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PROTEIN-ENERGY INSUFFICIENCY IN ADOLESCENTS. FEATURES OF THE CURRENT (LECTURE)

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Abstract. Protein-energy undernutrition is a global medical problem. The most vulnerable categories of the population are children and the elderly. According to World Health Organization, more than 17% of children under 5 years old suffer from various degrees of protein-energy undernutrition. It has been established that 25% of the Russian population experience nutritional deficiency, and 85% have various manifestations of hypovitaminosis. The widespread of nutritional and energy malnutrition is primarily due to socio-economic factors. The pathology is characteristic of residents of low-income countries who cannot afford food sufficient in calories and vitamin content. Adolescents represent a special group of the population, since at this age there is a formation of personality in society, the desire to achieve ideals of appearance and comply with modern fashion trends. It is they who, in pursuit of ideal figure parameters imposed by the media, are often victims of such advertising. In case of nutritional insufficiency, all organs and systems are involved in the pathological process. The degree of impairment depends on the duration and severity of malnutrition. With a slight lack of calories, the breakdown of glycogen in the liver is observed, due to which the body receives a sufficient amount of energy. There is a mobilization of fat reserves, an increase in the level of amino acids in the blood. Doctors of all specialties face manifestations of protein-energy deficiency, but a pediatrician is most often involved in identifying the initial forms of pathology. For diagnostics, it is very important to collect information about the nature of a person's nutrition, material and living conditions. This lecture highlights the basic concepts, diagnosis and treatment of this pathology.

Keywords: *adolescents, protein-energy undernutrition, diet therapy*

БЕЛКОВО-ЭНЕРГЕТИЧЕСКАЯ НЕДОСТАТОЧНОСТЬ У ПОДРОСТКОВ. ОСОБЕННОСТИ ТЕЧЕНИЯ (ЛЕКЦИЯ)

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Резюме. Белково-энергетическая недостаточность (БЭН) — глобальная медицинская проблема. Самые незащищенные категории населения — дети и пожилые люди. По данным Всемирной организации здравоохранения, более 17% детей младше 5 лет страдают от различных степеней БЭН. Установлено, что 25% населения России испытывают нутритивный дефицит, а у 85% выявлены различные проявления гиповитаминозов. Широкое распространение нутритивной и энергетической неполноценности питания обусловлено в первую очередь социально-экономическими факторами. Патология характерна для жителей стран с низким уровнем дохода, которые не могут позволить себе достаточную по калорийности и витаминному

содержанию пищу. Подростки представляют особую группу населения, поскольку в этом возрасте происходит становление личности в социуме, стремление достичь идеалов внешности и соответствовать современным тенденциям моды. Именно они в погоне за идеальными параметрами фигуры, навязываемыми средствами массовой информации, зачастую являются жертвами такой рекламы. При нутритивной недостаточности в патологический процесс вовлекаются все органы и системы. Степень нарушений зависит от длительности и тяжести недоедания. При небольшом недостатке калорий наблюдается распад гликогена в печени, за счет чего организм получает достаточное количество энергии. Происходит мобилизация жировых запасов, повышение уровня аминокислот в крови. С проявлениями БЭН сталкиваются врачи всех специальностей, но выявлением начальных форм патологии чаще всего занимается врач-педиатр. Для диагностики очень важно собрать сведения о характере питания человека, материально-бытовых условиях. В данной лекции освещены основные понятия, диагностика и лечение данной патологии.

Ключевые слова: подростки, белково-энергетическая недостаточность, диетотерапия

INTRODUCTION

Protection of health of the younger generation is the most important task of the state, because the basis of the adult's health is laid in childhood. Accelerated physical development (acceleration) was replaced by its slowdown (retardation). Over the past 30 years, a decrease in almost all somatometric indicators has been recorded. The patterns of physical development of modern children include gracilization of physique and underweight in 13–14% of children (in some regions this figure reaches 25%) [1]. Of particular concern is the disruption of physical development in adolescents, in particular an increase in the number of children with low weight and growth retardation [2], some of whom are on the verge of developing protein-energy undernutrition (PEU).

Protein-energy undernutrition — is a pathological condition characterized by the development of symptoms of proteins, energy, other macro- and micronutrients deficiency as a result of their relative or absolute deficiency. Such condition develops because of partial or complete starvation [3].

PEU can be primary or secondary depending on the reason of its development. Primary PEU develops on the background of insufficient food intake. As a rule, in patients with primary PEU, the diet is dominated by proteins of plant origin, which has low biological value. Secondary PEU develops on the basis of acute and chronic diseases: liver (hepatitis, cirrhosis), bowel (inflammatory bowel disease (IBD), celiac disease), pancreas (pancreatitis), infectious diseases. There is three degrees of PEU depending on percentage of weight loss.

- I — mild PEU (body mass deficiency is 10–20%);
- II — moderate PEU (body mass deficiency is 21–30%);

- III — severe PEU (body mass deficiency is 31% or more).

In the case of a sharp decrease in weight because of a chronic disease and, as a consequence, a change in the body composition, PEU is defined as cachexia.

The classification of cachexia is as follows:

- alimentary marasmus is a severe nutritional disorder caused by the depletion of somatic protein (mainly peripheral protein of muscle tissue);
- kwashiorkor is a severe nutritional disorder caused by the depletion of visceral protein (proteins of serum and internal organs);
- mixed form — marasmic kwashiorkor.

Nowadays, several mechanisms and nosological forms of this pathology are distinguished:

- 1) insufficient food intake: unbalanced nutrition for age, eating disorders, mental illness (anorexia, bulimia), gastrointestinal diseases: gastroesophageal reflux disease (GERD), chronic gastroduodenitis, peptic ulcer;
- 2) digestion and/or absorption disorders: intestinal enzyme deficiencies (disaccharidase deficiency), celiac disease, cystic fibrosis, Crohn's disease, ulcerative colitis;
- 3) accelerated catabolism: endocrinopathies (diabetes mellitus, hyperthyroidism), intestinal infections: viral infections, parasitic infections (helminthiasis, giardiasis);
- 4) increased need for nutrients: period of active growth during puberty, active physical activity, stress.

FEATURES OF COMPLAINTS AND PHYSICAL EXAMINATION OF ADOLESCENTS WITH PROTEIN-ENERGY UNDERNUTRITION

Diagnosis of PEU is often difficult due to the fact that this pathology does not have patho-

gnomonic symptoms and is accompanied by an abundance of non-specific complaints from various systems and organs. The main reasons for visiting a doctor are complaints of peeling skin, depigmentation, the appearance of ecchymosis, slow wound healing, hair thinning and hair loss, koilonychia, delamination and brittleness of nails. When examining mucous membranes, attention is paid to the development of cheilosis, glossitis, ulcers and cracks in the tongue, recurrent stomatitis, dry conjunctiva and cornea. When examining the musculoskeletal system, recurrent caries, muscle wasting and muscle pain are diagnosed. Patients report frequent infectious diseases associated with a decrease in body's immunobiological reactivity. Damage to the nervous system and development of emotional lability, decreased tolerance to physical activity, dizziness, headaches, and sleep disorders are possible to be presented in such patients. Impaired twilight vision, bleeding gums, and the development of anaemia indicate the development of polyhypovitaminosis. It is worth noting that the main complaint may be a noticeable decrease in weight or its indirect signs (change in clothing size, belt size), insufficient weight gain, and the presence of oedema.

Parents should pay attention to the appearance of "red flags": sudden changes in pace and volume of food intake, frequent trips to the toilet immediately after eating, extreme preoccupation with body shape and size, distorted body image, obsessive exercise, abuse of laxatives and/or diuretics.

Refeeding syndrome is a complex of metabolic disorders that occurs when refeeding in patients with initial nutritional deficiency. The clinical picture is dominated by multiple organ failure, arrhythmia, cerebral oedema, polyneuropathy, and DIC syndrome [4].

METHODS OF DIAGNOSTICS OF PROTEIN-ENERGY UNDERNUTRITION

Methods of diagnostics of PEU can be divided into few groups:

- 1) method based on a clinical picture and anamnesis;
- 2) laboratory diagnostics;
- 3) instrumental examination;
- 4) anthropometric measurement;
- 5) complex assessment methods.

The method based on a clinical picture and anamnesis includes collecting complaints and assessing the dynamics of weight gain. This method

also includes an assessment of actual nutrition, which includes many methods, the optimal ones being: the daily nutrition reproduction method, the method of food intake analysis and the method of directly recording the food intake.

The daily food reproduction method, or questionnaire-survey method, is based on an assessment of the actual food products consumed over the past day. The obtained data are used to conclude about the composition of these products, as well as to calculate the nutritional and energy value of the diet, the balance of its composition and its compliance with needs of the adolescent's body. A major drawback of this method is a short observation period, which can lead to false conclusions about the adolescent's diet. Therefore, it is recommended to use this method for several days.

The method of analyzing the frequency of food intake involves assessing the frequency of consumption of specific foods over a given period of time. This allows us to identify the correlation between the eating or exclusion of certain foods in the diet and appearance of clinical signs of the disease. Also, this allows to diagnose a possible development of an eating disorder caused by avoidance or limitation of the consumption of specific foods.

The method of directly recording the food intake basis on weighing food before eating it, weighing its remains after eating it, and counting the amount of eaten food. This method is not suitable for a patient with a suspected or diagnosed eating disorder, as it may worsen the adolescent's condition.

Based on the analysis of the actual nutrition of children, the correspondence of energy value of the diet to the body's energy expenditure, the content and ratio of animal and plant proteins, the ratio of proteins, fats and carbohydrates in the diet and their correspondence to body's needs are assessed.

Laboratory diagnostic methods are necessary to identify metabolic disorders and deficiency states [5]. Blood test is not specific in the diagnosis of PEU. It allows to identify the presence of iron deficiency states (haemoglobin level, erythrocytes, RDW, MCH, MCHC, MCV), as well as changes in the leukocyte formula and absolute leukocyte count in presence of infectious diseases.

The more specific test is proteinogram. Total protein content as a summary indicator depends on a large number of factors and is a low-sensi-

tivity indicator. It may give false negative results when fraction of globulin increased and there is a dehydration. Albumin is a marker of the visceral protein pool. About 40% of albumin circulates in the vascular bed, and the majority is found in the interstitial fluid. However, the half-life of albumin is 18–20 days, and therefore it may reflect the severity of the disease rather than undernutrition in acute disorders. Dehydration, renal failure, and infusion of albumin preparations may lead to an increase in albumin concentration. A decrease in albumin level is observed in a number of oncological diseases, oedema, and liver failure. Although albumin has a number of limitations as a marker of nutritional status, its low concentration correlates with the severity of PEU, especially in chronic undernutrition, allowing it to remain the main laboratory indicator for assessing nutritional status.

For a more accurate diagnosis of malnutrition, proteins with shorter half-lives, such as prealbumin (transthyretin) and transferrin, which have half-lives of 1–2 and 7 days, respectively, can be used. Prealbumin and transferrin undergo the same distribution as albumin but may be a better and more sensitive indicator of nutritional status. Prealbumin reliably reflects malnutrition when there are no signs of inflammation and may be a marker of the effectiveness of nutritional correction. To exclude the influence of inflammation on the prealbumin level, it is recommended to evaluate the ratio of C-reactive protein and prealbumin, the concentration of which correlates with the degree of inflammation. Transferrin is a representative of the β -globulin fraction involved in iron transport. A decrease in its concentration in serum allows for the detection of earlier changes in protein metabolism, while an increase is observed in iron deficiency states.

Creatinine is synthesized in muscle tissue by the breakdown of creatine phosphate. It is generally used to assess renal function, but its concentration also increases with muscle wasting, allowing creatinine levels to be used as a diagnostic marker for PEU. Another indicator of muscle wasting is 3-methylhistidine. As muscle tissue breaks down, its concentration in urine increases. Nitrogen balance assessment is used for timely diagnosis of catabolic stage of the pathological process, assessment of protein metabolism dynamics and prescription of an adequate diet.

Instrumental diagnostics involves the use of electrocardiography, echocardiography, ultra-

sound examination of abdominal organs, as well as endoscopic methods: fibrogastroduodenoscopy and colonoscopy with a biopsy of gastrointestinal mucosa [6]. These methods allow for differential diagnostics of etiological factors in the development of PEU.

Anthropometric measurement is a simple and accessible method for studying and diagnosing PEU. The following are used: measuring weight and length (in bedridden patients)/height, measuring body mass index (BMI), body weight-to-age ratio, body weight-to-height ratio, height-to-age ratio, and BMI-to-age ratio [7, 8].

BMI is recommended as a reliable indicator of nutritional status and is calculated using the formula: $BMI = M \text{ (kg)} / \text{height}^2 \text{ (m)}$

Степень БЭН / Degree of PEU	ИМТ, кг/м ² / BMI, kg/m ²
БЭН I / I PEU	17–18, 4
БЭН II / II PEU	15–16, 9
БЭН III / III PEU	меньше 15 / less than 15

There is a risk of obtaining false BMI data in the presence of oedema, which increases weight.

The mid-upper arm circumference of the non-working arm is also assessed: a decrease of 10–20% is considered a mild degree of malnutrition, 20–30% is considered moderate, and 30% or more is considered severe.

Also, the body composition is assessed. Total body mass (TBM) consists of lean, or fat-free mass (LM), which is an indicator of protein metabolism, and adipose tissue (AT), which reflects energy metabolism: $TBM = LM + AT$.

Body composition can be determined using bioimpedance measurement. Bioimpedance analysis is based on measuring the total electrical resistance (impedance) of the human body to alternating current. The method is also based on differences in the specific electrical resistance of biological tissues due to their different fluid and electrolyte content [9]. The electrical impedance of biological tissues has two components: active resistance, the substrate of which are cellular and extracellular fluids, and reactive resistance, the substrate of which are cellular membranes.

Complex assessment methods. Subjective Global Assessment (SGA) proposed in 1987 by A. Detsky et al., includes anamnesis data (weight loss dynamics, dietary changes, gastrointestinal

Table 1. Subjective Global Assessment (SGA) by A. Detsky

Таблица 1. Субъективная глобальная оценка (SGA) по A. Detsky

Категории SGA / Categories SGA	A	B	C
Прием пищи / Meals	Не изменены по сравнению с обычными / Not changed from usual	Снижен или жидкая диета / Reduced or liquid diet	Гипокалорийная жидкая диета или голод / Hypocaloric liquid diet or hunger
Потери веса (% к обычному) за последние полгода / Weight loss (% to normal) over the past six months	Нет потерь или менее 10%, но вес стабилен в течение последнего месяца / No loss or less than 10%, but weight is stable during the last month	Потери 5–10%, вес продолжает снижаться / Loss 5–10%, weight continues to decrease	Более 10%, особенно если потери веса происходят в течение последнего месяца / More than 10%, especially if weight loss occurs within the last month
Симптомы нарушения функций желудочно-кишечного тракта / Symptoms of gastrointestinal dysfunction	Отсутствуют или длятся менее двух недель / Absent or lasting less than two weeks	Ежедневно рвота и/или диарея / Daily vomiting and/or diarrhea	Симптомы, препятствующие приему пищи или нарушению всасывания, длительностью более двух недель / Symptoms of obstruction or malabsorption lasting longer than two weeks
Функциональные возможности / Functionality	Не изменены / Not changed	Снижение активности, слабость, переутомление / Decreased activity, weakness, overwork	Постельный режим, слабость, повышение температуры вследствие переутомления / Bed rest, weakness, fever due to overwork
Стрессорный фактор / Stressor	Нет системных эффектов первичного заболевания / No systemic effects of primary disease	Отдельные системные эффекты, такие как лихорадка / Selected systemic effects such as fever	Тяжелый стресс, острый колит, травма, септицемия / Severe stress, acute colitis, trauma, septicemia
Осмотр выраженности симптомов / Examination of the severity of symptoms: • потери подкожного жира / subcutaneous fat loss; • мышечная слабость / muscle weakness; • другие признаки / other signs	Не выражены / Not pronounced	Выражены / Pronounced	Ярко выражены / Strong pronounced
Питательная поддержка / Nutritional support	Не нужна / No need	Противоречивые мнения, дополнительная нутритивная поддержка 20–24 ккал/кг может быть успешной / Conflicting opinions, additional nutritional support of 20-24 kcal/kg can be successful	Обязательна / Mandatory

symptoms, functional capabilities — bed rest or normal physical activity), examination results (muscle and subcutaneous fat thickness, oedema and ascites) [10].

According to this scale, patients with normal nutritional status are assigned grade A, with moderate PEU — grade B, with severe PEU — grade C (Table 1).

Degree II of PEU is characterized by pronounced changes in all organs and systems. Decreased appetite, periodic vomiting, sleep disturbance. BMI is 15–16.9. The skin is pale, pale-gray, dry and flaky (signs of polyhypovitaminosis). Elasticity, tissue turgor and muscle tone are reduced. Hair is dull and brittle. There is decreased food tolerance. Such patients have concomitant somatic pathology (pneumonia, otitis, pyelonephritis), deficiency states.

Degree III PEU is characterized by anorexia, general lethargy, decreased interest in the environment. BMI is less than 15. Breathing is shallow, sometimes apnoea may be observed. Heart sounds are weakened, muffled, a tendency to bradycardia and arterial hypotension may be observed.

METHODS OF TREATMENT/CORRECTION OF PROTEIN-ENERGY UNDERNUTRITION

Therapy for PEU in adolescents includes several stages:

- 1) search for the etiological factor and treatment of the underlying disease, for example, psychotherapy for nervous anorexia; sanitation of chronic foci of infection; treatment of diseases of the gastrointestinal tract, biliary system; special therapeutic nutrition for metabolic disorders, etc.;
- 2) adequate diet therapy;
- 3) additional drug correction if necessary;
- 4) provision of psychosocial assistance.

Diet therapy is one of the main methods of correcting PEU. The diet, rational menu with easily digestible dishes, increased frequency of meals, and an increase in daily caloric intake by 10–20% are important. To conduct adequate diet therapy, it is necessary to establish the degree of body weight deficiency, determine the child's needs for essential nutrients and energy in accordance with the degree of malnutrition, calculate the actual nutrition for the teenager and correct the qualitative and quantitative composition of the diet taking into account the obtained data and functional capabilities of a patient.

Calculation of the content of essential nutrients in the daily diet [11]: proteins (g/day) = AEE (actual energy expenditure) 0.15/4, but not more than 2–2.5 g/kg; fats (g/kg) = AEE 0.3/9; carbohydrates (g/kg) = AEE 0.55/4.

For seriously ill patients, the most universal and acceptable calculation is the actual energy requirement using the formula: $AEE = BR \cdot AF \cdot DF \cdot TF \cdot BMD$, where AEE is the actual energy expenditure; BR is

the basal metabolic rate (kcal/day); AF is the activity factor, DF is the damage factor, TF is the terminal factor; BMD is the body mass deficit.

The calculation of the basal metabolic rate for young men (10–18 years) is carried out using the formula $(17.5 \cdot \text{weight}) + 651$, for girls of the same age: $(12.2 \cdot \text{weight}) + 746$.

There are basic correction factors:

- AF: bed rest — 1.1, hospital ward — 1.2, general — 1.3;
- TF: body temperature 38 °C — 1.1, 39 °C — 1.2, 40 °C — 1.3, 41 °C — 1.4;
- BMD: from 10 to 20% — 1.1, from 20 to 30% — 1.2, more than 30% — 1.3;
- DF: minor surgeries — 1.1, fracture — 1.2, major surgeries — 1.3, peritonitis — 1.4, sepsis — 1.5, multiple injuries — 1.6, traumatic brain injury — 1.7, burns — from 1.7 to 2.2 depending on the area of damage.

There is also a need to adjust the diet towards increasing the caloric content of dishes, which can be done in several ways: increase the volume of food consumed per day, which is often problematic due to the lack/decrease in appetite in a teenager. It is necessary to increase the caloric content of the diet due to products with a high content of protein (cottage cheese, cheese, meat, eggs) and fats, which is a difficult task due to the reduced capabilities of the gastrointestinal tract.

The optimal way to enhance nutrition remains the use of special products for nutritional support, which are characterized by a complete, balanced composition of proteins, fats, carbohydrates, vitamins, minerals and micronutrients. It also has a low risk of water-electrolyte overload, the ability to accurately dose the product, and minimizes the risks of developing gastrointestinal dysfunction. The tasks of nutritional support include: ensuring the body's energy and building needs, maintaining active protein mass, tissue function, especially the immune system, skeletal and respiratory muscles, restoring existing losses, correcting metabolic disorders, preventing and treating multiple organ failure.

The algorithm for carrying out nutritional support includes the following stages:

- 1) determining indications and contraindications for nutritional support;
- 2) assessing the patient's needs for nutrients;
- 3) choosing the method of carrying out nutritional support;
- 4) choosing the formula;
- 5) monitoring the effectiveness of the nutritional support being carried out.

There are several ways to provide nutritional support [12]:

- sipping is the independent oral intake of liquid nutrition through a tube or in small sips in order to maintain and correct nutritional status in accordance with the patient's current needs for energy, protein, vitamins, minerals and microelements [13];
- enteral tube feeding (through a nasogastric or nasointestinal tube);
- enteral nutrition through a stoma (percutaneous endoscopic, laparoscopic, laparotomic) if the disease lasts more than 6 weeks; the choice of access is determined by the patient's ability to eat independently and the absence of signs of dysphagia;
- parenteral nutrition (PN) is the administration of nutrients intravenously, passing the gastrointestinal tract, in order to maintain and correct nutritional status in accordance with the patient's current needs for energy, protein, vitamins, minerals and microelements;
- mixed nutrition.

When choosing a method of nutritional support, preference should be given to enteral nutrition, which promotes maximum preservation of the gastrointestinal tract, in particular preservation of intestinal functions, the structure of the small intestine, limitation of bacterial translocation and septic complications, and reduces the likelihood of developing multiple organ failure. It should be remembered that the choice of tube feeding may entail the development of a number of complications, such as damage to the tube itself (for example, its twisting), damage to the mucous membrane, aspiration of gastric contents, and the manifestation of signs of dyspepsia.

With parenteral administration, the necessary formulas are administered through a peripheral or central vein. Parenteral nutrition (PN) can be complete or partial. In case of complete PN, preparations that provide the body's energy and building needs (amino acid solutions, fat emulsions and carbohydrate solutions) are used. Partial PN is of an auxiliary nature, is used to solve problems of short-term nutritional support of the body, includes individual nutritional components.

In addition to nutritional support, the treatment of PEU requires drug correction, which includes the administration of enzyme preparations. The most optimal forms are microspherical and microencapsulated forms of pancreatin, vi-

tamins to correct deficiency states (ascorbic acid, B vitamins, vitamins A, E, D, K), iron preparations, and probiotics.

PROGNOSIS

The development of PEU can lead to a number of consequences, including digestive disorders, delayed wound healing, muscle mass reduction, decreased resistance to infections, anaemia, lymphopenia and hypoproteinemia, oedema formation and impaired blood transport function [14, 15]. Timely recognition of the pathology and correct selection of therapy contribute to the complete restoration of all systems in the adolescent, which significantly improves the patient's quality of life.

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Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

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