NUTRITION FOR THE PEDIATRIC SURGICAL PATIENT: APPROACH IN THE PERI-OPERATIVE PERIOD

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Nutrition is essential for maintenance of physiologic homeostasis and growth. Hypermetabolic states lead to a depletion of body stores, with decreased immunocompetence and increased morbidity and mortality. The purpose of this paper is to provide an update regarding the provision of appropriate nutrition for the pediatric surgical patient, emphasizing the preoperative and postoperative periods. Modern nutritional support for the surgical patient comprises numerous stages, including assessment of nutritional status, nutritional requirements, and nutritional therapy. Nutritional assessment is performed utilizing the clinical history, clinical examination, anthropometry, and biochemical evaluation. Anthropometric parameters include body weight, height, arm and head circumference, and skinfold thickness measurements. The biochemical evaluation is conducted using determinations of plasma levels of proteins, including album, pre-albumin, transferrin, and retinol-binding protein. These parameters are subject to error and are influenced by the rapid changes in body composition in the peri-operative period. Nutritional therapy includes enteral and/or parenteral nutrition. Enteral feeding is the first choice for nutritional therapy. If enteral feeding is not indicated, parenteral nutrition must be utilized. In all cases, an individualized, adequate diet (enteral formula or parenteral solution) is obligatory to decrease the occurrence of overfeeding and its undesirable consequences.

DESCRIPTORS: Nutritional support. Nutritional assessment. Nutritional therapy. Pediatric surgery. Nutrition.

INTRODUCTION

A large body of research indicates that adequate nutrition is essential for maintenance of physiologic homeostasis. Nutrient requirements during childhood are different than those of adults. This difference involves the pediatric need for growth and development and the rapid changes that occur during the functional maturation of organs and systems[1]. Additionally, the growth velocity during early infancy is higher than any other period during childhood. For example, full-term infants double their birth weight in 5 months and triple it in 12 months of life. Organ growth accompanies this process. Therefore, energy needed to maintain this accelerated growth rate represents 30% to 35% of the energy requirements in term neonates, and it is greater in preterm infants.

Prolonged fast, disease, stress, or trauma lead to a depletion of body stores, mainly protein reserves, which is accelerated by a hypermetabolic state. These conditions decrease immunocompetence and increase morbidity and mortality[2].

Modern nutritional support protocols for the surgical pediatric patient are the result of contributions of numerous investigators[3]. Since 1968, when a newborn with multiple jejunoileal atresias was maintained with total parenteral nutrition for more than 22 months, with normal weight gain and increased head circumference, techniques of parenteral and enteral nutrition have been utilized with pediatric surgical patients, with dramatic improvements in survival of patients who previously would have died after surgical correction of their congenital anomaly.

Over the past few decades, mortality associated with surgery in children has rapidly declined. This progress is

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attributable to a better understanding of the physiopathologic changes in the peri-operative period that can be supported with adequate nutrition[4].

Several important points should be considered regarding pediatric surgical patients[5]:

- the disease process that necessitates surgical intervention influences decisions about the correct approach;
- surgery *per se* provokes an increase in stress response parameters;
- the acute stress response is catabolic and involves the mobilization of substrates (protein, fat, and carbohydrates);
- this mobilization results in provision of energy for the catabolic process;
- catabolic metabolism occurs in apposition to the accelerated somatic growth (characteristic of the healthy child);
- the response to injury is variable and depends on age, the degree of organ maturity, underlying nutritional status, and severity of the insult; and
- individualized, adequate nutritional support in the peri-operative period decreases morbidity and mortality.

METABOLIC RESPONSE

The acute metabolic response represents a catabolic state. Endogenous tissue stores of protein, carbohydrate, and fat are invariably decreased during this period, resulting in failure to thrive[6]. Table 1 shows the metabolic status in critically ill infants. It is important to emphasize that the metabolic status is lower in children than in adult patients.

In the postoperative period, because of the reductions in activity and insensible losses observed in sedated infants in a thermo-neutral intensive care environment, caloric requirements are reduced to amounts necessary to meet basal metabolic needs[7].

After uncomplicated surgical procedures, energy expenditure does not increase substantially over baseline values[8]. When the acute phase of metabolic stress resolves, the anabolic phase begins, resulting in somatic growth, with decreasing concentrations of acute-phase reactants, proteins, and total urinary nitrogen values, and with increasing concentrations of visceral proteins[8].

Therefore, if caloric repletion based on the requirements for healthy infants is administered during the acute phase of metabolic stress in critically ill infants, an overfeeding may be established[9,10]. Table 2 shows the metabolic consequences of overfeeding.

Table 1 - Metabolic status in critically ill infants.

Energy	hypermetabolic state ↑ O_2 consumption maldistribution of blood flow ↑ gluconeogenesis
Carbohydrate	hyperglycemia ↑ respiratory quotient (initially) ↑ pyruvate and lactate insulin resistance
Protein	↑ protein catabolism ↑ gluconeogenic amino acids (via Cori cycle) ↑ glutamine production (gut mucosal fuel) ↓ hemoglobin synthesis ↑ inflammatory mediators ↓ albumin synthesis
Fat	↑ lipolysis ↓ lipogenesis ↑ triglyceride oxidation ↓ ketone bodies

Table 2 - Metabolic consequences of overfeeding.

Hyperglycemia
Hyperosmolarity, osmotic diuresis, and dehydration
Hypertriglyceridemia
Hyperazotemia
Respiratory complications
Increased quotient respiratory
Prolonged ventilator support
Hepatic dysfunction
Cholestasis
Steatosis
Altered immune function

ASSESSMENT OF NUTRITIONAL STATUS

Parameters for the assessment of body energy and protein reserves have been developed over the last century[11]. Despite progress and the development of new techniques to assess nutritional status, assessment still remains complicated for the pediatric surgical patient, and a reliable assessment of nutritional status depends on various parameters. This fact makes the nutritional assessment hard and laborious, but essential for the institution of an adequate nutritional therapy[12].

It is important to note that despite the recent advances in nutritional assessment, a clinical evaluation of the patient's status (subjective global assessment) performed by a experienced physician can be as reliable as more sophisticated tests. However, this subjective global assessment is better applied to adult patients than to pediatric patients.

Although nutritional assessment is considered by the pediatricians to be a critical aspect of the initial evaluation of all patients that are candidates for nutritional therapy, it is well known that the incidence of malnutrition in the surgical patient is quite high. Therefore, in clinical practice, the malnourished patient with a digestive surgical disease is easily identified by history and physical examination, with special evaluation of previous weight and weight loss, anorexia or vomiting, as well as physical evidence of muscle wasting and loss of adipose subcutaneous tissue.

Clinical assessment needs to focus on the following[13]:

- nutritional intake,
- the disease process and its catabolic effect,
- current physical state of malnutrition and weight loss, and
- functional status of the central nervous system.

Besides the subjective evaluation of nutritional status, the objective portion of the assessment includes the basic anthropomorphic measurements of height, weight, and head circumference, and comparison with standardized growth curves obtained from normal children of each country or region[14].

Anthropometry is widely used because it is an inexpensive method, and it can be easily applied to all patients, primarily to pediatric patients. Additionally, anthropometric indices are useful because they are fairly constant and do not change rapidly[15,16].

The measurement of skinfold thickness is a simple method for determining fat stores, because subcutaneous fat is indicative of total body fat levels. Usually, the triceps and biceps skinfold are used. From the measurement of the arm circumference and the triceps skinfold, it is possible to calculate the values of the muscle and adipose compartments[15].

The body mass index (BMI) shows a relationship between weight and height. It is usually indicated for a clinical assessment of overweight or obesity. In critically ill patients, the body weight may be influenced by fluid shifts.

Biochemical measurements of nutritional status can be performed using the plasma levels of albumin, transferrin, pre-albumin, and retinol-binding protein[15,16]. Although plasma protein concentrations are used for assessment of nutritional status and nutritional therapy, they are not specific, and many factors may modify the plasma protein levels[17,18]. Among these parameters, albumin plasma level is available in any hospital and is considered the classic biochemical marker used to assess a malnourished state. The other parameters are not readily accessible by most clinicians and are not commonly used in the clinical practice.

Urinary creatinine excretion is proportional to muscle creatine and to total muscle mass. In acute illness and the postoperative period, creatinine excretion is altered and is not a valuable index. The creatinine/height index correlates creatinine excretion to muscle tissue, and a reduction in muscle mass produces a proportional reduction of the index[14].

The nitrogen balance is the difference between nitrogen entering and exiting the body. Therefore, nitrogen balance is an indirect measure of protein conservation, and a negative balance shows a catabolic state in the critically ill patient[14].

Many indices have been developed to prospectively quantitate the perioperative risk:

- the prognostic nutritional index (PNI) attempts to correlate nutritional status with postoperative outcome and complication rate. Many anthropometric and biochemical parameters are included in this index, such as: triceps skinfold thickness, serum albumin and transferrin levels, and cutaneous delayed hypersensitivity reactivity. The PNI may reveal the patient who needs preoperative nutritional support[19].
- the prognostic inflammatory and nutritional index (PINI) combines anthropometrics and biochemical parameters (albumin and pre-albumin) and values of C-reactive protein[19].

The analysis of these indices shows that only a limited number of anthropometric and biochemical parameters may have a clear correlation with postoperative outcome[20]. Furthermore, the large individual variation in the disease status mandates caution in the interpretation of these indices.

The assessment of immune status includes the blood total lymphocyte count and test for skin hypersensitivity, because malnutrition may modify the immunological defenses.

Recently, various methods of direct measurement of pediatric body composition have been described for academic purposes, with few practical results; these include isotopic dilution techniques, bioelectrical impedance analysis, dual photon absorptiometry, and dual energy x-ray absorptiometry.

Finally, all the parameters (anthropometric, biochemical, and indices) described above are subject to observer error and are influenced by changes in body composition induced by non-nutritional factors[21]. Furthermore, the growth rate of the pediatric patient is an additional important factor that must be considered.

Nutritional Requirements

Several methods can be used to estimate fluid and nutrient requirements of the pediatric patient. None of these are always completely accurate[1]. An ill child often has different requirements from those of a healthy child.

The energy, water, amino acid, electrolyte, mineral, vitamin, and trace element requirements of infants and children are summarized in tables 3 and 4[22,23].

Table 3 - Daily requirements for children undergoing parenteral nutrition (per kg of body weight).

	< 10 kg	11 to 20 kg	>21 kg
Water	130 mL	90-100 mL	70-90 mL
Calories	100 cal	90 cal	80 cal
Amino acids*	2.5 g	2.0 g	1.5 g

*renal failure – 0.5 g; liver failure – 0.5 g; burns – 3.5 g; prematurity – 3.5 to 4.0 g depending on gestational age

Table 4 - Daily requirements of electrolytes, trace elements, and vitamins (per kg of body weight).

Sodium	3-5 mEq
Potassium	3-5 mEq
Magnesium	0.3-0.5 mEq
Calcium	2-4 mEq (preterm, 4-6 mEq)
Phosphorous	1-2 mEq
Zinc	150-200 mg (preterm, 400-600 mg)
Copper	10-20 mg
Iron	1 mg
Vitamin A	233 units
Vitamin C	6 mg
Vitamin D	66 units
Vitamin E	0.66 units
Vitamin B_1 (thiamine)	0.055 mg
Vitamin B_2 (riboflavine)	0.07 mg
Vitamin B_3 (niacine)	0.9 mg
Vitamin B_5 (pantothenic acid)	0.3 mg
Vitamin B_6 (pyridoxine)	0.05 mg
Biotine (vitamin B_7)	30 mg
Folic acid (vitamin B_9)	8 mg
Vitamin B_{12} (cyanocobalamine)	0.04 mg

Energy

Direct and indirect calorimetry or empirical equations are used to assess the energy requirement[24]. Direct calorimetry is very complicated and expensive, so it is rarely utilized in the clinical setting[25]. Indirect calorimetry measures the heat production from O_2 consumption and CO_2 production, and from these measures, the metabolic rate can be calculated[26].

Empirical approximate equations can estimate the basal metabolic rate, or the energy required for the body at rest. The most frequently used equation is the Harris-Benedict formula, which is based on indirect calorimetry[27]:

- BMR = 66 + (13.7 x BW) + (5 x H – 6.8 x A) → male
- BMR = 655 + (9.6 x BW) + (1.7 x H – 4.7 x A) → female

BMR = basal metabolic rate
BW = body weight (kg)
H = height (cm)
A = age (years)

This equation estimates the basal energy expenditure from the patient's gender, weight, height, and age. Furthermore, it is necessary to apply a stress correction factor (Table 5) to increase the basal metabolic rate in the surgical patient. The Harris-Benedict equation does not apply to children under 6 years of age or 25 kg[14,27].

Table 5 - Stress correction factors.

Injury	Correction factor
Absence	1.0
Postoperative state	1.1 to 1.5
Sepsis	1.3
Multiple trauma	1.5 to 1.6
Burns	1.2 to 2.0

Although empirical equations are simple and quick methods, they are not always accurate because there is a thermogenic response to trauma, surgery, and infection[27,28].

Protein

Proteins are essential for maintaining lean body mass. Protein breakdown continues during periods of stress or trauma, and it may be minimized by provision of dietary protein. Amino acids are essential for synthesis of somatic and visceral protein as well as enzymes, hormones, immunoglobulins, and neurotransmitters. An appropriate proportion of essential and nonessential amino acids may be provided, as well as a balance of protein and non-protein calories[23].

Protein requirements are influenced by energy intake, availability of vitamins, minerals, and cofactors, gestational and postnatal age, presence of clinical conditions (trauma, sepsis), and some medications (steroid therapy)[29]. Table 3 summarizes daily requirements.

Lipid

Lipid intake serves 2 basic functions: providing essential fatty acids and providing energy.

Essential fatty acid deficiency was described in patients receiving prolonged (more than 2 or 3 weeks) feeding of fat-free diets (enteral or parenteral) in critically ill patients, during prolonged fast, and in preterm neonates[30]. There is considerable evidence that premature or ill term infants may not effectively convert, by elongation and desaturation, essential fatty acids into long-chain polyunsaturated fatty acids, such as arachidonic and docosahexaenoic acids[31].

The symptoms of essential fatty acid deficiency are dry or scaled skin, sparse hair growth, increased susceptibility to infections, thrombocytopenia, failure to thrive, hypotonia, increased metabolic rate, impaired water balance, red blood cell fragility, and electroencephalographic and electrocardiographic alterations.

Preterm newborn infants are especially susceptible to developing essential fatty acid deficiencies, because tissue stores are minimal and requirement for them is great as a result of rapid growth. In the neonatal period, essential fatty acid deficiency may produce alterations in neurological and retinal development[30,32].

Usually, 20% to 60% of calories are provided by lipids, and essential fatty acid requirements may be met with 2% of total calories as lipids[32].

Glutamine

Glutamine is the most abundant amino acid in the organism, and its functions are[33-35]:

- to provide a structural component of proteins;
- to provide for nitrogen transfer between tissues;
- to act as a substrate for ammonia productions (kidney);
- to serve as a precursor of purine and pyrimidine; and
- to provide fuel for enterocytes and lymphocytes.

Glutamine has traditionally been classified as a nonessential amino acid, but in critically ill patients, its stores are depleted and its biosynthetic pathway cannot meet the increased demands; therefore it becomes a conditional essential amino acid[36,37].

Pediatric surgical patients are at high risk for nutritional insufficiency and catabolism. They often receive parenteral support, because enteral nutrition is commonly difficult to provide. Therefore, various investigators have proposed that enteral and/or parenteral glutamine supplementation might result in protection against sepsis and improved tolerance to rapid enteral feeding, as well as in decreased length of hospital stay by pediatric surgical patients[38-40]. However, new research with pediatric patients reveals that the benefits of using glutamine supplementation are questionable[35].

Carnitine

Carnitine, a nonessential amino acid with a 6-carbon molecule, is important in the transfer of fatty acids into mitochondria and in the b-oxidation of these nutrients, with subsequent energy release[3].

Carnitine deficiency, revealed by low plasma concentration and commonly observed in infants receiving prolonged parenteral nutrition, may inhibit fatty acid oxidation. Carnitine deficiency can occur in[41]:

- long-term total parenteral nutrition;
- low birth-weight infants;
- severe malnutrition; and
- sepsis.

Premature or low birth-weight neonates are particularly prone to carnitine deficiency because they have low body stores and a great dependence on fatty acid oxidation for energy. Therefore, carnitine deficiency could lead to impaired lipid metabolism reflected by increased free fatty acids in tissues and plasma. However, the need to provide carnitine supplementation for the ill newborn infant receiving parenteral lipids remains unclear[23].

NUTRITIONAL DELIVERY SYSTEMS ENTERAL FEEDING

The concept that enteral route is ideal for feeding is classic. When enteral feeding is given, even in small amounts, the intestinal microvillus structure is preserved and bacterial translocation from the intestines to the blood is prevented. Enteral feeding is also a more economical route than parenteral feeding. Finally, septic complications that represent the most important problem of parenteral nutrition are far less common during enteral nutrition[42,43].

Feeding routes may range from oral intake to nasogastric, nasoduodenal, nasojejunal, or jejunostomy feeding tubes. If the intestines can be involved in the preoperative or postoperative period, the route of access needs to be determined. For infants who have abnormal sucking or swallowing reflexes or for those who are not alert enough to swallow, placing a tube feeding should be considered. Gastric feeding is preferred because it allows for a normal digestive process. Although transpyloric tube placement is classically indicated for infants who have a high risk for aspiration, such as those with documented gastroesophageal reflux, coma state, or depressed reflexes, the location of the tube in the duodenal or jejunum and the maintenance of position are very difficult. As a consequence, the gastric tube is preferable, with the use of a slow, continuous infusion of the liquid diet.

Formula Selection

The choice of formula depends on the age of the patient, the condition of the gastrointestinal tract, and the disease or diseases of the patient[44]. For example, infants with biliary atresia should not be given diets with long-chain fatty acids. In general, term infants should be maintained on human milk. In the absence of human milk, similar formulas may be utilized. A lactose-based formula is generally the first choice because it is the most physiologically similar to human milk, and is the least expensive. For lactose-intolerant infants, as in the postoperative period of intestinal atresias or intestinal resections, the formula may be changed to a lactose-free, soy protein-based formula. Calories can be added by increasing the volume delivered, increasing the concentration of the formula or by supplementing the feedings. Formula concentrations may be increased to 1 kcal/mL; however, highly concentrated formulas may be difficult for some infants to digest and have also occasionally been associated with necrotizing enterocolitis[45,46]. In general for surgical patients, primarily for those with short bowel syndrome, elemental or semi-elemental formulas may be utilized, and natural diets based on chicken meat protein may be an option. As a matter of fact, there are no metabolic advantages to the utilization of elemental diets over the natural diets. In a previous study with infants with biliary atresia in the preoperative period of liver transplantation, it was demonstrated that a natural diet based on skimmed milk enriched with 10% carbohydrates is metabolically superior to an isocaloric isonitrogenous elemental diet.

Table 6 resumes formula indications considering age and disease, and table 7 shows formula classification[47,48].

Table 6 - Formula indication.

Clinical condition	Suggested formula
Prematurity	Preterm formula
Full-term	Standard formula Casein/lactoalbumin 60:40 Casein
Lactose intolerance	Soy formula Lactose-free Sucrose-free
Casein sensibility	Soy formula Partial hydrolysate protein
Organ dysfunction or failure	Low electrolytes Low osmolarity
Steatorreia Ileal dissection Lymphatic anomalies	Low MCT
Soy sensibility Absorption deficiency Digestion deficiency Intraluminal transport deficiency Severe malnutrition	Hypoallergenic formula MCT addition Lactose-free Sucrose-free Partial/total hydrolysate High energy

MCT: medium-chain triglycerides

Table 7 - Formula classification.

Complete
- **Polymeric** (intact macronutrients)
  - Natural protein
    - Basis – cow milk
  - Purified protein
    - Basis – casein
    - Basis – lacto-albumin
    - Basis – soy
    - *Special* – prematurity

– inborn errors of metabolism

Oligomeric
- Semi-elementary (partial hydrolysate)
- Elementary (total hydrolysate)

Incomplete
- **Modulate** – supplements
  - Protein
  - Carbohydrate – glucose polymers
  - Lipid – MCT
  - – LCT

MCT: medium-chain triglycerides
LCT: long-chain triglycerides

MINIMAL ENTERAL NUTRITION

There is increasing evidence that failure of barrier and immune function in the gut promotes translocation of bacterial flora, toxin penetration, and cytokine release[48]. Many of these features can be minimized by minimal enteral intake (minimal enteral nutrition, gut priming, trophic feeding, hypocaloric enteral feeding). Minimal enteral nutrition is defined as a volume less than or equal to 10 mL/kg per day of choice diet. These feedings stimulate the gastrointestinal tract in preparation for more substantial enteral nutrition later[49]. Also, many nutrients, including glutamine and omega-3 fatty acids, may contribute to preserving the integrity of the gut barrier[49,50].

In addition, bacterial fermentation of carbohydrates produces short-chain fatty acids, such as butyrate, that are substrates for enterocyte nutrition[46,48].

Luminal starvation is associated with gut atrophy and decreased absorption, and as mentioned above, increased bacterial translocation across the intestinal mucosa at any age[45].

Table 8 shows beneficial effects of minimal enteral nutrition[45,46].

Table 8 - Beneficial effects of minimal enteral intake.

No increase in incidence of necrotizing enterocolitis
Less cholestatic jaundice
Less osteopenia
Increased glucose tolerance
Increased weight gain
Earlier tolerance of full enteral intake
Increased gut hormones
Prevention of gut atrophy

TOTAL PARENTERAL NUTRITION

Conventional formulations of total parenteral nutrition (TPN) were developed in the late 1960s and early 1970s. The specific goals of this nutrition include positive calorie and nitrogen balance, homeostatic control of fluids, electrolyte balance, and metabolic function to maintain or restore visceral and somatic proteins[3].

Ideally, parenteral nutrition should mimic a healthy diet, providing macro- and micronutrients according to each individual's requirements and metabolic tolerance.

Total parenteral nutrition requires cooperation from supporting services such as pharmacy, central supply, infection control, metabolic and nutrition support, surgical, and nursing that are necessary to achieve successful treatment.

Parenteral nutrition solutions are compounded with a ratio of calories of nitrogen that provides an adequate (neutral or positive) nitrogen balance. The amount of each component and type of solution used varies depending on age, maturity, and clinical diagnosis of the infant or child[23].

Appropriate metabolic support for critically ill surgical patients includes a relative increase of amino acids and lipids, decrease in glucose intake, and the administration of certain "new" nutrients to modulate inflammatory response[51]. Also, the TPN solution may contain electrolytes, minerals, vitamins, and trace elements. The requirement of any of these elements depends on the degree of malnutrition and hypermetabolism, and the length of time the child is expected to be without oral intake[51].

The emerging consensus is that enteral feeding is the desired method in pediatric surgical patients, except for the following situations[2]:

- immediate postoperative period,
- hemodynamic instability,
- intractable vomiting, and
- active gastrointestinal bleeding.

Relative indications include[2]:

- ileus,
- intestinal fistula, and
- pancreatitis.

Under surgical conditions expected to create difficulties for nutritional intake, TPN can be initiated presurgically and continued from the immediate postoperative period for any length of time necessary.

Additionally, parenteral nutrition is indicated as a supplement to enteral feeding. Most surgical patients receive both types of nutrition—parenteral and enteral[52].

There are 2 types of TPN, based on the physical site of the infusate tubing – peripheral or central. The peripheral type limits the infused glucose concentration to up to 12 g/dL. A higher concentration of glucose can be achieved (20 g/dL to 30 g/dL) with central TPN, but central TPN has the most complications due to infection, because it requires a central venous catheter[53].

Central TPN is warranted to allow an extended period of bowel rest in some postoperative periods, or when nutritional requirements exceed the capabilities of peripheral parenteral nutrition. Parenteral nutrition is usually administered through central venous infusion, since most ill pediatric surgical patients have central venous access for drug administration and monitoring[3].

Table 9 shows the differences between parenteral nutrition solutions used in central and peripheral access.

Parenteral nitrogen sources are available in the form of crystalline amino acid solutions, with essential, conditional essential, and nonessential amino acids. Many pediatric amino acid formulations are commercially available. These solutions are better adapted to the needs of pediatric patients than are standard adult amino acid solutions. The benefits of pediatric amino acid solutions are that they[29]:

- produce plasma amino acid levels that approximate those of healthy breast-fed infants;
- promote weight gain and positive nitrogen balance;
- minimize the abnormalities in liver function; and
- increase calcium and phosphorous solubility.

Table 9 - Parenteral nutrition solutions.

Constituent	Central vein	Peripheral vein
Glucose 50%	400 mL	100-150 mL
Amino acids 10%	200 mL	150 mL
Sodium acetate (10%)	40 mL	40 mL
Magnesium sulphate (20%)	5 mL	5 mL
Potassium chloride (19.1%)	8 mL	8 mL
Potassium acid phosphate (25%)	10 mL	10 mL
Calcium gluconate (10%)	20 mL	20 mL
Folic acid (0.1%)	5 mL	5 mL
Vitamin K	0.2 mg	0.2 mg
Vitamin B	1 amp	1 amp
Vitamin C	250 mg	250 mg
Distilled water to	1000 mL	1000 mL
Osmolarity (mOm/L)	1800 mOm/L	650-700 mOm/L
N/cal ratio	1/250	1/100 to 1/150

Major differences between pediatric and adult amino acid formulations are the addition of taurine, histidine, tyrosine, glutamic, and aspartic acids, and lower amounts of methionine, phenylalanine, and glycine[2].

Glucose is presently used almost exclusively as the carbohydrate source for TPN, because it is safe, economical, and readily available. Additionally, glucose is responsible for the high osmolarity of parenteral solutions[53].

Parenteral lipids are available as an emulsion of medium- and long-chain triglycerides. Soybean and safflower-oil based preparations are the currently used lipid emulsions. They may be used daily to meet essential fatty acids requirements, providing at least 4% of total daily calories. These lipid preparations provide polyunsaturated fatty acids for peripheral tissues after endogenous hydrolysis by lipoprotein lipase[31].

The use of 20% lipid solutions is preferable for conserving fluid and for decreasing the incidence of hyperlipemia, because the ratio of phospholipid to triglyceride is lower than in the 10% emulsion, which results in less inhibition of lipoprotein lipase activity due to infused phospholipid[30].

In clinical practice, parenteral solutions can be individualized or standard admixtures. Individualized solutions provide for almost all nutritional requirements, but the clinical benefit of standard or "3 in 1" solutions is a lower risk of infections, because the growth of pathogenic organisms is restrained. Additionally, "3 in 1" solution are stable and inexpensive, and they can de prepared and then stored under refrigeration[54].

The monitoring of nutritional status in pediatric surgical patients receiving parenteral nutrition is summarized in table 10.

The greatest risks associated with TPN are systemic infection from an infected insertion site, systemically acquired bacteremia from the urinary or intestinal tract, contaminated solutions, and nosocomial infections.

The metabolic risks associated with TPN are[55]:

- hyperglycemia with glucosuria and osmotic diuresis and dehydration;
- cholestasis, hepatic steatosis, and cholelithiasis;
- hyperammonemia and hyperazotemia;
- hyperchloremic metabolic acidosis;
- rising blood transaminase levels;
- hyperlipidemia (hypertriglyceridemia and/or hypercholesterolemia);
- hypophosphatemia;
- iron deficiency (long-term TPN); and
- trace element and certain vitamin deficiencies (long-term TPN).

Table 10 - Monitoring of nutritional status.

Parameter	Frequency
Fluid input and output	daily
Body weight	daily
Height	weekly
Head circumference	weekly
Arm circumference and triceps skinfold	weekly
Serum glucose (reagent strip)	2-3x/day
Glucosuria	2-3x/day
Serum electrolytes	2-3x/week
Triglycerides, albumin, pre-albumin	biweekly
Nitrogen balance – if available	weekly
Indirect calorimetry - if available	biweekly

FINAL CONSIDERATIONS

Evidence confirms that pediatric surgical patients need individualized and adequate nutritional support during the peri-operative period to decrease the morbidity and mortality.

This adequate nutritional approach includes a nutritional assessment, correct nutritional requirements for all nutrients, and ample knowledge about the metabolic response of the pediatric critically ill patient.

The assessment of nutritional status is performed utilizing clinical examination, anthropometric parameters, including body weight, height, head and arm circumference, and the measurement of triceps skinfold thickness, and biochemical determinations, such as plasma level proteins.

Enteral feeding is the first choice for the nutrition therapy. If the gastrointestinal tract cannot be utilized, parenteral nutrition is indicated. In any case, an adequate formula for enteral nutrition or an adequate solution for parenteral nutrition must be selected.

RESUMO

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A nutrição é essencial para a manutenção da homeostase fisiológica e para o crescimento. Estados hipermetabólicos acarretam depleção dos estoques corpóreos, com prejuízo da função imune e aumento da morbimortalidade. O objetivo deste artigo de atualização é mostrar uma abordagem mais ampla da terapia nutricional na criança que necessita de cirurgia, enfatizando os períodos pré e pós-operatório. Nessas crianças, um suporte nutricional atual resulta do conhecimento de várias etapas, incluindo a avaliação nutricional, as necessidades nutricionais e a terapia nutricional propriamente dita. A avaliação nutricional consiste da anamnese, do exame físico, da antropometria e de determinações laboratoriais. Os parâmetros antropométricos incluem o peso, a estatura, os perímetros cefálico e braquial e dobras cutâneas. A avaliação bioquímica pode ser realizada através das proteínas plasmáticas, como a albumina, a pré-albumina e a proteína ligada ao retinol. Todos esses parâmetros podem estar sujeitos a erros, pois alterações bruscas na composição corpórea podem ocorrer nos períodos pré e pós-operatórios. A terapia nutricional inclui as alimentações enteral e/ou parenteral, sendo a enteral a de primeira escolha. Na impossibilidade da nutrição enteral, a parenteral deve ser instituída. Em ambas as situações, a escolha de uma dieta adequada (fórmula enteral ou solução parenteral) é imprescindível, para se evitar a superalimentação e suas conseqüências indesejáveis.

DESCRITORES: **Suporte nutricional. Avaliação nutricional. Terapia nutricional. Cirurgia pediátrica. Nutrição.**

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