Parenteral Nutrition
Current Consensus
Intestinal Failure – current role

Speaker: Naveen Mittal

Disclosure Slide
- Educational Support for the CDHNF/NASPGHAN Parenteral Nutrition Slide Set was provided by Baxter
- Speaker Disclosure – No financial disclosure

Parenteral Nutrition - History
- Late 1930s
  - positive nitrogen balance with infusion of protein hydrolysates in children
- 1944
  - glucose, casein, olive oil/lecithin preparation in 5-month-old marasmic infant for 5 days via peripheral vein
- 1961
  - safe intravenous fat preparation
- 1966
  - administration of hypertonic dextrose/amino acid solutions via central lines in beagle puppies
- 1968
  - First clinical report of successful use of PN in infant with short bowel syndrome resulting in normal growth and development

* Dudrick et al. Surgery 1968;64:134-142.
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Parenteral Nutrition - History
- Mid-1970s
  - protein hydrolysates replaced by crystalline amino acid solutions resulting in fewer allergic reactions
- 1980
  - infant-specific crystalline amino acid solutions
- 1981
  - Pediatric-specific vitamin and mineral solutions
- 1988
  - Guidelines for vitamin and mineral dosing for neonate and pediatric patients


Parenteral Nutrition - Indications
- Always use Enteral Nutrition (EN) whenever possible
- Use PN only when
  - Unable to meet nutritional requirements via the GI tract
  - Bowel dysfunction resulting in inability to tolerate EN for
    - 1-3 days in infants
    - 4-6 days in children and adolescents
    - 7-10 days in adults
- If you’re going to start PN, there needs to be a reason why you can’t use EN

Parenteral Nutrition - Route of Administration

• Central versus peripheral venous access
  - Defined by where the tip of the catheter is positioned
  - Central
    - Tip is positioned in the superior or inferior vena cava or right atrium
    - Types: peripherally inserted central catheter (PICC), tunneled and non-tunneled central catheters, umbilical venous catheter, implanted port
  - Peripheral
    - Tip is not positioned in the superior or inferior vena cava or right atrium
    - Type: peripheral intravenous catheter
• Intradialytic PN

Parenteral Nutrition - Peripheral vs. Central

Peripheral PN
• Used for <2 weeks
• Patient has no fluid restriction and nutrient needs can be met
• Osmolarity 900-1000 mOsmol/L *
  - Maximum 10-12.5% dextrose

Central PN
• Used for >2 weeks
• Patient is fluid restricted and nutrient needs cannot be met by peripheral PN
• Peripheral access limited
• Can use hypertonic solutions


Pediatric Issues

• Tunneled and non-tunneled catheters
• The more lumens the greater the risk of infection
• Impregnated catheters useful in the short-term
  - Can be impregnated with antibiotics or antiseptics
  - May prevent catheter-related infection
  - May cause allergic reactions
• Removal in the case of sepsis may not be an option (especially for neonates or SBS)
• Line needs to be secured


Parenteral Nutrition - Administration

• Type of solution
  - 2-in-1: dextrose and amino acids
  - 3-in-1: dextrose, amino acids and lipids
• Filters
  - 0.22 micron filters
    - Remove most pathogenic bacteria
    - Used only with 2-in-1 solutions
    - Lipid solutions are sheared by the smaller filters
  - 1.2 micron filters
    - Removes only Candida and large lipid droplets
    - Can be used with 3-in-1 solutions
  - Never remove a filter!

Components of PN

• Non-protein energy
  - Carbohydrates (dextrose)
  - Fat (lipid)
• Protein (amino acids)
• Electrolytes
• Minerals, vitamins, trace elements
• Water
• Miscellaneous: heparin, medications (e.g. ranitidine)
Components of PN - Macronutrient Guidelines

<table>
<thead>
<tr>
<th>Weight</th>
<th>Daily Recommendation</th>
<th>Weight</th>
<th>Daily Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>10-20 kg</td>
<td>1.2-2.5 g/kg</td>
<td>&gt;20 kg</td>
</tr>
<tr>
<td>Energy/Caloric</td>
<td>10-20 kg</td>
<td>60-80 kcal/kg</td>
<td>&gt;20 kg</td>
</tr>
<tr>
<td>Fluid</td>
<td>&gt;20 kg</td>
<td>&gt;1000 mL + 5 mL/kg</td>
<td>&gt;20 kg</td>
</tr>
<tr>
<td>Carbohydrates (Dextrose)</td>
<td>10-20 kg</td>
<td>20-25 g/kg</td>
<td>&gt;20 kg</td>
</tr>
<tr>
<td>IV Fat Emulsion</td>
<td>&gt;18 kg</td>
<td>1-2 g/kg</td>
<td></td>
</tr>
</tbody>
</table>

Examples of Amino Acid Solutions

- Aminosyn
- TrophAmine
- STANDARD
- Aminocarno

**Components of PN - Protein**

- Functions of protein
  - Provides structure (e.g., muscle)
  - Provides function (e.g., enzymes, transport proteins)
  - Acts as a nitrogen donor to other compounds (e.g., nucleic acids, carnitine, taurine)
- Protein should not serve as an energy source
- Protein requirements vary by age and disease state
- Infants
  - Infants need conditional amino acids like histidine, taurine and cysteine because of immature synthetic abilities
  - Infant amino acid solutions are based on the serum amino acid pattern seen in breastfed infants
- Excess protein intake leads to hyperammonemia

**Minimum Carbohydrate Requirements for Age**

<table>
<thead>
<tr>
<th>Age</th>
<th>mg/kg/min</th>
<th>g/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>7.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Children</td>
<td>4.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Adolescents</td>
<td>1.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Adult</td>
<td>1.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>

**Estimation of Glucose Infusion Rate (GIR)**

- GIR varies with the age of the patient
- Need 3-4 mg/kg/min to meet glucose utilization needs and to maintain normal blood glucose levels
- Maximal glucose oxidation rate under most circumstances 7-13 mg/kg/min
  - Above this rate, fat synthesis significantly increases leading to increased RQ (CO2/O2)
  - In presence of pulmonary disease, large energy intake may lead to CO2 retention
- GIR
  - neonates and infants: 12.5 mg/kg/min
  - children & adolescents: 6 mg/kg/min
- GIR (mg/kg/min) = (Dextrose [g/kg] * Infusion Rate [mL/hr] / 0.167) / wt [kg]

OR use an online calculator:
- http://www-users.med.cornell.edu/~spon/picu/calc/glucinfr.htm
- http://www.users.mcd.com/edu/wnh/nutrition/glucinfr.htm

**Components of PN - Dextrose**

- Major source of non-protein calories is D-glucose
- Typically provide 40-55% of caloric intake
- Monohydrate form provides 3.4 kcal/g
- Stepwise increase to allow appropriate response of endogenous insulin preventing glucosuria & osmotic diuresis
- Glucose increases osmolality (risk of phlebitis)

**Examples of Amino Acid Solutions (per 100 mL)**

<table>
<thead>
<tr>
<th>Conditionally Essential</th>
<th>Standard</th>
<th>Essential</th>
<th>Nonessential</th>
<th>Nonessential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Asparagine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Valine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Proline</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
<td>0.6 g</td>
</tr>
</tbody>
</table>
Amino Acid Requirements in PN

- Amino acids

<table>
<thead>
<tr>
<th>Group</th>
<th>g/kg/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm</td>
<td>2.5-4.0</td>
</tr>
<tr>
<td>Term infant</td>
<td>2.2-3.5</td>
</tr>
<tr>
<td>Child: 5-20 kg</td>
<td>1.8-2.5</td>
</tr>
<tr>
<td>20-40 kg</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>Adolescent</td>
<td>0.8-2.0</td>
</tr>
<tr>
<td><em>Maximum daily maintenance</em></td>
<td></td>
</tr>
</tbody>
</table>

- Increased protein needs
  - Malnutrition
  - Enteric/urinary protein loss
  - Stress
  - Drugs (e.g. corticosteroids)
  - Burns

Components of PN - Fat

- Fat
  - Concentrated source of calories
  - In children, only use 20% emulsion (provides 2 kcal/mL)
  - Currently in the U.S., lipid solutions are composed of triglycerides from soybean oil and safflower and emulsified by egg yolk phospholipid

  - Minimum of 1:2% of calories from a combination of linoleic and linolenic acid to meet EFA needs (met with 0.5-1.0 g/kg/day)

  - Serum triene/tetraene ratio is reflective of EFA status

  - A triene/tetraene ratio < 0.2 is generally considered to reflect EFA sufficiency

  - Infused over 24 hours to maximize tolerance

  - Monitor triglycerides to assess tolerance

Lipids & Essential Fatty Acid Deficiency (EFAD)

- EFAD can be seen within days of fat-free PN in neonates

- Deficiency is cumulative

- Can cause
  - Decreased growth
  - Skin and hair changes
  - Increased susceptibility to infection
  - Poor wound healing

- To avoid EFAD need minimum of

  - 2% to 4% of total caloric intake as linoleic acid

- Deficiency is cumulative

- Enteric/urinary protein loss

- Drugs (e.g. corticosteroids)

- Stress

- A triene/tetraene ratio > 0.2 or linoleic acid levels

- Diagnosis: triene/tetraene ratio > 0.2 or linoleic acid levels

- In premature infants EFAD can be prevented by supplying 0.6 to 0.8 g/kg/day IVFE

Suggested Doses for Lipids

<table>
<thead>
<tr>
<th>Group</th>
<th>Starting Dose (g/kg/day)</th>
<th>Maximum Dose (g/kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neonate/Infant</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Children</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Adolescent/Adult</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Components of PN - Micronutrient Guidelines

- Daily Electrolyte Requirements

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Infants &amp; Toddlers / Children</th>
<th>Adolescents</th>
<th>A.S.P.E.N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>4-6 mEq/kg</td>
<td>3-5 mEq/kg</td>
<td>1.2 mEq/kg</td>
</tr>
<tr>
<td>Potassium</td>
<td>3-4 mEq/kg</td>
<td>7-10 mEq/kg</td>
<td>1.5 mEq/kg</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.6-1.8 mEq/kg (infants &amp; toddlers)</td>
<td>10-45 mEq/kg</td>
<td>0.5-1.2 mEq/kg</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.5-7.0 mmol/kg</td>
<td>5-8 mmol/kg</td>
<td>10-20 mmol/kg</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.25-1.0 mEq/kg</td>
<td>0.3-0.6 mEq/kg</td>
<td>10-30 mEq/kg</td>
</tr>
<tr>
<td>Chloride</td>
<td>2.4-3.5 mEq/kg</td>
<td>6-9 mEq/kg</td>
<td>Chloride/Acute - As needed to maintain acid-base balance</td>
</tr>
</tbody>
</table>

Comparison of Lipid Emulsions

- Soybean oil, medium chain triglycerides, olive oil and fish oil

- *Approximate % total fatty acids

- Soybean oil and safflower and emulsified by egg yolk phospholipid

- The ASPEN Nutrition Support Practice Manual reflects EFA sufficiency

- 0.2 is generally considered to reflect EFA sufficiency

- http://www.fresenius-kabi.com/
**Calcium and Phosphorus**

- There are limitations to amounts of Ca and Phos that can be supplied in PN.
- Ca and Phos can precipitate depending on the amounts added to the PN solution.
- Cysteine lowers pH and may be added to neonate/infant PN (by using TrophAmine®) to increase solubility of Ca and Phos.

**Components of PN - Trace Elements**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>MultiTrace®4 (per mL)</th>
<th>MultiTrace®4 Concentrate (per mL)</th>
<th>MultiTrace®5 Concentrate (per mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Neonate</td>
<td>Pediatric</td>
<td>(Adolescent/Adult)</td>
</tr>
<tr>
<td>Zinc (as Sulfate)</td>
<td>1.5 mg</td>
<td>1 mg</td>
<td>5 mg</td>
</tr>
<tr>
<td>Chromium (as Chloride)</td>
<td>0.85 mcg</td>
<td>1 mcg</td>
<td>10 mcg</td>
</tr>
<tr>
<td>Selenium (as Selenious Acid)</td>
<td>none</td>
<td>none</td>
<td>60 mcg</td>
</tr>
<tr>
<td>Copper (as Sulfate)</td>
<td>0.1 mg</td>
<td>0.1 mg</td>
<td>1 mg</td>
</tr>
<tr>
<td>Manganese (as Sulfate)</td>
<td>25 mcg</td>
<td>25 mcg</td>
<td>0.5 mg</td>
</tr>
</tbody>
</table>

**Dosing Recommendations for Pediatric Parenteral Multiple Vitamins**

<table>
<thead>
<tr>
<th>Manufacturer Recommendations</th>
<th>NAG-AMA Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>1.5</td>
</tr>
<tr>
<td>1-3</td>
<td>3.25</td>
</tr>
<tr>
<td>&gt;3</td>
<td>5</td>
</tr>
</tbody>
</table>

* MVI-Pediatric® assumes normal organ function

0 Nutrition Advisory Group-American Medical Association

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**Multivitamin Requirements with Examples of some Multivitamin Products**

- **Vitamin A, IU**
  - Term infants: > 1 yr: 700-1500 IU
  - Neonate: > 0 days: 2200 IU

- **Vitamin E, IU**
  - Term infants: > 1 yr: 15 IU
  - Neonate: > 0 days: 10 IU

- **Vitamin D, IU**
  - Term infants: > 1 yr: 400 IU
  - Neonate: > 0 days: 100 IU

- **Vitamin K, mg**
  - Term infants: > 1 yr: 0.1 mg
  - Neonate: > 0 days: 0.2 mg

- **Thiamine, mg**
  - Term infants: > 1 yr: 1.2 mg
  - Neonate: > 0 days: 1.2 mg

- **Riboflavin, mg**
  - Term infants: > 1 yr: 1.4 mg
  - Neonate: > 0 days: 1.4 mg

- **Niacin, mg**
  - Term infants: > 1 yr: 17 mg
  - Neonate: > 0 days: 17 mg

- **Biotin, mcg**
  - Term infants: > 1 yr: 5 mg
  - Neonate: > 0 days: 15 mg

- **Vitamin B12, mcg**
  - Term infants: > 1 yr: 0.3 mg
  - Neonate: > 0 days: 0.3 mg

- **Vitamin C, mg**
  - Term infants: > 1 yr: 80 mg
  - Neonate: > 0 days: 80 mg

**Components of PN - Iron (Fe)**

- Not part of standard PN though iron deficiency is common in patients receiving PN.
- Addition of parentral Fe is controversial because of the potential risk of increased sepsis and because Fe is an oxidant.
- Consider in patients who have been NPO for > 2 months.
- Avoid Fe in infants until age 2 months because of frequent blood transfusions and the possibility of Fe overload.
- Parenteral Fe preparations
  - Fe dextran is the only iron prep that can be given in PN.
  - Fe dextran is incompatible with fat emulsions and 3-in-1 solutions.
  - Consider daily or weekly dose in bags that do not contain lipid or in 2-in-1 solutions.
  - Intravenous dose for Fe dextran
    - 0.1 - 0.2 mg/kg for infants (age > 2 months) and children
    - 2 - 4 mg/kg for older children and adolescents.
  - Continued monitoring of Fe status is recommended to prevent Fe overload.

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Zinc (Zn)

- Zn is an important trace element especially in growth and wound healing.
- Signs of Zn deficiency:
  - Dermatitis, alopecia, diarrhoea, immune deficiency
  - Menorrhagia and menometrorrhagia
- Zn excreted mainly in feces:
  - Increased needs in diarrhoea, hypercatabolic states, ostomy losses, mucositis, and chest tube losses.
- Measure of Zn status:
  - Serum Zn is a poor measure but is the only measure clinically available.
  - A low alkaline phosphatase may suggest Zn deficiency but this is not diagnostic.
- Can increase intake in PN to 1.5 times usual dose in conditions associated with increased needs.

Copper (Cu)

- Cu deficiency is rare:
  - Risk factors: malabsorption, prematurity, and severe malnutrition.
  - Can present with anemia (hypochromic, macrocytic), leukopenia, neutropenia, bone abnormalities.
- Biliary tract is the predominant route for Cu excretion:
  - Patients with cholestasis have decreased Cu excretion; maybe at increased risk for toxicity, may be a sign than cause of cholestasis.
- Patients with diarrhoea have increased Cu needs.
- Monitoring:
  - In addition to checking serum Cu level, clinical picture should be used to assess status.
  - Assess levels periodically.

Selenium (Se)

- Se deficiency can develop within 6 weeks of Se-free PN:
  - Can cause cardiomyopathy, growth retardation, pseudo-albinism, white fingernails, and skin disorder.
  - Suggested that patients be supplemented if on exclusive PN for >4 weeks.
- Toxicity is rare:
  - Can cause nausea, diarrhoea, irritability, fatigue, peripheral neuropathy, hair loss, nail changes.
- Total plasma selenium:
  - Most widely used test of Se status.
  - Fairly accurate.
  - In the presence of systemic inflammation, levels decrease.
- In patients with impaired renal function, remove Se from PN and monitor levels.

Parenteral Nutrition

- Cycling PN:
  - Daily administration of PN over a period of time which is < 24 hours e.g., 8-20 hour cycle; average 10-12 hours.
  - Pre-requisite:
    - Stable regimen.
    - Ability to handle large volume of fluid and nutrients over a short amount of time.
    - The smaller the infant the less tolerant they may be of the cycle.
  - Putative benefits:
    - Decreased hepatic steatosis.
    - Allows for a more normal daytime routine.
    - Increases mobility of the patient.
  - Wean PN rate for the last hour by decreasing the rate by 50%.
  - Check serum glucose 30-45 minutes after stopping PN with every change in length of cycle.

- Transitioning to Enteral Feeds:
  - Enteral feeds should be started as soon as possible in trophic amounts (~20% of goal calories/volume).
  - Once enteral feeds are tolerated, PN volume is weaned as feeds are increased.
  - Goal fluid volume for feeds may not result in goal caloric intake and enteral feeds may need to be concentrated to achieve goal caloric intake.
  - Cycling PN during the transition to enteral feeds is useful in infants and young children; continuous feeds will help with maintenance of normal serum glucose levels and tolerance of cyclic regimen.
Parenteral Nutrition - Monitoring

- Growth
  - Weight
  - Length/height
  - Head circumference
- Laboratory
  - Electrolytes/minerals
  - Triglycerides
  - Liver and renal function
  - Hemoglobin
- Trace element, carnitine and vitamin levels


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial</th>
<th>Weekly</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolytes</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Glucose</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Calcium</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>BUN</td>
<td>✔</td>
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<td>✔</td>
</tr>
<tr>
<td>Creatinine</td>
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<tr>
<td>Magnesium</td>
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<tr>
<td>ALT</td>
<td>✔</td>
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<tr>
<td>AST</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>GGT</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Prealbumin</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Conjugated bilirubin</td>
<td>✔</td>
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</tr>
<tr>
<td>Total protein</td>
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<tr>
<td>Trace elements</td>
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<tr>
<td>Vitamins</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
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</table>

Parenteral Nutrition - Complications

- Infectious
- Mechanical
  - Infusate-related
  - Catheter-related
- Metabolic
  - Electrolyte-, mineral-, trace element- and vitamin-related
  - PN-Associated Liver Disease (PNALD)
  - Bone disease
  - Overfeeding and underfeeding
  - Refeeding syndrome
  - Allergy
  - Miscellaneous e.g. nephropathy

Parenteral Nutrition - Infectious Complications I

- Bacterial and fungal causes
- Infection vs. colonization (22% of all hubs)
- Causes
  - Colonization
    - inside catheter or hub
    - outside of the subcutaneous catheter
    - in fibrin sleeve
    - in subcutaneous tract
  - Contamination
    - from blood seeding
    - skin contamination along the catheter tract
    - non-sterile entries into the line
    - contaminated PN solutions
- Risk of sepsis is reported at 1.5 episodes a year in home PN patients


Parenteral Nutrition - Infectious Complications II

- Prevention
  - Sterile technique during placement
  - Use line only for PN and not for blood draws
  - Dressing changes per protocol
  - Avoid multi-lumen catheters
  - Avoid catheters in groin/diaper area
  - Inadequate pediatric data on the benefits of antibiotic and ethanol locks and antibiotic-impregnated catheters

Parenteral Nutrition - Mechanical

- Most common non-infectious complication of central venous catheters
- Thrombotic vs. non-thrombotic
  - Resistance to flushing and aspiration
  - Treatment: thrombolytic or specific agents i.e., alcohol for lipid precipitates
- Fibrin sleeve at distal catheter tip
  - Can flush easily but difficulty in aspiration
  - Treatment: thrombolytic therapy

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Parenteral Nutrition - Liver Disease I

- Well described complication of PN
- Develops in 40 – 60% of neonates: ~15% in children
- Variable degree of injury
  - Mild: mild cholestasis, gall stones, hepatic steatosis
  - Severe: cirrhosis and liver failure
- Pathogenesis:
  - Multifactorial
  - Prolonged duration of PN
  - Lack of enteral feeding
  - Prematurity and low birth weight
  - Early and recurrent sepsis
  - Length of bowel remnant
  - Reduced enterohepatic circulation
  - Deficiency or toxicity of components of PN solutions (excess glucose, excess energy, amino acid content, manganese, copper, and fat emulsions)


Parenteral Nutrition - Liver Disease II

Treatment
- Provide maximal tolerated EN
- Provide cyclical PN as soon as possible
- Consider and treat small bowel bacterial overgrowth
- Consider reducing intravenous lipids, if conjugated bilirubin rises with no other explanation
  - Consider fish-oil based lipids, if the above strategy fails
- If transaminases, alkaline phosphatase or conjugated bilirubin continue to increase, consider commencing ursodeoxycholic acid


Short Bowel Syndrome with PN Liver Disease

Feeding tube

Options at Referral Centers

- TPN optimization
- AGIR: Autologous Gastro-Intestinal Reconstruction
  - Ostomy creation/closure; Anastomosis; Resection
  - Bowel lengthening procedures
    - Bianchi’s procedure
    - STEP procedure
- Organ Transplant – Intestine; Liver; Combined

TPN Optimization - Fat Emulsions

Changing the Paradigm: Omegaven for the Treatment of Liver Failure in Pediatric Short Bowel Syndrome

Ivan R. Diamond, Anca Sterescu, Paul B. Poncherz, Jae H. Kim, and Paul W. Wales

Group for Improvement of Intestinal Function and Treatment, The Hospital for Sick Children, Toronto, Canada
Comparison of Lipid Emulsions

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>Soy</th>
<th>Fish Oil</th>
<th>SMOF*</th>
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<tbody>
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<td>Linoleic</td>
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<tr>
<td>Arachidonic</td>
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</tbody>
</table>

*Approximate % total fatty acids

# Soybean oil, medium chain triglycerides, olive oil and fish oil

TPN Optimization - Fat Emulsions

Proponents of Fish oil based lipid:
- No phytosterols - known to cause cholestasis
- Widely used in Europe, Asia – Safe to use
- Multiple reports in humans to show resolution of biochemical and histological cholestasis

TPN Optimization - Fat Emulsions

Opponents of Fish oil based lipid:
- Not FDA approved – expensive and inconvenient
- No randomized controlled trial so far
- Benefit over historical controls not EBM
- Reduction of lipid dose is equally effective
- Animal model studies and human case reports showing accelerated fibrosis in liver

Autologous Gastro-Intestinal Reconstruction - Bianchi Procedure
**Current Indications – Consensus**

Indications for pediatric intestinal transplantation: A position paper of the AST

Kaufman S, Bianchi A, Mittal N, Tsakis A.

Pediatric Transplantation - April 2001

Indications for pediatric intestinal transplantation: A position paper of the American Society of Transplantation


**Intestinal Failure – High Mortality Risk Despite Best Parenteral Nutrition**

- Congenital mucosal disorders
  - Microvillus Inclusion Disease (MID)
  - Tufting enteropathy

- Ultra short bowel syndrome
  - < 10 cm of jejunum; No Ileo-Cecal Valve

**MID – Not All MID are Doomed**

Microgroup in the mini group has good future

Lateral vs. Apical
Short Bowel Syndrome - With life-threatening Complications of Parenteral Nutrition

- Parenteral nutrition dependency
- High risk of dying due to PN complications

Parenteral Nutrition Dependency in SBS

- Length of the residual small intestine
  - Less than 30 - 40 cm
- Absent Ileo-Cecal valve
- Failure to tolerate 75% of enteral nutrition by age 3 months

Serum Citrulline as a Functional Marker of SBS

Life-threatening Complications of Parenteral Nutrition

- Irreversible liver disease
- Recurring sepsis
- Brain abscess
- Infective endocarditis
- Multi-organ failure
- Loss of central venous access

Proposed Algorithm

Intestinal Transplant in San Antonio
Dallas First - Intestinal Transplant

PN - Economics in Patients with SBS

- Billable charges during the first 5 years after onset of SBS exceeded $1.6 million
  - Costs were highest in the first year
  - Inpatient hospitalization accounted for 80% of all expenses
  - Home care costs were low in the first year and increased every year thereafter as long as the child required home care for care of SBS
  - Mean parental nutrition costs varied between $80,000 and $150,000 per year
- Costs vary on number of hospitalizations
- Reducing septic episodes reduces costs


Parenteral Nutrition - Conclusions

- PN can be lifesaving in patients with limited tolerance of enteral nutrition
- Development of a PN regimen should take into account the age and clinical condition of the patient
- The practitioner must be aware of the risks of PN
- Monitoring is key to successful therapy

Thank Y'all