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AGE-RELATED FEATURES OF THE HEMOSTASIS SYSTEM AND THEIR PHYSIOLOGICAL AND CLINICAL SIGNIFICANCE

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Abstract

The hemostasis system plays a crucial role in maintaining blood fluidity and preventing excessive bleeding or thrombosis. Its functional characteristics undergo significant changes throughout different stages of human development, from the neonatal period to old age. These age-related variations are determined by the maturation and gradual decline of coagulation factors, anticoagulant mechanisms, platelet function, and fibrinolytic activity.

This article analyzes the physiological characteristics of the hemostasis system across different age groups, including neonates, children, adults, and elderly individuals. Special attention is given to the balance between procoagulant and anticoagulant components and how this balance shifts with age. In early childhood, the hemostasis system is characterized by functional immaturity, which influences the risk of bleeding disorders. In adulthood, the system reaches a relatively stable equilibrium, while aging is associated with a tendency toward hypercoagulability and an increased risk of thrombotic events.

The clinical significance of age-related changes in hemostasis is also discussed, particularly in relation to diagnosis, prevention, and treatment of hemorrhagic and

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https://eurekaoa.com/index.php/5

thromboembolic conditions. Understanding these age-dependent features is essential for optimizing clinical decision-making, individualizing therapeutic approaches, and improving patient outcomes in both pediatric and geriatric populations.

Keywords: Hemostasis system, age-related changes, coagulation, fibrinolysis, platelet function, thrombosis, bleeding disorders, clinical significance.

Introduction

The hemostasis system is a complex physiological mechanism responsible for maintaining the balance between bleeding and thrombosis, thereby ensuring the integrity of the circulatory system. It includes the coordinated interaction of vascular endothelium, platelets, coagulation factors, anticoagulant pathways, and the fibrinolytic system. Any imbalance within this system may lead to hemorrhagic or thrombotic complications, which are among the leading causes of morbidity and mortality worldwide.

Throughout human life, the hemostasis system undergoes continuous structural and functional changes. These changes are closely associated with developmental, hormonal, metabolic, and age-related physiological processes. From birth to old age, variations in plasma coagulation factors, platelet activity, and regulatory mechanisms significantly influence the overall hemostatic balance. Therefore, the concept of “developmental hemostasis” has been introduced to describe the dynamic nature of the hemostatic system across different age groups.

In neonates and young children, the hemostasis system is functionally immature, characterized by lower levels of several coagulation factors and reduced platelet reactivity. Despite these differences, healthy children usually maintain effective hemostasis due to compensatory mechanisms. In contrast, aging is associated with progressive changes that favor a prothrombotic state, including increased

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

levels of certain coagulation factors, endothelial dysfunction, and reduced fibrinolytic activity.

Understanding age-related features of the hemostasis system is of great physiological and clinical importance. These variations influence the interpretation of laboratory parameters, the assessment of bleeding and thrombotic risks, and the selection of appropriate therapeutic strategies. Age-specific reference ranges and individualized clinical approaches are essential for accurate diagnosis and effective management of hemostatic disorders.

The aim of this article is to analyze age-related changes in the hemostasis system and to evaluate their physiological and clinical significance across different stages of human life.

Main Body

Hemostasis in Neonates and Infants

The hemostasis system in neonates and infants is characterized by functional immaturity, which reflects the developmental adaptation of the coagulation mechanism after birth. Plasma concentrations of several coagulation factors, including factors II, VII, IX, and X, are significantly lower in neonates compared to adults. In addition, levels of natural anticoagulants such as protein C, protein S, and antithrombin are also reduced during the neonatal period.

Platelet count in neonates is generally comparable to that in adults; however, platelet function is qualitatively different. Neonatal platelets exhibit reduced aggregation and secretion responses, which may influence primary hemostasis. Despite these differences, healthy newborns rarely experience spontaneous bleeding, as compensatory mechanisms, including higher levels of von Willebrand factor and enhanced vascular integrity, help maintain hemostatic balance.

Clinically, the immaturity of the hemostasis system in neonates increases vulnerability to both bleeding and thrombotic complications under pathological

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https://eurekaoa.com/index.php/5

conditions such as prematurity, sepsis, or hypoxia. Therefore, age-specific reference ranges are essential for accurate interpretation of coagulation tests in this population.

Hemostasis in Children and Adolescents

During childhood and adolescence, the hemostasis system undergoes gradual maturation. Levels of coagulation factors progressively increase and approach adult values, while anticoagulant mechanisms become more stable. Platelet function also improves, leading to more effective primary hemostasis.

In this age group, the balance between procoagulant and anticoagulant pathways is generally well maintained, resulting in a relatively low incidence of thrombotic disorders. However, bleeding tendencies may still be observed in children with congenital coagulation disorders or platelet dysfunctions. Hormonal changes during adolescence may further influence hemostatic regulation, particularly in females.

From a clinical perspective, understanding the developmental changes in hemostasis is important for diagnosing inherited bleeding disorders and managing anticoagulant therapy when required. Pediatric patients require individualized evaluation to avoid misinterpretation of laboratory findings based on adult reference standards.

Hemostasis in Adults

In adulthood, the hemostasis system reaches a relatively stable physiological equilibrium. Coagulation factors, platelet function, and fibrinolytic activity are well balanced, allowing effective prevention of both bleeding and thrombosis under normal conditions. This stability supports efficient wound healing and vascular protection.

However, lifestyle factors, chronic diseases, pregnancy, and pharmacological interventions can significantly affect hemostatic balance in adults. Conditions

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

such as obesity, diabetes mellitus, and cardiovascular disease may shift the system toward a hypercoagulable state. Conversely, liver disease or vitamin K deficiency may impair coagulation capacity.

Clinically, adults represent a heterogeneous group in which individualized assessment of hemostatic function is crucial. Monitoring and managing hemostasis is particularly important during surgical procedures, pregnancy, and long-term anticoagulant therapy.

Hemostasis in the Elderly

Aging is associated with significant changes in the hemostasis system, often resulting in a prothrombotic state. Increased levels of coagulation factors such as fibrinogen and factor VIII, along with decreased fibrinolytic activity, contribute to enhanced clot formation. Endothelial dysfunction and chronic low-grade inflammation further exacerbate this tendency.

Platelet activation and aggregation are often increased in elderly individuals, while natural anticoagulant mechanisms may become less effective. These changes explain the higher incidence of thromboembolic events, including deep vein thrombosis, stroke, and myocardial infarction, in older populations.

From a clinical standpoint, age-related hypercoagulability necessitates careful risk assessment and personalized anticoagulant strategies. At the same time, age-associated comorbidities and increased bleeding risk require cautious therapeutic decision-making to ensure patient safety.

Conclusion

The hemostasis system undergoes continuous physiological changes throughout the human lifespan, reflecting the dynamic balance between coagulation, anticoagulation, platelet function, and fibrinolysis. These age-related variations play a crucial role in maintaining vascular integrity and preventing pathological bleeding or thrombosis under normal conditions.

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
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https://eurekaoa.com/index.php/5

In neonates and infants, the hemostasis system is functionally immature, yet effective compensatory mechanisms usually ensure adequate hemostatic control. During childhood and adolescence, gradual maturation leads to stabilization of coagulation and anticoagulant pathways. In adulthood, the hemostasis system reaches a relatively balanced state, although it remains sensitive to external factors such as disease, lifestyle, and medical interventions. Aging, however, is associated with a shift toward a prothrombotic state due to increased coagulation factor levels, endothelial dysfunction, and reduced fibrinolytic activity.

The clinical significance of age-related changes in hemostasis is substantial. Accurate interpretation of laboratory tests, risk assessment for bleeding or thrombosis, and selection of appropriate therapeutic strategies require consideration of age-specific physiological characteristics. Awareness of these differences is essential for optimizing diagnosis, prevention, and treatment of hemostatic disorders in both pediatric and elderly populations.

In conclusion, understanding the age-related features of the hemostasis system provides an important foundation for personalized medicine and improved clinical outcomes across all stages of life.

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