ANATOMICAL AND PHYSIOLOGICAL CHARACTERISTICS OF HEMATOPOIETIC ORGANS IN CHILDREN AND ADOLESCENTS. PERIPHERAL BLOOD COMPOSITION IN DIFFERENT AGE GROUPS. SEMIOTICS AND SYNDROMES OF HEMATOPOIETIC SYSTEM DISORDERS IN CHILDREN

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Abstract: This article describes the anatomical and physiological characteristics of hematopoietic organs in children and adolescents. Changes in the composition of peripheral blood in children of different age groups, specific features of the hematopoiesis process, and stages of development of the hematopoietic system are analyzed. In addition, diseases caused by dysfunction of hematopoietic organs in children, their clinical manifestations, semiotics, and diagnostic significance are discussed. The article serves as an important theoretical source for students studying pediatrics.

Keywords: pediatric hematology, hematopoiesis, peripheral blood, erythrocyte, anemia, hemorrhagic syndrome, splenomegaly

Introduction

The hematopoietic system in children possesses distinctive anatomical and physiological characteristics that evolve with age. The primary hematopoietic organs in children include the bone marrow, lymph nodes, spleen, and thymus gland. In newborns, red bone marrow is present in all bones and demonstrates high hematopoietic activity. With advancing age, red bone marrow predominantly remains in the epiphyseal regions of long bones. Lymph nodes are relatively larger in young children and gradually decrease in size over time. Similar regressive changes occur in the spleen: during childhood, it functions actively, while in subsequent life stages, its activity partially diminishes. The thymus gland is the most active organ in children up to 12 years of age. Thereafter, the thymus progressively loses its functions, undergoes regression, and is replaced by adipose tissue.

The process of hematopoiesis initiates during the embryonic period at 2-3 weeks of gestation, when blood islands form from mesenchymal cells, and their differentiation leads to the development of vascular endothelium. By the 6th week of

fetal development, hepatic hematopoiesis commences and reaches peak activity by the 5th month of gestation. At the 3rd month of fetal development, the spleen joins the liver in hematopoietic function. By the 4th month of gestation, hematopoiesis begins in the bone marrow and continues throughout the individual's lifespan. Peripheral blood composition varies significantly across different pediatric age groups. For instance, newborns exhibit elevated hemoglobin levels (180-220 g/L) due to fetal hemoglobin predominance. Leukocyte counts are also elevated (10-30 × 10^9/L). Between 1 month and 1 year of age, a condition known as "physiological anemia" occurs, characterized by decreased erythrocyte counts. This phenomenon results from the gradual replacement of fetal hemoglobin with adult hemoglobin. In children aged 1-6 years, peripheral blood composition approaches adult values. During adolescence, hormonal changes lead to increased hemoglobin and erythrocyte levels in males, while females face an elevated risk of anemia due to the onset of menstruation. Hematopoiesis in children exhibits high functional activity, which is essential for adequate growth and development. Furthermore, hematopoietic activity supports active immune system development. However, this system remains highly sensitive to external factors, and exposure to infections, vitamin deficiencies, or toxic substances increases the risk of developing various types of anemia. Currently, the prevalence of hematopoietic system disorders in children continues to rise. Notably, iron deficiency anemia and hemorrhagic syndromes are among the most common conditions. The primary cause of iron deficiency anemia is inadequate dietary intake of vitamins and minerals, or impaired absorption of these micronutrients. Iron is an essential trace element that participates in numerous enzymatic processes and plays a critical role in hematopoiesis. Iron deficiency leads to impaired hemoglobin synthesis or decreased heme and globulin production, resulting in the formation of erythrocytes with reduced hemoglobin content, manifesting as hypochromic anemia.

Materials and Methods

This study involved a comprehensive analysis of scientific literature on pediatric hematology, anatomy, and physiology published over the past two decades. The research utilized a descriptive analytical approach, synthesizing data from textbooks, peer-reviewed journals, and international guidelines. A systematic review was conducted on the anatomical and physiological features of hematopoietic organs in children and adolescents, age-related changes in peripheral blood parameters, and clinical syndromes associated with hematopoietic system dysfunction. Statistical data regarding normal hematological values across different pediatric age groups were compiled and analyzed. Additionally, clinical manifestations and diagnostic criteria for common hematopoietic disorders in children were examined through literature review and clinical case analysis.

Results

Age-Related Changes in Hematopoietic Organs

The development of hematopoietic organs in children follows a distinct chronological pattern:

Prenatal Period: Hematopoiesis progresses through three consecutive stages:

1. **Mesoblastic (yolk sac) stage** – begins at 2-3 weeks of gestation
2. **Hepatic stage** – begins at 6 weeks of gestation, reaches peak activity at 5 months
3. **Medullary (bone marrow) stage** – begins at 4 months of gestation and continues throughout life

Postnatal Period:

- ✓ **Newborns:** Red bone marrow occupies all bone cavities with maximum hematopoietic activity
- ✓ **Infancy (0-12 months):** Bone marrow remains highly active; thymus reaches maximum relative size
- ✓ **Early childhood (1-6 years):** Progressive conversion of red to yellow marrow begins in diaphyses of long bones
- ✓ **School age (7-12 years):** Thymus begins regression; lymphoid tissue hyperplasia reaches peak
- ✓ **Adolescence (13-18 years):** Hematopoietic activity stabilizes at adult levels; hormonal influences become prominent

Peripheral Blood Composition by Age

Newborn Period:

- ✓ Hemoglobin: 180-220 g/L (predominantly fetal hemoglobin)
- ✓ Erythrocytes: 5.0-7.0 × 10^{12}/L
- ✓ Leukocytes: 10-30 × 10^{9}/L
- ✓ Platelets: 150-400 × 10^{9}/L
- ✓ Hematocrit: 45-65%

Infancy (1-12 months):

- Physiological anemia occurs at 2-3 months (Hb: 90-110 g/L)
- Leukocyte count decreases to 6-12 × 10^{9}/L
- Lymphocyte predominance develops

- Fetal hemoglobin gradually replaced by adult hemoglobin

Early Childhood (1-6 years):

- Hemoglobin: 110-140 g/L
- Erythrocytes: 3.8-5.0 × 10^{12}/L
- Leukocytes: 6-15 × 10^{9}/L
- Blood composition approaches adult values

School Age (7-12 years):

- Hemoglobin: 115-150 g/L
- Leukocyte differential stabilizes
- Erythrocyte indices normalize

Adolescence (13-18 years):

- Males: Hb increases to 130-160 g/L; erythrocytes: 4.5-5.5 × 10^{12}/L
- Females: Hb 120-150 g/L; erythrocytes: 4.0-5.0 × 10^{12}/L (risk of iron deficiency due to menstruation)
- Hormonal influences affect hematological parameters

Discussion

The hematopoietic system in children exhibits remarkable plasticity and age-related dynamism compared to adults. Understanding these developmental changes is crucial for accurate interpretation of laboratory findings and timely diagnosis of hematological disorders. The transition from fetal to adult hemoglobin during infancy represents a critical period when physiological anemia may occur, requiring careful differentiation from pathological conditions.

The high hematopoietic activity in children makes them particularly susceptible to nutritional deficiencies, especially iron deficiency. The prevalence of iron deficiency anemia in children remains a significant public health concern globally. Early detection through appropriate screening programs and laboratory investigations is essential for preventing long-term consequences, including cognitive impairment and growth retardation.

The diagnostic significance of laboratory tests in iron deficiency anemia extends beyond simple confirmation of the diagnosis. Biochemical markers such as ferritin and transferrin saturation provide valuable information about the stage of iron depletion, enabling targeted therapeutic interventions. The presence of specific clinical syndromes – anemic, sideropenic, hemorrhagic, or hemolytic – assists clinicians in establishing differential diagnoses and identifying underlying etiologies.

Recent advances in pediatric hematology have improved our understanding of the

molecular mechanisms underlying various hematopoietic disorders. However, the fundamental importance of thorough clinical examination combined with appropriate laboratory investigations remains paramount in pediatric practice. The recognition of semiotic features and syndromic presentations allows for early detection and prompt management of potentially serious conditions.

The thymus gland's role as a primary lymphoid organ during childhood highlights the intimate connection between the hematopoietic and immune systems. Progressive thymic involution after puberty explains the age-related changes in immune function observed during adolescence. Similarly, the spleen's participation in both hematopoiesis and immune surveillance underscores the importance of monitoring splenic size and function in children with suspected hematological disorders.

Conclusion

Children and adolescents exhibit hematopoietic organs (bone marrow, spleen, and lymphoid system) that are functionally more active compared to adults, with hematopoiesis characterized by age-specific dynamic changes. Peripheral blood composition demonstrates unique features at each developmental stage, directly correlating with the organism's growth, development, and adaptive capacities.

Disruption of hematopoietic system function manifests in various pathological syndromes – anemic, hemorrhagic, hemolytic, and immunodeficiency states – which are identified through clinical signs and laboratory alterations. Therefore, in-depth knowledge of age-specific characteristics of the hematopoietic system is crucial for early diagnosis, accurate differential diagnosis, and establishing effective treatment strategies for hematological disorders in pediatric patients.

Early recognition of semiotic features, appropriate interpretation of laboratory findings, and understanding of developmental hematopoiesis form the foundation of pediatric hematology practice. This knowledge enables healthcare providers to prevent complications, improve outcomes, and ensure optimal growth and development of children and adolescents.

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