PEDiatric PARENTERAL NUTRITION

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We won’t cover what you’ve already covered, but look at differences between adult and pediatric TPN.

Complications (side effects) will be the same.
Introduction

- Premature Infant
- Infant
- Child
- Adolescent
- Adult
Differences

- Body water
- Organ development
- Energy needs
- Growth rate
Indications:

- Will be similar to adults
- Premature infants often placed on TPN to maximize calorie intake and promote growth
TPN Components

- Fluids
- Energy needs
- Protein needs
- IV Fat
- Electrolytes
- Vitamins
- Minerals
Determine fluid requirements

- Holiday-Segar Method
- Surface area method (can be used in children > 10 kg = 1500-2000 ml/m²/day)
- Neither method suitable for neonates < 14 days old
- To determine maintenance fluids
Holiday-Segar Method

- 1st 10 kg body weight = 100 ml/kg
- next 10 kg body weight = 50 ml/kg
- each additional kg (>20 kg) = 20 ml/kg
Surface area method

- can be used in children > 10 kg
- = 1500-2000 ml/m²/day
Adjustments to fluids

Ongoing fluid losses
- vomiting
- diarrhea or increased ostomy output
- fever
- sweating
- hyperventilation
- Hyperthyroidism
- Lights, incubator

Retention of fluids
- renal disease
- renal failure
Differences in substrate utilization

- Carbohydrates
- Fat
- Protein
Carbohydrate utilization

- Based on Hepatic Oxidation Rates
- Some call *Glucose Infusion Rate*
- Measured in mg/kg/min
- Rates

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
<th>Advance</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Premies</td>
<td>4-6</td>
<td>0.5 - 1</td>
<td>15-20</td>
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<tr>
<td>Infant</td>
<td>7</td>
<td>3 - 5</td>
<td>15-20</td>
</tr>
<tr>
<td>Child</td>
<td>7</td>
<td>3 - 5</td>
<td>15-20</td>
</tr>
<tr>
<td>Adolescent</td>
<td>3-5</td>
<td>2 - 5</td>
<td>6-10</td>
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</tbody>
</table>
Fat utilization

- Measured in Gm/kg/day
- Rates

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
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<th>Final</th>
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<tbody>
<tr>
<td>Premies</td>
<td>0.5</td>
<td>0.5-1</td>
<td>3</td>
</tr>
<tr>
<td>Infant</td>
<td>1</td>
<td>1</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Child</td>
<td>1 (2)</td>
<td>1</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Adolescent</td>
<td>1 (2)</td>
<td>1</td>
<td>3 (4)</td>
</tr>
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</table>
Protein utilization

- Measured in Gm/kg/day
- Rates

<table>
<thead>
<tr>
<th></th>
<th>Start</th>
<th>Advance</th>
<th>Final</th>
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<tbody>
<tr>
<td>Premies</td>
<td>?</td>
<td>?</td>
<td>3 (3.5)</td>
</tr>
<tr>
<td>Infant</td>
<td>?</td>
<td>?</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Child</td>
<td>1 (2)</td>
<td>1</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Adolescent</td>
<td>1 (2)</td>
<td>1</td>
<td>3 (4)</td>
</tr>
</tbody>
</table>
Nutritional Assessment

- Determine IBW
- Determine weight to height ratio
- Waterlow Criteria
IBW (Ideal Body Weight)

- Needed to determine energy needs
- Harris Benedict Equation is not accurate for pediatric patients
- Must use growth charts
Growth Chart for IBW
Growth Chart

Birth to 36 months: Boys
Head circumference-for-age and
Weight-for-length percentiles

Published: May 23, 2000 (modified 12/16/99).
SOURCE: Developed by the National Center for Health Statistics in collaboration with
the National Center for Chronic Disease Prevention and Health Promotion (2000).
http://www.cdc.gov/nchs/birth
Waterlow Criteria

- Based on % of IBW
- Adequate is 90 to 100%
- Mild acute malnutrition is 80 to 89%
- Moderate acute malnutrition is 70 to 79%
- Severe acute malnutrition is < 70%
Determine Nutritional Needs

- Calories
- Protein
- Other
Calorie (Energy) Needs

- **RDA (recommended daily allowance)** - the amount a healthy individual needs
- “Catch-up” - amount needed to catch-up to where the patient should be
- These are the oral calorie needs
RDA Calories

- Birth to 6 months = 108 Kcal/kg
- 6 to 12 months = 98 Kcal/kg
- 1 to 3 years = 102 Kcal/kg
- 4 to 6 years = 90 Kcal/kg
- 7 to 10 years = 70 Kcal/kg

These are initial goals, but will need to be adjusted based on individual response.
Catch-up Calories

- $Kcal/kg = \frac{IBW \times RDA}{Actual\ Weight}$ (for height age)
Protein (RDA) needs

- Birth to 6 months = 2.2 Gm/kg
- 6 to 12 months = 1.6 Gm/kg
- 1 to 6 years = 1.2 Gm/kg
- 7 to 10 years = 1 Gm/kg
### Ages 11 thru 22

<table>
<thead>
<tr>
<th>Age</th>
<th>Calories/cm</th>
<th>Protein Gm/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M - F</td>
<td>M - F</td>
</tr>
<tr>
<td>11-14</td>
<td>16</td>
<td>0.3</td>
</tr>
<tr>
<td>15-18</td>
<td>17</td>
<td>0.3</td>
</tr>
<tr>
<td>19-22</td>
<td>16</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Note:** needs based on height, not weight
Other needs

- Fat
- Vitamins
- Electrolytes
- Trace elements
Fat

- Fat emulsion (Intralipids, Liposyn)
- 10% vs. 20%
  - 10% provides 1.1 cal/ml
  - 20% provides 2 cal/ml
    (difference comes from emulsifying agent)
- Initially designed to prevent essential fatty acid deficiency, but only 4% of total calories from fat will prevent.
Fat (slide 2)

- Also is a good calorie source
- Advantages as calorie source
  - neutral pH for peripheral line
  - provides calories with affecting the glucose infusion rate
## Electrolyte Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Infant (mEq/kg)</th>
<th>Child &gt; 1 yr (mEq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>2-4</td>
<td>2-4</td>
</tr>
<tr>
<td>K</td>
<td>2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>Cl</td>
<td>2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>Phos (mM/kg)</td>
<td>0.5-1</td>
<td>0.5-1</td>
</tr>
<tr>
<td>Ca (mEq/kg)</td>
<td>1-2</td>
<td>1</td>
</tr>
<tr>
<td>Mg (mEq/kg)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
# Trace Mineral Requirements

<table>
<thead>
<tr>
<th>Element</th>
<th>Infant</th>
<th>Child &gt; 1</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium (mcg/kg)</td>
<td>0.2</td>
<td>0.2</td>
<td>5 mcg</td>
</tr>
<tr>
<td>Copper (mcg/kg)</td>
<td>20</td>
<td>20</td>
<td>300 mcg</td>
</tr>
<tr>
<td>Manganese (mcg/kg)</td>
<td>1</td>
<td>1</td>
<td>50 mcg</td>
</tr>
<tr>
<td>Molybdenum (mcg/kg)</td>
<td>0.25</td>
<td>0.25</td>
<td>5 mcg</td>
</tr>
<tr>
<td>Selenium (mcg/kg)</td>
<td>2</td>
<td>2</td>
<td>30 mcg</td>
</tr>
<tr>
<td>Zinc (mcg/kg)</td>
<td>100-400</td>
<td>50</td>
<td>5 mg</td>
</tr>
</tbody>
</table>
Special Amino Acids

- TrophAmine and Aminosyn PF
- Developed for infants
- Premature and newborns may lack fully developed organ systems
- Standard amino acids contain essential amino acids and some nonessential aa.
- These pediatric formulas contain more nonessential amino acids
Cysteine often added

AA with shorter stability in solution

Has advantage of lowering pH of final solution

This helps keep more Ca & Phos in solution than standard amino acids.
Some specific complications

- Calcium & phosphate
- Liver disease
- Re-feeding syndrome
Calcium & Phosphorus

- Infants & children have higher needs
- Calcium & Phosphorus will ppt in solution (form concrete)
- Amino acid in TPN will allow them to be mixed together.
- Do not mix together in any other solution
Calcium & Phosphorus (slide 2)

- Mono-basic vs. di-basic Calcium Phosphate
- A very complex phenomenon
- Affected by Calcium final concentration, calcium salt used (Gluconate best), AA final concentration, type of AA, dextrose concentration, temperature, pH of solution, other additives & order of mixing
Liver disease

- TPN associated cholestasis
- A major pediatric TPN problem
- Life threatening
Ways to minimize cholestasis

- Promote enteral intake
- Photo degradation
- Watch aluminum intake
- Do not overfeed or provide too much protein
- Have a “balanced solution”
Re-feeding Syndrome

- Occurs in severely malnourished patients after nutrition started
- It is severe hypophosphatemia, hypokalemia, hypomagnesemia, vitamin deficiencies, fluid and/or glucose intolerance.
- Advance calories & protein slowly and monitor patient closely
Monitoring

- Expected growth rate
- Watch I & O
- Labs
- Liver disease
### Expected Daily Growth Rate

<table>
<thead>
<tr>
<th>Age</th>
<th>Males (Gm/day)</th>
<th>Females (Gm/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 month</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>1 - 2 month</td>
<td>35</td>
<td>29</td>
</tr>
<tr>
<td>2 - 3 month</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>3 - 4 month</td>
<td>21</td>
<td>18.5</td>
</tr>
<tr>
<td>4 - 5 month</td>
<td>16.5</td>
<td>16</td>
</tr>
<tr>
<td>5 - 6 month</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>6 - 9 month</td>
<td>12.5</td>
<td>11</td>
</tr>
<tr>
<td>9 - 12 month</td>
<td>10.5</td>
<td>10</td>
</tr>
<tr>
<td>12 - 18 month</td>
<td>7</td>
<td>8.5</td>
</tr>
<tr>
<td>18 - 24 month</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2 - 6 year</td>
<td>5.5</td>
<td>5</td>
</tr>
<tr>
<td>6 - 7 year</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>7 - 8 year</td>
<td>6.5</td>
<td>8</td>
</tr>
<tr>
<td>8 - 9 year</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>
Labs

- Initial
  - Na, Cl, K, PO$_4$, CO$_2$ - daily (or BID)
  - Glucose - Q4-6hrs
  - Ca, Mg - daily
  - LFT - daily to every other day
  - Tg - with each change & at least weekly
  - BUN, Cr - daily
Labs

- Maintenance
  - Na, Cl, K, PO₄, CO₂ - every other day or less
  - Glucose - Q4-6hrs or less
  - Ca, Mg - twice a week or less
  - LFT - weekly or less
  - Tg - with each change & at least weekly
  - BUN, Cr - twice a week or less
Monitoring for liver disease

- LFT (alk phos, AST, ALT) are non specific
- Bilirubin is a better indicator
  TPN associated cholestasis is associated with a direct bilirubin of 2.0 or higher
Monitoring protein status

- **Albumin**
  - usually monitored weekly
  - has a long $t_{1/2}$ (approx 3 weeks)
  - good indicator of protein status

- **Pre-albumin**
  - shorter $t_{1/2}$ (2 - 4 days)
  - not everyone uses (expensive, affected by renal disease)
Case Study 1

- 5 mo BB, former premie with a history of narcotizing enterocolitis (NEC) who now has short bowel syndrome (SBS) and will be discharged home on TPN. He has failed all attempts at enteral feedings. Weight is 5.6 kg and height is 24 inches. Recommend a home TPN solution and develop a plan of therapy, including follow-up monitoring. A hickman catheter has been placed and he has a gastric tube.
Case 1
Case 1

- Weight of 5.6 kg = < 5\textsuperscript{th} percentile
- Height of 24 inches = 5\textsuperscript{th} percentile
- Weight to height approximately 5\textsuperscript{th} percentile
- Calculated IBW = 6.4 kg
- Patient is 87.5% of IBW, so he is moderately malnourished.
Case 1

Calculate fluid need

Holiday-Segar Method
1st 10 kg body weight = 100 ml/kg
next 10 kg body weight = 50 ml/kg
each additional kg (>20 kg) = 20 ml/kg

So 100 ml/kg x 5.6 kg = 560 ml

Adjustments to fluids
No renal problems, no vomiting or ostomy output without feeds, no fever at this time.
Case 1

Calculate energy needs

Birth to 6 months = 108 Kcal/kg

These are initial goals, but will need to be adjusted based on individual response.

5.6 kg x 108 Kcal/kg = 604.8 Kcal

Review of current inpatient TPN shows weight gain of 20 gm/day averaged over the last week. Current TPN ordered at 23 ml/hr continuous infusion of 22% Dextrose and 2.5 Gm Protein/kg/day. He is also getting 20% Lipids at 3 ml/hr for 18 hours a day.
Case 1

Protein needs

- Birth to 6 months = 2.2 Gm/kg based on RDA
- Since patient is recovering from bowel surgery, he will have increased needs for wound healing and for additional growth.
Case 1

- **Determine current intake**
  - TPN at 23 ml/hr for 24 hrs/day = 552 ml
  - Lipids at 3 ml/hr x 18 hrs/day = 54 ml
  - Total daily intake = 606 ml

  **Calculated volume = 560 ml**
Case 1

- **22% Dextrose provides:**
  \[
  22 \text{ Gm/100 ml} \times 552 \text{ ml} = 121.4 \text{ Gm}
  \]
  Each gram provides 3.4 Kcal, so
  \[
  3.4 \times 121.4 = 413 \text{ Kcal}
  \]

- **2.5 Gm Protein/kg provides:**
  \[
  2.5 \text{ Gm/kg} \times 5.6 \text{ kg} = 14 \text{ Gm}
  \]
  Each pram provides 4.1 Kcal, so
  \[
  14 \times 4.1 = 57 \text{ Kcal}
  \]

- **54 ml of 20% Lipids provides:**
  \[
  2 \text{ Kcal/ml}, \text{ so}
  54 \text{ ml} \times 2 \text{ Kcal/ml} = 108 \text{ Kcal}
  \]

**TOTAL Kcal = 578**
Case 1

- Receiving 578 Kcal compared to our estimated needs of 605
- Receiving 2.5 Gm Protein compared to our estimate of 2.2
- Receiving 606 ml fluids compared to estimated needs of 560 ml.
Case 1

- How do we proceed with getting this patient ready to go home on TPN?
Case 1

- Home TPN is usually cycled - this means instead of infusing over 24 hours a day, the same volume is given over fewer ours.
- This is done to give the patient and family some time off.
- It has been shown to decrease the chances of TPN associated cholestasis.
- Must look at glucose infusion rate to determine how many hours the patient can be off TPN.
Case 1

- Current TPN provides 121.4 Gm of dextrose every 24 hours.
- We want to determine the mg/kg/min
  - \( \frac{121,400 \text{ mg}}{1440 \text{ min}} = 84.3 \text{ mg/min} \)
  - Divided by 5.6 kg = 15 mg/kg/min
- Based on hepatic oxidation rate of glucose, an infant can tolerate 15 to 20 mg/kg/min.
Case 1

- If we decide to leave the glucose the same concentration, if we look at a 20 hour infusion, this would be 121,400 mg divided by 1200 min which equals 18 mg/kg/min.
- An 18 hr infusion (1080 min) = 21.6 mg/kg/min.
- It looks like 20 hours is the best we can do with this TPN infusion.
Case 1

- When cycling TPN, you must taper the rate over the last one hour so the pancreas can adjust the insulin production appropriately.
- Test blood sugar at intervals after stopping, often 20, 40 & 60 minutes to be sure hypoglycemia does not occur.
- Need to have a plan for what to do if the blood sugar does drop. NPO patients present a problem.
Labs - if current labs are good, no need to adjust lytes unless you are concerned with Ca-Phosphate compatibility. Review published solubility curves before recommending.

Most home TPN solutions are mixed 3:1 (also called TNA or All-in-1) solutions with the lipids mixed together. This is a problem visually identifying Ca-Phos ppt.

Need to educate family on what a “Cracked” TPN emulsion looks like. Creaming is ok, but an oily separation or brown or yellow streaks should not be used.
Case 1

- Due to high risk of liver disease, recommend starting enteral, even if just at 1 ml/hr to stimulate gut.
- Have patient run home solution at least one day in hospital prior to discharge to be sure he tolerates.
- Need to follow up in clinic within a week. May want to order labs in a few days to be drawn at home.
Case 1

- Any other question on this patient?
Case Study 2

- 9 yo boy admitted to hospital with exacerbation of Crohn's Disease. He has received TPN several times in the past and needs to be started. A central line will be placed. Current weight is 20 kg and current height is 120 cm. This will place him < 5% weight & < 5% height. IBW calculates to 22 kg, so he is 90% IBW. Develop a plan for TPN therapy including goals for calories & protein.
7 year old girl admitted to the hospital for an appendectomy, which has ruptured. Will need parenteral nutrition through a peripheral line, since anticipate she will be NPO for over a week. Her weight is 22 kg (50%) and her height is 120 cm (50%). She is at her IBW. Develop a nutritional plan including goals for calories & protein.