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DIFFERENCES IN THE CIRCULATORY SYSTEM OF THE FETUS AND NEWBORN: MECHANISMS AND CAUSES

Axrorxonov Rustamxon Akmalxon o'g'li

BKP va poliklinik pediatriya kafedrasi assistenti

Abstract: This article is about the differences in blood circulation in fetuses and infants.

Keywords:Fetus, mother, blood, mechanism, liver, umbilical vein, pulmonary artery, pulmonary vein, hemodynamics

Introduction:

The fetal circulatory system is designed to meet the unique needs of the developing fetus, as it is entirely dependent on the maternal circulatory system for oxygen and nutrient exchange. However, after birth, the circulatory system undergoes a dramatic transformation to establish a fully functional and independent system that supports life outside the womb. These changes involve complex physiological mechanisms, hormonal influences, and structural modifications in the cardiovascular system. This article provides an in-depth exploration of the circulatory changes that occur from fetal to neonatal life, focusing on the key mechanisms and the clinical implications of these transitions.

Fetal Circulatory System: Specialized Structures and Functions

1. Placental Circulatory System

The placenta is the organ that facilitates the exchange of gases, nutrients, and waste products between the mother and fetus. During fetal development, the placenta serves as the main interface for oxygen and nutrient supply. The blood from the placenta flows into the fetus through the umbilical cord, carrying oxygen-rich blood to the fetal circulation while removing waste products. Oxygenated blood from the placenta enters the fetal bloodstream via the umbilical vein. This system plays a pivotal role in fetal health, as the fetus relies entirely on maternal blood for its oxygenation and metabolic needs.

2. Specialized Shunts (Bypass Mechanisms)

Fetal circulation includes several shunts that allow blood to bypass the organs that are not yet functioning, such as the lungs and liver. These shunts are crucial for ensuring that blood is directed to the vital organs and the placenta, bypassing non-functional organs:
- Ductus Venosus:This vessel allows blood from the umbilical vein to bypass the liver and flow directly into the inferior vena cava, thereby optimizing blood flow to the heart.
- Foramen Ovale:This is a hole in the septum between the right and left atria of the heart, allowing blood to flow directly from the right atrium to the left atrium, bypassing the lungs.
- Ductus Arteriosus:This vessel connects the pulmonary artery to the aorta, enabling blood to bypass the non-functional lungs and flow directly into the systemic circulation.

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3. Pressure Distribution and Hemodynamic Changes

The hemodynamics of fetal circulation are influenced by high pulmonary vascular resistance, as the lungs are filled with fluid and not involved in oxygen exchange. This results in the following physiological adaptations:

- Increased Right Atrial Pressure:Due to the high pulmonary resistance, the right atrium's pressure is higher than that of the left atrium. This causes the blood to flow through the foramen ovale from right to left.

- Decreased Pulmonary Circulation:Because the lungs are non-functional, the blood bypasses the pulmonary circuit through the ductus arteriosus, which diverts it directly to the aorta.

- Low Systemic Resistance:The systemic resistance is lower than the pulmonary resistance during fetal development, primarily due to the placental circulation.

Postnatal Changes in the Circulatory System

1. The First Breath and Initiation of Pulmonary Circulation

At birth, the newborn takes its first breath, which triggers a cascade of changes that shift the circulatory system from fetal to neonatal circulation. This transformation is primarily due to the onset of pulmonary respiration, which leads to the following physiological changes:
- Reduction in Pulmonary Vascular Resistance:** As the lungs expand with air, the pulmonary vasculature dilates, significantly decreasing the resistance in the pulmonary circuit. This reduction is further facilitated by the release of nitric oxide (NO) from the pulmonary endothelial cells, promoting vasodilation.

- Increased Systemic Vascular Resistance:With the cessation of placental circulation, the systemic vascular resistance rises, as the newborn's circulatory system must now handle the full load of systemic blood flow.

- Changes in Heart Function:The left side of the heart now takes over the primary circulatory duties, as it is responsible for pumping oxygenated blood through the systemic circulation.

2. Closure of Specialized Shunts

Once the newborn starts breathing, the fetal shunts close, transitioning the cardiovascular system to a fully functional postnatal system. These changes include:
- Ductus Venosus Closure: After birth, the ductus venosus constricts and becomes the ligamentum venosum, halting the diversion of blood away from the liver.
- Foramen Ovale Closure:The increased pressure in the left atrium, as a result of increased

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systemic circulation, causes the foramen ovale to close, forming the fossa ovalis. - Ductus Arteriosus Closure:As the oxygen levels rise in the newborn, prostaglandin levels drop, causing the ductus arteriosus to constrict and eventually become the ligamentum arteriosum.

Hemodynamic Mechanisms in the Transition from Fetal to Neonatal Circulation

1. Changes in Pulmonary and Systemic Resistance

- In the Fetus:The pulmonary vascular resistance is extremely high, and the systemic vascular resistance is relatively low due to the placental circulation. Blood is mainly shunted through the placenta, bypassing the lungs.

- In the Newborn:After birth, the placenta is no longer part of the circulatory system, which causes the systemic vascular resistance to increase. As pulmonary vascular resistance decreases with the initiation of breathing, blood flow to the lungs increases.

2. Changes in Heart Function and Distribution of Blood Flow

- In the Fetus:The right side of the heart is responsible for pumping blood to the placenta, where oxygenation occurs. The right ventricle pumps blood through the ductus arteriosus to the aorta.

- In the Newborn:Following birth, the left ventricle takes on the majority of the circulatory load, pumping oxygenated blood into the systemic circulation. This transition is accompanied by a shift in the distribution of blood, with more blood now directed to the lungs.

Congenital Heart Defects and Their Hemodynamic Basis

1. Patent Foramen Ovale (PFO)

A patent foramen ovale (PFO) occurs when the foramen ovale fails to close after birth. This condition can result in abnormal blood flow between the right and left atria, leading to hypoxemia, as deoxygenated blood may enter the systemic circulation. In severe cases, it can also contribute to the development of stroke or other complications.

2. Patent Ductus Arteriosus (PDA)

A patent ductus arteriosus (PDA) is a condition in which the ductus arteriosus remains open after birth, allowing blood to shunt from the aorta to the pulmonary artery. This condition can cause increased blood flow to the lungs, leading to pulmonary congestion, increased heart workload, and, if untreated, heart failure.

Conclusion

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The transition from fetal to neonatal circulation represents one of the most critical physiological adaptations after birth. Understanding the mechanisms behind the closure of fetal shunts, the transition in blood flow, and the role of oxygenation is vital for clinicians. This knowledge aids in diagnosing and managing congenital heart defects and ensures the healthy transition of the newborn into postnatal life. In clinical practice, early detection and intervention of abnormal circulatory transitions can significantly improve outcomes for affected newborns.

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