Parenteral Nutrition (Pediatrics)

With **parenteral nutrition**, we provide the body with all or part of its nutrient and energy needs. Parenteral nutrition is always indicated when the patient cannot receive food enterally. In principle, there are no general contraindications for total parenteral nutrition. We routinely use antibacterial filters.

Indications

- congenital defect of digestive tract
- NEC
- post operative conditions
- ileus
- polytrauma
- burns
- sever imaturity
- HMD
- severe respiratory diseases
- malabsorption, prolonged diarrhea
- inflammatory bowel diseases – m. Crohn, ulcerative colitis
- acute pancreatitis
- sepsis
- anorexia nervosa
- systemic diseases
- MODS
- hemato - oncological indications (bone marrow transplantation)
- extensive intestinal resection - short bowel syndrom

According to the coverage of the need for nutrients, parenteral nutrition is divided ***into parietal = parietal***, when we mainly supply fluids, electrolytes and partly energy. ***With complete = total*** parenteral nutrition, we supply fluids, electrolytes, vitamine, trace elements and completely cover energy needs.

In terms of time, we distinguish ***short-term*** (< 2 weeks) and ***long-term*** (> 2–4 weeks) parenteral nutrition.

According to the method of application, we distinguish ***peripheral*** parenteral nutrition, when peripheral venous access is provided, most often with a short cannula. Here we can administer glucose up to a maximum of 15% (equivalent to 775 mosmol/l), amino acids up to a maximum of 5% and, in general, solutions with an osmolality of a maximum of 800–900 mosmol/l. With ***central*** parenteral nutrition, access to the central venous channel is ensured - either through a peripheral vein via a "swimming catheter" or by cannulation of large veins using the Seldinger method - internal jugular vein, subclavian vein, etc. Here we can administer high-osmolar solutions, 40% glucose and concentrated solutions amino acids.

Recently, multi-bottle and all-in-one systems are widely used:

All-in-one systems

Individual items (amino acids, fats, sugars, vitamins and trace elements) are drawn in a predetermined volume into plastic bags and administered at a given interval. The advantage is less material consumption, less demanding technical support and reduced risk of bacterial complications. The condition for the use of this system is the certificate of stability of the mixture given by the manufacturer. Indications are mainly chronic diseases - Crohn's disease, short bowel syndrome.

Multibottle

A multi-bottle system, best suited for pediatric emergency care.

Parenteral nutrition planning

The composition of parenteral nutrition should ensure, among other things, the supply of usable energy substrates, stability of homeostasis, functional restitution, healing, growth and development. The basis of planning is the budget for the following components of parenteral nutrition:

- *liquids and ions*
- *energy*
- *protein* (AA) + *caloric nitrogen ratio* (CNR)
- *sugar*
- *fats*
- *nutrient ratios in percent*
- *vitamins*
- *trace elements*

The planning of parenteral nutrition **in the stress state** is an important part of the treatment of this condition itself. It is necessary to supply usable sources of energy: branched AMK "as a medicine", because unusable sources are converted into lipids, which leads to steatosis of the organs. **In children** we have to keep in mind smaller reserves and at the same time a higher energy turnover, therefore the risk of malnutrition is real.

Water and electrolytes

Water and electrolyte needs provide a basic starting point for an individual calculation. In practice, we absolutely must take into account:

- hydration status
- phototherapy
- fever
- fluid and electrolyte losses through GIT fistulas
- diuretic therapy

Hourly diuresis provides us with invaluable feedback, as do weight beds.

liquids

We calculate the daily basal need for fluids according to the **Holiday-Segar formula**:

> - *100 ml/kg for the first 10 kg of weight*
> - *50 ml/kg on the second 10 kg of weight*
> - *20 ml/kg for additional kilograms of body weight (i.e. for weight over 20 kg)*

This formula is valid for children from 14 days of age. For newborns weighing > 2000g, we administer 50 ml/kg/d on the 1st day, then increase by 20 ml/kg/d to a final dose of 150 ml/kg/d. We have to calculate that fever increases fluid intake by 12-15% for each degree of temperature increase, and hypothermia, on the other hand, analogously reduces fluid intake by 12-15% for each degree of temperature decrease.

According to the same formula, approximately:

- 4 4 ml/kg for the first 10 kg of weight
- 2 ml/kg on the second 10 kg of weight
- 1 ml/kg per additional kilogram of body weight (i.e. for weight over 20 kg)

For more information see Dehydration (pediatrics).

Elektrolytes

Electrolytes requirement

Sodium	2–4 mmol/kg/24 hours.
Potassium	1–3 mmol/kg/24 h.
Chloride	3–5 mmol/kg/24 h.
Phosphorus	0,5–1 mmol/kg/24 h.
Magnesium	0,1–0,7 mmol/kg/24 h.
Calcium	0,5–1 mmol/kg/24 h.

> *To determine the intake of minerals, it is absolutely necessary to monitor changes in their plasma levels with known intake and losses!*

Potassium

We use 7.5% KCl (1ml = 1 mmol potassium) or 13.6% KH_2PO_4 (1ml = 1 mmol potassium).

Calculated total amount of potassium = physiological need 1-3 mmol/kg/day + calculated allowances to cover the metabolism of amino acids and sugars.

We give approximately 1/3-1/2 of the calculated dose in 24 hours, more precisely guided by potassium levels, ECG křivkou, waveform ABB values and urinary potassium wastes.

The recommended safe dose of potassium is 0.5 mmol/kg/hour. (exceptionally 1 mmol/kg/hour).

Calcium a phosphorous

Calcium is added to parenteral nutrition as 10% calcium gluconicum (9 mg/ml) or 10% calcium chloratum (27 mg/ml). It is absolutely necessary to observe a safe Ca/P ratio, which should be equal to or greater than 2:1, so that precipitation of the solution does not occur. We use 13.6% KH 2 PO 4 (1 ml of solution contains 1 mmol of phosphorus and 1 mmol of potassium).

Magnesium

Magnesium is administered in the form of a 10% or 20% solution of $MgSO_4$. To maintain the stability of the infusion solution, it is recommended that the concentration of Ca^{2+}, Mg^{2+} be < 8 mmol/l.

Energy

Nutrient and energy needs change with age and depend on physical activity, disease severity and current nutritional status. We assess the individual state of nutrition clinically and anthropometrically - weight, subcutaneous fat layer. The optimal use of energy sources is ensured by the percentage distribution of nutrients: Carbohydrates 45–55 %, proteins 10–20 %, lipids 30 %.

Determining the energy supply with determination, and thus also respecting the requirements of the organism, is ensured in the conditions of clinical care by indirect calorimetry. In general, different protocols are recommended, shortened measurements lasting 5 minutes or measurements lasting up to thirty minutes. **Basal metabolic need** (BMR = basic metabolic rate) (BMR = basic metabolic rate) is measured before waking up or immediately after waking up, before eating food or showing other activity. It is a reflection of bodily functions in a thermally neutral environment, at rest, after 12 hours of fasting. The so-called **resting energy expenditure** (REE = resting energy expenditure) is measured at rest, 2 hours after a meal. Values are usually 10% higher than BMR (in an afebrile patient in bed).

We start the calorimetric measurement only after 10 minutes of the rest period. The energy expenditure, which we determine in the conditions of resuscitation care, is the closest to the conditions determined for resting energy needs.

Resting energy needs are higher in critically ill patients, as is catabolism. However, administration of carbohydrates does not suppress gluconeogenesis. Despite an adequate supply of energy, patients have a negative nitrogen balance. The condition is greatly complicated by gluconeogenesis and recycling of lipids while reducing the activity of their oxidation processes. In general, we can say that for the 1st day of parenteral nutrition, 10% glucose, is fully sufficient for energy coverage , after 48 hours we add amino acids, after 72 hours we add lipids. To calculate the daily energy requirement, we take into account the basal metabolism and load factors, activities and a factor reflecting the patient's body temperature. To this day, the question of whether to include amino acids in the energy supply remains open. This will need to be further considered, as the portion of amino acids undergoing oxidation can be significantly higher in specialized nutrition and reach values > 30% of their total amount. In general, it is believed that the oxidation of amino acids in a stress situation generates approx. 10-25% of energy.

Basal metabolism (basal energy requirement; basic metabolic rate, BMR)

Basal energy requirement

infants	40–50 kCal/kg
children 1–12 years	30–40 kCal/kg
children 12–16 years	30 kCal/kg
> 16 years	25 kCal/kg

- or the formula for calculating the basal energy requirement can be used:

90 - (nx 5) = energy requirement in kCal/kg (*n*.....child's age in years)

For children under full load, we can use the following recommendations:

- *0–10 kg*: 100 kCal/kg
- *11–20 kg*: 1000 kCal + 50 kCal/kg
- *21–30 kg*: 1500 kCal + 25 kCal/kg

Physical activity/stress (activity factor, AF)

It is the most variable item, it is calculated by estimation/coefficients:

- *at rest in bed*: 1,2
- *on the bed but mobile*: 1,25
- *movable*: 1,3

Thermal factor (thermic factor, TF)

- 38 °C: 1,1
- 39 °C: 1,2
- 40 °C: 1,3

- 41 °C: 1,4

Note: approx. for 1 st. TT: we calculate 12% of the total energy, etc.

Load factor (injury factor, IF)

- *postoperative condition/oncology patient*: 1,1
- *fractures*: 1,2
- *sepsis*: 1,3
- *peritonitis*: 1,4
- *polytrauma*: 1,5
- *polytrauma + sepsis*: 1,6
- *burns 30–50 %*: 1,7
- *burns 50–70 %*: 1,8
- *burns 70–90 %*: 2,0

- **actual daily energy expenditure** (actual energy expenditure, AEE) = BMR x AF x TF x IF

kCal to kJ is converted by multiplying by a correction factor of 4.18

Carbohydrates

Of the monosaccharides used in parenteral nutrition, **glucose**. is the sugar of choice . Glucose is the preferred substrate for the brain and nervous tissue, as well as the energy substrate for erytrocytes, leukocytes and kidney medulla. Under normal circumstances, it is the main source of energy. However, glucose is not the preferred energy source in the intestinal mucosa. This is where SCFA (short chain fatty acid = fatty acids with a short chain) comes into play.

- *1 gram of glucose represents 4.1 kCal of energy*

Estimation of parenteral glucose requirements

- the utilization coefficient for glucose is 7–12 g/kg/24 h depending on the age and condition of the patient, which represents a consumption of 0.7–1.2 ml/kg/h. 40% glucose
- for premature infants and newborns, we start with a dose of up to 5 g/kg/24 hours with a slow increase of 3 g/kg/24 hours
- for older children, we expect a need of 7–12 g/kg/day

Lipids

Fats are the second component of non-protein energy. Fats in parenteral nutrition are a source not only of energy, but also of essential fatty acids. In a load situation, they should provide approx. 15-20% of energy needs, in normal situations 30-50% of energy needs. In order to avoid a deficiency of essential fatty acids, approximately 5% of the energy needs must be covered by fat emulsions. Their combination with glucose has the highest anti-catabolic effect when the energy coverage is 1:1.

Fat emulsions are given in continuous infusion for 24 hours, max. rate 0.1-0.2 g/kg/hour. If it is necessary to take markers of lipid metabolism, we must stop the supply of lipids in the infusion for 4 hours.

We do not administer lipids in hypercholesterolemia, hypertriacylglycerolemia, acute liver failure (on the contrary, they are beneficial in chronic liver insufficiency and are recommended if the conditions of safe administration are observed), pancreatitis acuta, unstable diabetes, are a relative contraindication , in septic conditions we do not exceed the dose of 2 g/kg/d.

Blends of long-chain polyunsaturated fatty acid triglycerides and medium-chain triglycerides (LCT/MCT blends) are currently available.

- *1 gram of lipids represents energy of 9.1 kCal*

Omega-3 and omega-6 polyunsaturated fatty acids

These fatty acids show significant pharmacological effects and can significantly influence the body's inflammation response to stress. Omega-3 polyunsaturated fatty acids, which are contained in higher concentrations in fish oil, give rise to leukotrienes and prostaglandin with significantly lower inflammatory potency than the degradation products of omega-6 polyunsaturated fatty acids. Of the omega-3 polyunsaturated fatty acids, interest has focused on eicosapentaenoic acid (EPA) and decosahexaenoic acid (DHA). The goal of nutritional manipulation in critical conditions is to reduce the production of inflammatory leukotrienes and prostaglandins, and thus the modulation of the body's inflammatory response, to reduce the damage to the capillary endotelium and to influence the reactivity of the immune system.

Estimation of parenteral fat requirements

- premature babies, newborns: initial dose 0,5 g/kg/d

- infants: initial dose 1 g/kg/d
- we gradually increase to the maximum. doses 3–4 g/kg/d

lipid preparations

Fat emulsions for parenteral nutrition:

- soy oil emulsion – LCT (long chain triglycerides)
- mixtures of soybean oil with MCT oil – 1:1 (middle chain triglycerides)
- LCT / MCT particles

Proteins

The primary goal of therapeutic nutritional intervention is to prevent catabolism and promote anabolism. With the timely supply of **amino acids** solutions, we should prevent the occurrence of some deficiencies in stress states so that favorable conditions for proteossynthesis. are permanently created . We start parenteral administration of amino acids as early as possible, even in the phase of circulatory instability and organ damage.

the initial dose of amino acids in case of catabolism and reduced glucose tolerance is 1.0–1.5 g/kg/day, and in this situation we choose an increased proportion of branched amino acids of 40–60% "regardless" of the amount of supplied energy. I.e. we introduce branched AMK as a "medicine" in a stress situation (we usually give a basic amino solution + Nutramin VLI), in a stress situation the share of amino acids in the total energy requirement can be > 30%. In conditions of significant tissue insulin resitance amino acids serve as a quick source of energy for membrane systems.

To start anabolism, it is necessary to simultaneously administer an adequate amount of non-protein energy (carbohydrates, fats) and potassium. In case of insufficient "covering", the proteins themselves would become a source of energy. the so called **CNR (caloric/nitrogen ratio):** must be determined

- *CNR = kCal / 1gr of amino acids*

In general, the greater the stress, the less "coverage" of amino acids.

We apply amino solutions in a continuous infusion for a period of 24 hours, max. the recommended rate is 0.2 g AMK/kg/hour. If, during the course of treatment, there is an increase in the level of urea in the plasma in a short period of time, it can be considered as a manifestation of intolerance of the mixture, and the profile or dose of amino solutions should be adjusted.

- *1 gram of protein represents energy of 4.1 kCal*

supply of amino acids and their composition is controlled

- basic need of the organism
- severity and phases of the exercise response
- organ disability
- load tolerance of amino solutions

Calculation of amino acid supply

A clinically common parameter for monitoring the effect of amino acid administration is the assessment of *nitrogen* balance. From a practical point of view, the balance between nitrogen input and output must be monitored. The nitrogen balance value represents the difference between nitrogen intake and output.

We calculate nitrogen waste as follows: losses in urine are supplied by the laboratory in the value of urea content in mmol/l. With a known diuresis for the monitored interval, we determine the absolute amount urea in the evaluated period by multiplying the urea concentration by the volume of urine in liters. To determine the loss of nitrogen in grams, we multiply the obtained value by a coefficient of 0.0336. We can use the formulas for nitrogen waste:

- *waste N (g) = U x V x 0,0336*

  U (urine in urea mmol/l)
  V (volume of urine per 24 h.in litrech)
  0,0336 (factor for conversion of urea nitrogen to total nitrogen and conversion of value in mmol to grams)

Protein determination with known nitrogen content:

- *protein content = nitrogen (g) x 6,25*

We convert proteins into grams of amino acids according to the formula:

- *protein (g) = amino acids (g) x 0,9*

Estimation of parenteral protein requirements

- *new born + infants*: 2–2,5 g/kg/d

- *small children*: 1,5–2 g/kg/d
- *adolescents*: 1–1,5 g/kg/d

Amino acid preparations

- **amino solutions taking into account age**
    - for adults
    - for newborns and children up to 18 months of age
    - for premature babies
- **amino solutions according to the recipe**
    - balanced = balanced (contain 50% essential and 50% assisting amino acids)
    - organ specific (hepatic, renal failure)
    - for stressful conditions (trauma, sepsis, burns)
    - branched chain amino acids (valin, leucin, isoleucin)
    - suplimentary
    - dipeptide solutions for stress conditions and metabolic interventions

Of the commercially produced amino acids, the L-forms are best tolerated as 4-8% solutions. Common, balanced amino solutions of the so-called first generation contain 50% essential and 50% assisting amino acids. In all amino solutions, cystein, is permanently deficient , incompatible with other amino acids.

Specialized amino solutions called II. generation (Nutramine) are aimed at the treatment of metabolic disorders in organ lesions. Their spectrum of amino acids is not complete, therefore, after the organ disorder subsides, it is necessary to switch to a balanced solution.

During growth and development, as well as during various diseases, the need and importance of individual amino acids changes. Commercially produced mixtures respond to these differences by producing special mixtures for individual clinical situations.

Vitamins

Administering vitamins is necessary because their deficiency leads to disorders of intermediary metabolism. Vitamins act as coenzymes of many metabolic chains, which can seriously affect the patient's treatment, wound healing, disrupt calcium metabolism, etc. Vitamins must be supplemented throughout the entire profile during parenteral nutrition, except for vitamin D. We give water-soluble vitamins from the 3rd day at the latest. B-complex meets the needs of most |B vitamins]], except for pantothenic acid, vitamin B12 can only be administered intramuscularly. Folic acid is also administered in gradually increasing amounts. Of the other water-soluble vitamins, vitamin C must be supplemented. Fat soluble vitamins we can administer together with fat emulsions, we start their substitution from the 14th day at the latest, exceptionally immediately, e.g. in case of long-term malnutrition.

Trace elements

We give trace elements from the 4th week of parenteral nutrition at the latest, zinc from the 2nd week. In case of increased loss of these elements (e.g. increased waste during intestinal fistulas), we pay for them immediately. If the patient is in catabolism, we also pay for the zinc immediately. For premature babies, we also start with supplementation immediately after the start of parenteral nutrition. Trace elements are available in commercial mixtures. We routinely cover:Iron, zinek, Copper, chromium, selenium, manganese a iodine.

Parenteral nutrition supplements

Carnitine

LCT and partially MCT can pass through the mitochondrial membrane only as carnitine ester. With a lack of carnitine, the metabolism of the heart and skeletal muscles is impaired. Indications other than the above are limited utilization of fats and chronic dialysis documented by indirect calorimetry. Contraindications are severely damaged kidney function, allergy to the components of the preparation. Dose in children: 5-100 mg/kg/day

For more information see Carnitine transport system.

Glutamine

A non-essential amino acid under physiological conditions. According to current opinions, it represents one of the most important amino acids for critically ill patients. Depletion of glutamine leads to deepening of catabolism, reduction of immune functions. Glutamine substitution should be considered for all patients hospitalized > 7 days, where there is a combination of protracted sepsis with organ dysfunction, intolerance of enteral nutrition and the assumption of significant immunodeficiency. Other indications are hypercatabolism, intestinal dysfunction, reduced immunity, advanced tumor cachexia. Dosage: 1.5–2.0 ml/kg/day, max. 20% of the total administered amino acids. We add it to infusion solutions or amino solutions.

General recommendations for the breakdown of parenteral nutrition

1. We determine the total volume of liquids and the total number of calories that we want to serve within 24 hours.
2. We divide the total number of calories as a percentage according to the proportion of amino acids, lipids and glucose. The ratio of nutrients should be approximately: carbohydrates 50-60%, proteins 10-15%, lipids 30-35% with a deviation of plus/minus 10%.
3. According to calories, we convert the amount of amino acids, lipids and sugars into milliliters. In order to "save" the volume, we calculate with 20% lipids, we choose amino acids according to age, and initially we always calculate the volume of glucose for a 40% solution.
4. We will determine the amount of electrolytes, trace elements, vitamins (we will convert mmol to milliliters), possibly other pharmaceuticals that may represent a significant volume in the total daily volume calculation.
5. Now, from the determined total amount of fluids for 24 hours, we will subtract nutrients in milliliters (but only amino acids and lipids), solutions of ions, trace elements and vitamins in milliliters and pharmaceuticals (also in milliliters). The rest of the volume will be made up of glucose.
6. Already in point No. 3, we calculated the daily need for glucose in the volume of its 40% solution. The rest of the volume, which we obtained by subtracting amino acids, lipids, ions, vitamins and pharmaceuticals, is likely to be higher than the calculated volume of 40% glucose. Here there is room for us to make up the difference in volumes by replacing the proportion of the 40% glucose solution with 10% and 20% glucose solutions, possibly their combination.
7. Amino acids and lipids are given separately with linear dispensers. Glucose is administered together with ions, trace elements and vitamins. We budget the total volume of these solutions continuously for a period of 24 hours. Since the 13.6% KH 2 PO 4 solution is incompatible with 10% Calcium-gluconicum and 10% MgSO 4 , we usually choose "2 types" of glucose solutions:

    - glucose + NaCl + KCl + Ca-gluconicum + $MgSO_4$
    - glucose + NaCl + KH_2PO_4

Parenteral nutrition monitoring

Fluid balance, energy intake, carbohydrates, proteins, fats, electrolytes, vitamins and trace elements are monitored daily.

Monitoring the patient until stabilization

In addition to repeated clinical examination, weight control 1-2 times a day is an essential requirement (rapid weight gain is suspected of free water retention).

During the first week of parenteral nutrition, we check:

- 1x daily: Na, K, Cl, Ca, P, Mg, creatinine, urea, uric acid, triacylglycerol, lactate
- 3x daily glycemia
- glycosuria and U-osmolality several times a day

Monitoring of a patient on long-term parenteral nutrition

Regular anthropometric examinations inform us about the success of parenteral nutrition:

- for newborns and infants, weight, length and head circumference once a week
- for older children once a month

The evaluation of the aminogram, which often demonstrates an imbalance of amino acids in the serum, is of particular importance during long-term parenteral nutrition.

Complications of parenteral nutrition

Complications in connection with the introduction of CVK

- cardiac arrhythmia
- pneumothorax
- hemothorax
- fluidothorax
- centraln venous thrombosis
- perforation of the central vein
- changing the position of the catheter (we routinely perform an RTG check after catheter insertion)

Infectious complications

- Catheter sepsis

Metabolické komplikace

- hyper/hypoglykemia
- hyperazotemia

- hyper/hyponatremia
- hyper/hypokalemia
- hyper/hypocalcemia
- hyper/hypophosfatemia
- MAC
- hyperlipidemia
- cholestasis etc.

Links

Source

- HAVRÁNEK, Jiří: *Parenterální výživa*

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