phosphorus ratio is 1.25:1, and this is adequate.
5. Lipids: 0.6 ml/hr
   PN fluids: dextrose 8.9% at 8.1 ml/hr
6. Sodium: 3.1 mEq per 100 ml
   Potassium: 1.5 mEq per 100 ml
   Calcium: 2.7 mEq per 100 ml
   Phosphorus: 1.1 mMol per 100 ml
7. The calcium-to-phosphorus ratio is 1.22:1.
8. The total is 3.8 and can be added to the PN fluids
9. Lipids: 0.6 ml/hr
   PN fluids: 4.1 ml/hr
10. Glucose infusion rate: 10.8 mg/kg/min
11. Sodium: 1.76 mEq/kg/day
    Potassium: 0.86 mEq/kg/day
12. Urine output: 0.2 ml
14. Differential diagnoses: hyponatremia, hyperkalemia, and metabolic acidosis
15. Lipids: 0.7 ml/hr
    PN fluids: 4.8 ml/hr
16. Glucose infusion rate: 9.2 mg/kg/min
   The PN fluids would need to be increased to 5.8 ml/hr.

17. Sodium: 2.6 mEq per 100 ml PN fluids
    Potassium: 1.9 mEq per 100 ml PN fluids

18. 43 ml/kg/day

19. Glucose infusion rate: 6.7 mg/kg/min

20. 3.8 ml/hr

21. Glucose infusion rate: 11 mg/kg/min

22. 3.2 mEq of sodium/kg/day and 2.3 mEq of potassium/kg/day

23. 13 mEq of sodium/kg/day

24. 93 kcal/kg/day

25. Diagnoses: hypernatremia, hypokalemia, and hyperglycemia

26. The baby received 12 mEq of sodium/kg from blood product transfusions on the preceding day. You should consider removing or decreasing the sodium from the TPN and recheck the electrolytes in 6 hours.