Abstract

Objective: to present a review on parenteral nutrition in infants and children, characterizing the importance of nutrition therapy to support and recover their nutritional status.

Methods: articles from specific journals were analyzed. Information was also obtained from the author’s own experience in the area.

Results: major recommendations; venous access; protein-energy composition (electrolyte, vitamins and trace elements); formulation; administration; clinical and laboratorial control; and complications were also discussed.

Conclusions: parenteral nutrition, if well-indicated, is very important for the management of several childhood diseases, allowing the maintenance and restoration of nutritional status.

Introduction

IBRANUTRI, a multicenter study conducted throughout Brazil, revealed a prevalence of in-hospital malnutrition in adults around 50%.[1] There are no similar studies with children, however, we know that patients affected by malnutrition have high hospital admission rates, and diseased children end up developing in-hospital malnutrition due to their original pathology. Regardless of the pathology that determines the need for hospital admission, patients’ nutritional status must be maintained, and if it is deficient, it should then be rehabilitated. This is the basic rule in terms of nutritional therapy. Enteral nutrition (EN) is preferred to parenteral nutrition (PN), when the digestive tube may be used either orally or through a probe, using or not special diets. PN must be used when oral or enteral nutrition is not possible, difficult, inadequate, insufficient, risky or contraindicated. Enteral nutrition is always more physiological and safe. EN always allows a more harmonic and, usually more complete nutrition, in addition to stimulating the intestines, preventing atrophic villosity. It also prevents hydroelectrolytic imbalance and infections, risks that are usually present in intravenous nutrition. However, when it is well-recommended and adequately used, parenteral nutrition is fundamental and safe, and will bring benefits to patients who cannot do without nutritional support. Experience shows that an adequate nutritional status confers higher resistance to multifactorial metabolic stress situations such as surgeries, traumas and infections. It is easier to maintain a good nutritional status than to rehabilitate patients with malnutrition.
Presently, PN is defined as intravenous nutrient infusion, and total parenteral nutrition (TPN) as exclusively intravenous infusion of all necessary nutrients.

**Recommendations**

Protein or energy malnutrition results from several isolated or combined factors such as reduced food intake, deficient absorption, severe losses or increase in nutritional requirements secondary to hypercatabolism. Protein loss represents loss of essential function and malnutrition is accompanied with anemia, delayed wound cicatrization, immunodeficient response, higher incidence of infections, longer hospital stay, and higher morbidity and mortality. PN has revolutionized the treatment of severe and debilitating infections. Patients regarded as incurable in the past now have a new perspective for evolution and many are the cases in which PN has represented as essential means for rehabilitation and survival. Children with cancer should have their nutritional status monitored, and should be submitted to nutrition therapy as soon as nutrient intake deficiency is detected. Table 1 presents the major recommendations of PN for children.

**Table 1 - Main indications for parenteral nutrition**

- **Preoperative**
- **Postoperative**
- **Traumas and burns**
- **Gastrointestinal diseases:**
  - Small bowel syndrome
  - Pancreatitis
  - Fistulae
  - Severe inflammatory bowel disease (Crohn’s disease or ulcerative colitis)
  - Peritonitis
  - Severe chronic or persistent diarrhea
- **Insufficient enteral nutrition:**
  - Anorexia nervosa
  - Cachexia
  - Debilitating diseases
  - Cancer
- **In case of unconsciousness with contraindication of enteral nutrition**
- **Renal failure**
- **Hepatic coma**
- **Some pediatric conditions:**
  - Congenital malformations (omphalocele, gastroschisis)
  - Prematurity
  - Necrotizing enterocolitis

**Access routes**

Parenteral nutrition may use two major access routes: peripheral route, through common veins, and central route, through the placement of a central catheter. The advantages and disadvantages of each access route are described in Table 2.

**Table 2 - Advantages and disadvantages of peripheral and central parenteral nutrition**

<table>
<thead>
<tr>
<th>Access routes</th>
<th>Peripheral Advantages</th>
<th>Central Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simpler, cheaper, with lower risk for complications, such as infections, thrombosis, etc.</td>
<td>Allows the use of hyperosmolar solutions (patients with water restriction that require more concentrated caloric solutions); use of parenteral nutrition for a long period.</td>
</tr>
<tr>
<td></td>
<td>It does not allow hyperosmolar solutions (glucose at a concentration higher than 12% is avoided); need for frequent change of place in order to avoid thrombophlebitis.</td>
<td>Higher risk for infections and other complications (deep vein thrombosis, for example).</td>
</tr>
</tbody>
</table>

For long-term and/or home parenteral nutrition (over 1 month), we recommend the placement of semi-implantable catheters with subcutaneous cuff for anchorage, since these allow the removal of suture stitches for fixture 10 days after implantation, and present a long subcutaneous tunnel, providing protection against skin bacteria migration, as the cuff has antibacterial properties. These catheters when properly handled may last for a long time. Total training of team and family members (if necessary) on how to handle solutions, catheter, and PN infusion is of paramount importance to prevent infection, PN most frequent complication.

We recommend the following routine every time the catheter, cannula, extensions, and parenteral nutrition bag: (1) exhaustive handwashing with water and neutral soap; (2) material: 9 gauze dressings (4 gauze dressings embedded in alcoholic iodine or iodine-povidone, and 5 gauze dressings embedded in alcohol 70%); (3) rub each of the 4 gauze dressings embedded in alcoholic iodine 70% on the connection that will be opened or on the point that will be punctured, with an alternate proximal and distal distance of 10 cm, without returning to the place that will be manipulated; (4) repeat the procedure using the 4 gauze dressings embedded in iodine-povidone or alcoholic iodine; (5) wrap the point that will be manipulated in 1 gauze dressing embedded in
alcohol 70% for 3 minutes, and then use it as support for manipulation; (6) always clamp the central catheter before opening it, thus preventing air from flowing in and the consequences that may result from air inflow; (7) in case of cyclic parenteral nutrition, when the catheter is not in use, inject heparin solution 100U/ml in 2.5-3.0 ml (average volume of central catheters) - 300U/3 ml and close with proper sterilized cap.

Hospital Infection Control Practice Advisory Committee, summoned by CDC in Atlanta, Georgia, USA, publishes prevention guidelines for infections related to intravascular systems in 1996. This committee, after extensively revising the literature on the topic, defines as scientifically proved procedures: (1) recommended change of the whole infusion connection set every 72 hours if solution 3:1 (carbohydrate, amino acids and lipids). In case of separate lipid infusion, perform it within 12 hours; (2) catheter wound dressing with sterilized gauze or transparent dressing, which should be replaced when the infusion system is substituted, or whenever necessary (dressing is loose, wet, etc). Check the dressing every day, touching it externally. If patients report pain, spread the dressing open and check it. In case of fever of unknown origin, also spread the dressing open. To replace the dressings, it is not necessary to use sterilized gloves, but exhaustive handwashing is needed. Do not use antimicrobial ointment on the catheter wound dressing; (3) there is no recommendation for the use of filters for regular infection control; these should only be used when preparing solutions. There is no recommendation for profilactic use of intravenous antimicrobial drugs; (4) choose single-lumen catheters for implantation.

**Composition**

**Calories**

Usually, calorie requirements correspond to the following in terms of basal situation: Low-birth newborns need 150 kcal/kg/day and normal newborns require 100-120 kcal/kg/day; breast-fed infants, 100-140 kcal/kg/day; preschool children (1-7 years), 75-90 kcal/kg/day; schoolers (7-12 years), 60-75 kcal/kg/day; and adolescents (12-18 years), 30-60 kcal/kg/day.

For simple calculation of caloric requirements, we can use the following: from the first month up to 10 kg - 100 kcal/kg; from 10 to 20 kg - 1000 kcal + 50 kcal/kg above 10 kg; over 20 kg - 1500 kcal + 20 kcal/kg above 20 kg. Depending on the patients’ clinical status (fever, sepsis, cystic fibrosis, etc), it may be necessary to add some calories in order to provide adequate nutritional status. In case of fever, caloric requirements are increased in 12%; mechanic ventilation may also require 20-30% more calories; in severe infections, around 40-60% more calories; and in case of burns, depending on the length of the affected area, 100% more calories may be necessary. For patients with malnutrition or who present weight loss, the calculation of calories must be done using ideal weight instead of current weight. Ideal weight may be calculated by considering patients’ previous weight (prior to weight loss) or obtained through height. In this case, height is measured, and by means of growth curves, we define the age to which the obtained height would be a percentile 50th, then we find percentile 50th weight for the corresponding age (weight/height). We must always check calories using current weight, since we cannot provide more than 200-240 kcal/kg/day in relation to current weight. In case of breast-fed infants, especially during the first semester, ideal weight is obtained by adding monthly average increases to weight (700 g/month during the first three months and 600 g/month in the following three months).

Calorie sources include glucose (3.4 kcal/g), lipids (see below) and amino acids (4 kcal/g). Lipid solutions available in the market are: (1) lipid solution at 10% → 11 kcal/g of lipid; (2) lipid solution at 20% → 10 kcal/g of lipid.

For calculating TPN calorie content, we usually disregard the calories contained in amino acids, as the objective is protein synthesis. This is a controversial statement; it is true for newborns and breast-fed infants, but in the case of older children and adults, there is a tendency to consider the 4 calories per gram of amino acid as part of total calorie calculation, as usually done in enteral nutrition. For adequate use of amino acids (incorporation of nitrogen and positive nitrogen balance), we should offer at least 150 calories in the form of carbohydrates and fat for each gram of nitrogen or 24 kcal/g of amino acids (1 g N2=6.25 g Aa).

Glucose is the first carbohydrate option for TPN. A minimum rate of 40% of caloric requirements in the form of glucose prevents accumulation of cetonic bodies. When we infuse PN into a peripheral vein, we can safely use a 12% concentration of glucose, any concentration higher than this may cause phlebitis. If PN is infused into a central vein, concentration may be higher, not exceeding 25%, and a careful control over glycosuria and glycemia will be necessary.

In breast-fed infants, especially newborns, glucose infusion rate must be calculated. In healthy newborns, initial infusion should be between 7 and 8 mg/kg/min. In premature babies, initial glucose infusion must be around 6 mg/kg/min. Initial glucose infusion rate may be progressively increased up to 11 and 14 mg/kg/min respectively in normal preterm and newborn babies. Hyperglycemia in preterm babies may cause intraventricular hemorrhage.

We do not systematically calculate glucose infusion rate for full-term breast-fed infants, after 2 months of life, since this calculation usually reduces the amount of glucose to be infused. We normally use glucose concentrations between 15 and 18% when TPN infusion is carried out via a central route. This way, it is possible to achieve total calorie supply, as we understand that, if we submit patients to the risks of
such feeding technique, we have to offer them plenty of benefits. The concern with hyperglycemia may be easily controlled through glycosuria dosage, once a shift at the initial stage, by spacing control according to response.

Excessive use of glucose leads to an increase in CO₂, and as a consequence, respiratory quotients rises. High respiratory quotient (RQ=CO₂/O₂) causes lipogenesis and accumulation of CO₂, which in their turn increase ventilatory stimulus, and may even cause respiratory insufficiency in severely diseased patients. Therefore, it is recommended that the use of glucose and lipids, as calorie source, be combined, preventing lipogenesis and also overproduction of CO₂.8

Lipids have high caloric value and low osmolarity. Fat particles are metabolized in a similar way to those of natural kilomicra. In general, 2 to 3 g/kg/day are used, and may be increased up to 4 g/kg/day of lipids, providing that the amount of lipid calories in relation to the amount of general calories (protein and nonprotein) is around 35% and does not exceed 55%. Patients on cyclic parenteral nutrition, after receiving a lipid solution, should clarify their plasma within 4 hours, or in other words, they should not be lipemic and their triglyceride level should not be high at the time collected blood is inspected.

The minimal fat requirement to meet the needs for essential fatty acids (linoleic and linolenic acids, which will be converted into arachidonic acid) is approximately 0.5 g/kg/day or 2 to 4% of general calories. Remember that long-chain triglycerides are necessary for the supply of essential fatty acids. Essential fatty acid deficiency provokes skin disorders, especially pruritic desquamative rashes on the face and peri-official regions, hairfall, slow wound cicatization, anemia, thrombocytopenia with hemorrhages and growth retardation. Current recommendation is to always use lipids when prescribing a PN. In certain cases, the use of lipids should be restricted, e.g.: hyperbilirubinemia indirectly caused by carrier competition; coagulation disorders; and insufficient respiratory syndrome in preterm babies, in which fat emulsion may hinder oxygen diffusion.6 In these situations, we may use lower concentrations of lipids in PN, but not suppress this nutrient source.

Lipids at 10% and 20%, and combined solutions of medium-chain triglycerides are available in the market. Medium-chain triglyceride solutions are quickly hydrolyzed in several tissues and largely oxidized with low storage in tissues, favoring the elimination of infused triglycerides.9,10 We prefer these medium-chain triglyceride solutions with 20% of lipids, as they reduce volume and increase triglyceride elimination with low cholesterol levels, since these solutions contain lower concentration of phospholipids.

The fat overload syndrome is very rare, and is characterized by extreme serum triglyceride levels, fever, hepatosplenomegaly, coagulopathy and organ dysfunction. Therefore, serum triglyceride levels should be monitored.10

Proteins are essential components in cell structure, immunoresponse, growth, neuro muscular, enzymatic and mental processes. When we calculate a PN, we should pay attention to the balance between the amino acids provided and non-protein calories, which should be between 150 and 200 kcal of nonprotein calories per gram of nitrogen. Insufficient nonprotein calories cause amino acids to be burned for calorie instead of protein synthesis.6

Newborns require a higher amount of proteins per unit of weight if compared to older infants and adults. Studies have shown that an average amount of 3 g/kg/day of an adequate mixture of amino acids is necessary for an equivalent intrauterine weight gain of 15 g/kg/day and a nitrogen retention of 300 mg/kg/day. The estimated need, based on fetal incorporation rate for preterm newborns is 3.5 to 4.0 g/kg/day.11,12

Present feeding formulas contain enough dispensable and indispensable amino acids, allowing normal growth in newborns and preterm babies. However, these preparations do not seem to be adequate. Many of the problems with parenteral preparations are due to the fact that ingested proteins are submitted to more extensive enteral and hepatic metabolism than parenterally-fed amino acids, including conversion into other amino acids (e.g.: arginine) that reach the plasma through support or through protein synthesis. As this important source of amino acids does not occur when nutrients are parenterally-fed, the parenteral necessities of these amino acids are enhanced. In addition, when phenylalanine and methionine are converted into tyrosine and cysteine, respectively, parenteral feeding of phenylalanine and methionine does not lead to this conversion. While glutamine, branched-chain amino acids, and arginine seem to be important for breast-fed infants who suffer from stress and have their gastrointestinal function affected, more specific involvements have not been defined. Since some amino acids are insoluble (e.g.: tyrosine) and others are unstable in aqueous solutions (e.g.: glutamine and cysteine), it is necessary to find ways to administer them. Dipeptide solutions of all kinds are available and can be used efficiently and safely in adults. Probably, the same is valid for breast-fed infants, but there are not enough studies to prove their efficacy and safety in this age group.13

Infants should receive 2.5 to 3 g/kg/day of amino acids and no more than 3.5 g/kg/day so that their nitrogen balance is positive. In premature babies (especially), initial infusion should be 0.5-1.0 g/kg/day and should be increased to 0.5 g/kg every subsequent day.14 It is recommended that larger amounts of amino acids (3 up to 4 g/kg/day) be used for these premature babies.

There are 4 different types of crystalline amino acid solutions available in the Brazilian market: (1) crystalline amino acid solutions for adults with the 20 major amino acids that are found in natural proteins; (2) pediatric amino acid solutions with 20 amino acids in concentrations that suit the requirements of newborns and breast-fed infants. Pediatric amino acid solutions try to imitate plasmatic
concentration of amino acids in newborns after they have been breast-fed. These solutions must contain cysteine, taurine, tyrosine, and histidine; however, taurine solutions and adequate amount of cysteine are inexistent in the Brazilian market; (3) amino acid solutions for renal insufficiency, containing the eight essential amino acids, plus histidine; (4) amino acids solutions fortified with branched-chain amino acids (leucin, isoleucin e valine) seem to be useful for patients who suffer from hepatic insufficiency combined with encefalopathy. Apart from this situation, the use of solutions fortified with branched-chain amino acids is not scientifically proved. In the Brazilian market, these solutions contain approximately 50% of branched-chain amino acids and 50% of aromatic amino acids.

In pediatrics, we systematically use the pediatric amino acid solutions previously described.

**Water requirements**

Children’s water requirements depend on their age. For preterm newborns: start with 40-60 ml/kg, increase to 60-80 ml/kg. At the end of the first week of life: 100-120 ml/kg and at the end of the second week 130-140 ml/kg. Full-term newborns: 50-65 ml/kg on the first day; 60-80 ml/kg on the second day; 80-100 ml/kg until one month of life; 100-150 ml/kg between the first and twelfth months. After the first year: up to 10 kg - 100 ml/kg; between 10 and 20 kg - 1000 ml + 50 ml/kg above 10 kg; above 20 kg - 1500 ml + 20 ml/kg above 20 kg.

If patients have abnormal losses (diarrhea, vomiting, fistulas, ostomies, drainage, phototherapy, etc), the amount must be increased in order to compensate for the losses. Children with severe malnutrition have a higher water content than eutrophic children, and this should be taken into consideration on deciding the amount to be used.

Sometimes, it is necessary to use larger amounts to provide an adequate calorie intake; these amounts can be administered providing that there are no contraindications and patients tolerate it well.

**Other components**

**Electrolytes:** must be used according to patients’ needs. In general, parenteral nutrition should contain maintainance amounts (Table 3) and, if patients have hydroelectrolytic imbalance, this supplementation must be provided using a parallel intravenous solution, thus the prescription of parenteral nutrition does not need to be modified every day, or even several times a day, unnecessarily hindering our patients’ treatment. Table 4 presents the electrolytic concentration of major body fluids, which have to be restored in case of loss.

Phosphorus is usually commercialized in the form of potassium phosphate in the Brazilian market, which provides 2 mEq of potassium and 2 mEq of phosphate or 1 mMol of phosphorus per ml. The use of potassium phosphate is limited by calcium precipitation. The use of organic phosphorus has the advantage of being more compatible with calcium gluconate without any concentration limit. Every ml of organic phosphorus solution contains phosphorus at 0.33 mMol (10.23 mg), sodium at 0.66 mMol (15.33 mg), glucose at 0.33 mMol (60.09 mg).

**Vitamins:** vitamin requirements vary according to age and patients’ clinical status. Ideally, vitamin serum levels should be determined, but that is not possible in our environment. Normally, standard pediatric vitamin mixed solutions are used, in which doses may be adapted according to patients’ needs. The most commonly used polyvitamin treatment is POLIVIT® (Inpharma), in which 10 ml from bottle A and 5 ml from bottle B are used. For preterm newborns, it is recommendable to use 4 ml/kg from bottle A and 2ml/kg from bottle B up to the recommended amount.

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### Table 3 - Electrolytes for parenteral nutrition solutions

<table>
<thead>
<tr>
<th>Electrolytes</th>
<th>Preterm mEq/kg</th>
<th>Term newborn mEq/kg</th>
<th>Preschool mEq/100 kcal</th>
<th>School mEq/100 kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>2-3</td>
<td>3-5</td>
<td>3 mEq/100 kcal</td>
<td>3 mEq/100 kcal</td>
</tr>
<tr>
<td>Potassium</td>
<td>2-3</td>
<td>2-3</td>
<td>2 mEq/100 kcal</td>
<td>2 mEq/100 kcal</td>
</tr>
<tr>
<td>Chlorine</td>
<td>2-3</td>
<td>3-4</td>
<td>2 mEq/100 kcal</td>
<td>2 mEq/100 kcal</td>
</tr>
<tr>
<td>Calcium*</td>
<td>1.0-2.0 mEq/kg</td>
<td>1.0-2.0 mEq/kg</td>
<td>1.0-2.0 mEq/kg</td>
<td>1.0-2.0 mEq/kg</td>
</tr>
<tr>
<td>Phosphor**</td>
<td>0.5-2 mMol/kg</td>
<td>0.5-2 mMol/kg</td>
<td>0.5-2 mMol/kg</td>
<td>0.5-2 mMol/kg</td>
</tr>
<tr>
<td>Magnesium***</td>
<td>0.2-0.5 mEq/kg</td>
<td>0.25-0.3</td>
<td>0.3-0.5 mEq/kg</td>
<td>0.3-0.5 mEq/kg</td>
</tr>
</tbody>
</table>

* 1 ml calcium gluconate = 0.45 mEq Ca
** 1 ml KH₂PO₄=2 mEq K + 2 mEq PO₄ (1 mMol P)
***1 ml MgSO₄ 12.32% = 1 mEq Mg /1 ml de MgSO₄ 50%=4 mEq Mg
Table 4 - Additional electrolytic losses in body fluids (mEq/l)

<table>
<thead>
<tr>
<th>Origin</th>
<th>Sodium</th>
<th>Potassium</th>
<th>Chlorine</th>
<th>Bicarbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stomach</td>
<td>2-80</td>
<td>5-20</td>
<td>100-150</td>
<td>-</td>
</tr>
<tr>
<td>Pancreas</td>
<td>120-140</td>
<td>5-15</td>
<td>90-120</td>
<td>90</td>
</tr>
<tr>
<td>Bile</td>
<td>120-140</td>
<td>5-15</td>
<td>80-120</td>
<td>35</td>
</tr>
<tr>
<td>Small bowel</td>
<td>100-140</td>
<td>5-15</td>
<td>90-130</td>
<td>25</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>10-90</td>
<td>10-80</td>
<td>10-100</td>
<td>45</td>
</tr>
<tr>
<td>Urine</td>
<td>40</td>
<td>40</td>
<td>20</td>
<td>-</td>
</tr>
<tr>
<td>Sweat</td>
<td>10-30</td>
<td>3-10</td>
<td>10-35</td>
<td>-</td>
</tr>
<tr>
<td>Ileostomy</td>
<td>45-135</td>
<td>3-15</td>
<td>20-115</td>
<td>-</td>
</tr>
<tr>
<td>Burn*</td>
<td>140</td>
<td>5</td>
<td>110</td>
<td>-</td>
</tr>
</tbody>
</table>

* Proteins present in lost fluids of burn.

Source: Spolidoro, Trotta, Gazal & Brandão²

Table 5 - Daily trace element requirement for children

<table>
<thead>
<tr>
<th></th>
<th>Preterm (µg/kg/day)</th>
<th>Term newborn and infant (µg/kg/day)</th>
<th>Children (µg/kg/day) (maximum in mg/day)</th>
<th>OliPed® (µg/ml)</th>
<th>Ped Element® (µg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>400</td>
<td>150</td>
<td>50 (5000)</td>
<td>100.0</td>
<td>500.0</td>
</tr>
<tr>
<td>Copper*</td>
<td>20-60</td>
<td>20</td>
<td>20 (300)</td>
<td>20.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Selenium**</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0 (30)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chromium **</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2 (5.0)</td>
<td>0.20</td>
<td>1.0</td>
</tr>
<tr>
<td>Manganese*</td>
<td>1</td>
<td>2-3</td>
<td>1 (50)</td>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.25-1</td>
<td>0.25</td>
<td>0.25 (5.0)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iodine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0 (1.0)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Omit in patients with obstructive jaundice.

** Omit in patients with renal dysfunction.

Sources: Working Conference on Parenteral Trace Elements II²¹, Gramm, Kopf & Bratter²², Friel et al.²³
**Heparine** at a concentration of 0.5 to 1.0 units per ml of solution may reduce the risk for venous thrombosis and increase the life of peripheral veins, in addition to not interfering with coagulation. Heparin also activates lipoprotein lipase, accelerating lipid plasma clarification. This is useful for extremely low-weight newborns, whose lipolytic enzyme levels are low. In patients with hyperbilirubinemia, heparin may dislocate bilirubin from plasma proteins.

The recommendation of exogenous **insulin** for hypoglycemic patients is still controversial. This may occur in catabolic stages where there is an increase in anti-insulin hormones (catecholamines, corticoids and glucagon). The potential causes of this hypoglycemia must be assessed before insulin administration. When insulin is necessary, the initial dose should be 1 unit for each 10g of glucose. Premature babies seemingly have insulin deficiency, and when there is an evident intolerance to glucose, the continuous infusion of insulin (0.01-0.1 U/kg/hour) with rigid glycemia control is preconized.

**Other components** that may be added to the parenteral solution are, for example, H2-blockers such as cimetidine or ranitidine, recommended for children who suffer from the Short Bowel Syndrome, who have gastric hypersecretion after intestinal loss.

### Table 6 - Amount of calories and nonprotein calories/nitrogen gram ration in standard solutions proposed

<table>
<thead>
<tr>
<th>Formula for every 100 ml of solution</th>
<th>Calories/100 ml</th>
<th>Nonprotein calories/g N² ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) 12% gluc + 1.0 g lip + 1.0 g Aa</td>
<td>50.8</td>
<td>317.5</td>
</tr>
<tr>
<td>2) 12% gluc + 1.5 g lip + 1.5 g Aa</td>
<td>55.8</td>
<td>232.5</td>
</tr>
<tr>
<td>3) 12% gluc + 2.0 g lip + 2.0 g Aa</td>
<td>60.8</td>
<td>190</td>
</tr>
<tr>
<td>4) 12% gluc + 3.0 g lip + 2.5 g Aa</td>
<td>70.8</td>
<td>177</td>
</tr>
<tr>
<td>5) 15% gluc + 2.0 g lip + 2.0 g Aa</td>
<td>71</td>
<td>222</td>
</tr>
<tr>
<td>6) 15% gluc + 3.0 g lip + 2.5 g Aa</td>
<td>81</td>
<td>202.5</td>
</tr>
<tr>
<td>7) 18% gluc + 2.0 g lip + 2.0 g Aa</td>
<td>81.2</td>
<td>254</td>
</tr>
<tr>
<td>8) 18% gluc + 3.0 g lip + 2.5 g Aa</td>
<td>91.2</td>
<td>228</td>
</tr>
</tbody>
</table>

The solutions indicated have lipids at 20% and pediatric amino acids at 10%
Liquids

Up to 10 kg 10-20 kg 20 kg
100 ml/kg/day 1,000+50 ml/kg>10 kg* 1,500+20 ml/kg>20 kg**

Calories
Use the same calculation above, replacing ml with kcal

Proteins
2 to 3 gAA/kg/day (minimum 150 kcal nonprotein/1g nitrogen)

Lipids
2 to 3 gLip/kg/day (maximum 4 g/kg/day) → 35-50% total calories

Glucose
12-25 gGlic/100 ml parenteral nutrition → physiological TIG 5-9 mg/kg/min,
which may be overpassed if glycosuria and glycemia are controlled

Sodium
3-5 mEq/kg/day

Potassium
1-2 mEq/kg/day

Calcium
1-2 mEq/kg/day

Phosphor
0.5-2.0 mMol/kg/day

Magnesium
0.2-0.5 mEq/kg/day

Trace elements
Oliped® = 1 ml/kg/day (maximum 15 ml) or PedElement® = 0.2 ml/kg (maximum 3 ml)

Multivitamins
Polivit® = ampoule A = 10 ml + ampoule B = 5 ml

Heparin
0.5-1.0 UI/ml solution

* 50 ml per kg in patients weighing more than 10 kg.
** 20 ml per kg in patients weighing more than 20 kg.

Table 7 - Simplified calculation for the prescription of parenteral nutrition

Storage
When PN solutions are stored before infusion, they should be protected from light and properly refrigerated. Solutions prepared with lipids in a laminar flow chamber may be safely stored up to 72 hours and solutions without lipids may be stored for 7 days. PN solutions should be used within 24 hours if not prepared in a laminar flow chamber. Vitamins are unlikely to be present in desirable doses after a 24-hour storage period.

Complications
Infection is the most frequent complication of PN. The Hospital Infection Control Practice Advisory Committee defines positive hemocultures with the same agent, blood drawn through a catheter from a peripheral vein, with sepsis and without any other apparent source, as catheter sepsis. In the absence of laboratory confirmation, symptom resolution after the removal of the catheter may indicate this diagnosis. Coagulase-negative staphylococcus, especially *Staphylococcus epidermidis*, is the most commonly isolated agent in catheter infections (28%). *Staphylococcus aureus* is the second (16%), followed by enterococci (8%). Fungal infection occurs in 5-10% of cases, and *Candida* is the most common fungus. If there is suspicion of catheter infection, considering the sensitivity of the 3 most frequent bacteria, IV vancomycin and aminoglycoside (usually amicacine) are indicated while identification and hemoculture antibiogram are not available, maintaining only that specific antibiotic after the results. In case of staphylococcal infection, we should maintain catheter-fed vancomycin for 21 days. This procedure is indicated when totally or semi-implanted, high-cost, indwelling catheters are used; removal is preferred when simpler catheters are used. Staphylococcal infection usually has a good resolution with vancomycin, even in the case of tunnel cellulitis, allowing catheter maintenance. Gram-negative infections usually respond to antibiotic therapy. Fungal infection resolution is only achieved after catheter removal.

There are a great number of parenteral nutrition metabolic complications, which are usually detected through clinical and laboratory follow-up. We will not describe all of them here, with the exception of hepatic function due to its high prevalence. In general, hepatic function is associated with long-term PN, occurrence of sepsis and nonuse of enteral nutrition. In long-term PN patients, the use of ursodeoxycholic acid seems to prevent hepatic alterations, but there is no definite scientific proof of that.

PN administration - nursing care
Recommended nursing care: (1) check each glass bottle before administration, paying attention to changes in solution color, presence of particles, precipitation and phase separation; (2) observe glass bottle temperature, which should be at room temperature (never heat PN solutions). Solutions must be refrigerated (4°C) until the beginning of the subsequent infusion; after that they must be stored at room temperature, thus preventing solutions from being
infused at low temperature. Never freeze solutions; (3) do not allow room temperature to considerably rise. Some alterations in amino acid and lipid solutions may occur at 30°C; (4) check the label, paying attention to patient’s name, composition and dripping of the solution; (5) write the start time on the label; (6) register infusion start and finish time on the medical record; (7) before connecting the connection set to the system, perform asepsis as previously described to prevent catheter sepsis; (8) remove blood crusts and clean the catheter; (9) control solution dripping rigidly. When using an infusion pump, control the infused volume; (10) do not let sunlight strike on PN bottles; (11) in case of patients undergoing phototherapy, solutions must be protected from light; (12) do not open the bottle to add medication to avoid contamination or precipitation; (13) avoid using the infusion system for other purposes (PVC measurement, administration of blood, plasma or medication, blood withdrawal, restoration of abnormal losses). Use another route for administering necessary additives and supplements, or use the Y method (performing special cares to avoid later catheter sepsis); (14) change the bottles containing the nutrient solutions and the connection set every day or whenever there is continuity solution in the system; (15) have new equipment readily available and prepared before disconnecting and changing bottles and connection set; (16) instil glucose solution at 10% if solution is finished and there is no other preparation at hand to replace it; (17) dressings must be made using iodine solutions (iodophor or iodine povidone), but not topic antibiotic; (18) when patients have indwelling catheter (semi-implantable with subcutaneous cuff) and PN is not continuous for 24 hours, the catheter may be closed with heparine as described above; (19) in case the catheter is obstructed by a blood clot, the most effective deobstruction method is the use of streptokinase 5000 IU in 2 or 3 ml, infusing it into the catheter, letting it rest for some hours, and after that, trying to aspirate it or make injection/suction movements with a small syringe (1 or 3 ml), in order to mobilize the clot. This procedure must be carefully carried out, preferably by qualified personnel. Ethyl alcohol 70% has been used for presumable obstruction caused by lipids and hydrochloric acid 0.1N due to mineral and medication precipitation.30

Continuous or intermittent dripping: 24-hour continuous dripping is more commonly used since it presents greater glycemic stability, and lower risk for water overload. In long-term parenteral nutrition patients, especially home PN patients, infusion is performed during a shorter period, from 10 to 12 hours; the catheter is heparinized while it is not used for infusion. Some patients who require only protein-energy complementation through PN, can be submitted to parenteral nutrition on alternate days or with less frequency. This seems to be a more physiological form, preventing muscle catabolism that is caused by continuous stimulation of insulin secretion. To change from continuous to intermittent infusion, it is necessary to reduce infusion time in 1 to 2 hours a day until the desired interval is reached. Before suspending daily infusion, dripping should be reduced in half every 15 minutes (for approximately 45 minutes) until it stops, and rapid glycemic control should be performed at the end of 15 minutes after infusion is finished due to the risk for hypoglycemia, as insulin production was being enhanced until that moment.31 After intermittent infusion stabilization, this control is no longer necessary.

It is recommended that an infusion pump be used for adequate and safe PN infusion.

Clinical control

For clinical follow-up of a parenteral nutrition patient, the following steps should be taken: (1) daily thorough clinical examination (activity, general status, color of the skin and mucosas, hydration level, peripheral perfusion, pulsation, breathing, venous access, edemas, etc); (2) control of vital signs every 4 hours; (3) daily weight; (4) rigid control over water balance; (5) weekly height control and control of head circumference in premature babies; (6) lab exams (Table 8).

Proteinuria, gas blood analysis, cultures (hemocultures, urocultures, catheter tips, secretions) or more frequent repetitions of lab exams will be performed whenever there are specific recommendations.

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<tr>
<th>Table 8 - Laboratory control</th>
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* Indicated to follow the protein incorporation in patients with prolonged nutritional support. Pre-albumin usually increases before weight gain has happened, which forecasts nutritional improvement.
Conclusion

This article reviews the major aspects related to parenteral nutrition in children, including its importance, recommendations, access route, composition, formulation, preparation, administration care, and control over patients submitted to this type of nutrition therapy. It is of paramount importance that readers understand that children should always have nutritional care, regardless of their pathology. If enteral route, which is more physiological and inexpensive, is not possible, then parenteral nutrition, properly formulated, prepared and administered, is a safe way to keep and restore children’s nutritional status.

References