

NORMAL CARDIAC PHYSIOLOGY – TRANSITION FROM FETAL TO NEONATAL

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1. Introduction

Oxygen delivery to the tissues for a fetus in utero is a much different task than for the neonate, and the fetus has many unique mechanisms designed to maximize the efficiency of circulation. Once a baby is born however, it must begin to function with a circulatory system that resembles that of an adult. During the first 10 minutes after birth, the average heart rate is between 120-200 beats per minute (bpm). Thereafter, the average is approximately 120-130 bpm. Tachycardia may result from volume depletion, cardiorespiratory disease, drug withdrawal and hyperthyroidism ([link tachycardia section](#)). Bradycardia often results from apnea and is often seen with hypoxia ([link bradycardia section](#)). Given that the contractile strength of the neonatal heart has not had a chance to adjust to the new pulmonary and systemic circuitry and pressures, the neonate is highly dependent on heart rate for maintenance of cardiac output and blood pressure. Furthermore, the vasoconstrictive response of the neonate to hemorrhage or volume depletion is less than that of an adult. Following is a summary of the changes that occur in the cardiovascular system soon after birth.

2. Ductus Arteriosis

Ductus Arteriosis is a shunt from the descending aorta to the left pulmonary artery near the bifurcation of the pulmonary trunk. It stays open in the fetus because low PaO₂ and circulating prostaglandins (PGE₂) are vasodilatory on the ductus. In the neonate, when pulmonary oxygen saturation increases, there is less circulating PGE₂ and the ductus closes off. This usually occurs within the first day of life in the term infant. Permanent closure due to fibrosis takes 4-6 weeks, and the remnant is referred to as the ligamentum arteriosum.

3. Ductus Venosus

Ductus Venosus is a shunt of oxygenated blood from umbilical vein to IVC, bypassing the liver. The crista dividens in the right atrium deflects 1/3 of this blood through the foramen ovale, to the left atrium. The ductus venosus closes physiologically as soon as the umbilical vein is obstructed with the clamping of the cord, but with time it closes anatomically, and becomes the ligamentum venosus.

4. Umbilical Vein

The Umbilical Vein carries oxygenated blood from the placenta to the fetus in intra-uterine life. It flows into 1) the Ductus Venosus and 2) the IVC before it enters the liver. With the clamping of the umbilical cord, the umbilical vein closes physiologically, and after a few days anatomically. The remnant of this structure is called the round ligament of the liver (or ligamentum teres), and is clinically significant as it may be responsible for spreading tumors from the peritoneum to the umbilicus later in life.

5. Foramen Ovale

Foramen ovale is a flap valve in the atrial septum that shunts highly oxygenated blood from the IVC to the left ventricle. From the left atrium oxygenated blood is pumped through the aorta to the coronary circulation and the great vessels of the head and neck. The foramen ovale functionally closes at birth when the pressure in the left atrium (increased systemic resistance because loss of the placental parallel circuit) exceeds the pressure in the right atrium (decreased pulmonary resistance because of expanded lung vasculature with breathing), forcing the flap valve closed. It takes several months however for the atrial septum to fibrose, giving permanent closure to the foramen ovale, and leaving behind only the fossa ovalis.

6. Umbilical Artery

Two umbilical arteries carry deoxygenated blood from the internal iliac arteries of the fetus to the placenta. Delayed clamping of the cord in an infant held at a level higher than the placenta with delivery may decrease total blood volume as the blood is displaced to the placenta through the umbilical artery.

7. Placenta

Clamping of the umbilical cord removes the low resistance systemic diversion to the placenta, thereby forcing more blood to the lower limbs. This also increases systemic resistance, directing a larger proportion of blood through the pulmonary circulation.

8. Lungs

The cause-effect relationship of the onset of breathing and pulmonary vascular resistance is not completely understood. However, increased PaO_2 in the breathing neonate compared to the fetus lowers pulmonary vascular resistance and allows more blood to flow to the pulmonary circulation. The closing ductus arteriosus contributes to a higher blood flow to the lungs as less blood is diverted from the pulmonary trunk to the aorta. PO_2 rises from 20-30 mmHg in the fetus arterial blood to 60 mmHg at approximately 1 hour of life to 80-90 mmHg at 24 hours of life.

9. Right Ventricle

The right ventricle is the dominant ventricle in utero. It pumps 65% of the total cardiac output. In the neonate, a decreased pulmonary vascular resistance and closed ductus arteriosus requires less force from the right side of the heart.

10. Left Ventricle

The left ventricle is relatively quiescent in utero because of the parallel structure of the circulatory system, but as the ductus arteriosus closes, the left ventricle becomes responsible for the increasing cardiac output to the body. In the neonate, the systemic vascular resistance increases much more than the size of the fetus does, exerting much force onto the left ventricle, thereby causing hypertrophy of the left ventricle.

References

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