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METHODS OF EXAMINING THE CARDIOVASCULAR SYSTEM IN CHILDREN AND AGE-SPECIFIC NORMS

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Abstract. This article describes the main clinical methods of examining the cardiovascular system in children (history taking, inspection, palpation, percussion, auscultation), the procedure for measuring pulse and arterial blood pressure, and the norms of these indicators in different age groups. Criteria for distinguishing functional (physiological) from pathological heart murmurs are presented.
Keywords: propaedeutics of childhood diseases, cardiovascular system, pulse, arterial blood pressure, percussion, auscultation, age-specific norms.

Introduction

Propaedeutics of childhood diseases teaches the methods of examining a child's body and the age-related characteristics of a healthy child. A child's body is not a miniature adult body. The cardiovascular system changes constantly during growth and development. The size and position of the heart, heart rate, blood pressure and the auscultatory picture all differ with age.

For this reason, applying adult norms to a child leads to diagnostic errors. For example, a heart rate of 130 beats per minute is normal in a newborn but is regarded as tachycardia in an adolescent. A physician must therefore know the age-specific norms well before distinguishing pathological changes.

Aim: to systematize the methods of examining the cardiovascular system in children and the age-specific norms of the main indicators.

Anatomical and physiological features of the cardiovascular system in children

The following features must be known in order to interpret examination findings correctly:

- In a newborn the heart is relatively large and round. Its mass is approximately 0.8–0.9% of body weight.
- In early childhood the heart lies horizontally in the chest. Because the diaphragm is positioned high, the apex beat is located higher and more laterally than in adults.
- As the child grows, the heart elongates, becomes more vertical, and its borders change.
- In children the vessels are wider, the vessel wall is elastic and the capillary network is rich. As a result, blood pressure is lower than in adults.
- Heart rate is higher in younger children because of rapid metabolism and the predominance of the sympathetic nervous system. Vagal influence increases with age, so the pulse gradually slows.

Examination methods

1. History taking

In young children, complaints are usually obtained from the parents. Attention is paid to the following:

- easy fatigue and shortness of breath (in an infant: sweating during feeding, pausing to breathe while sucking, refusing to feed);
- bluish discoloration of the skin and lips (cyanosis), worsening with crying or physical effort;
- chest pain, palpitations, fainting;
- swelling of the limbs, frequent colds;
- lag in physical development.

Information about the course of pregnancy and delivery (for example, maternal infections during pregnancy, birth asphyxia) and a family history of congenital defects or early heart disease is also important.

2. Inspection

Inspection is carried out in a well-lit room while the child is calm. The following are assessed:

- **Skin and mucous membrane color.** Pallor, cyanosis and mottled skin may be present. Cyanosis is most visible on the lips, the nasolabial triangle, the earlobes or the fingertips (acrocyanosis). Nasolabial cyanosis that increases during feeding in an infant suggests a cardiac or pulmonary problem.
- **Shape of the chest.** A bulge over the heart ("cardiac hump") occurs with long-standing cardiomegaly or defects.
- **Apex beat.** It is sometimes visible, especially in thin children.
- **Neck veins:** pulsation and swelling.
- **Shape of the fingers.** In chronic hypoxia, "drumstick" fingers and "watch-glass" nails develop.

3. Palpation

Palpation is used to determine the following:

- **Apex beat:** location, width and force. A widened, stronger beat displaced to the left or downward indicates an enlarged heart.
- **Systolic thrill ("cat's purr"):** a vibration felt under the palm in some heart defects (for example, aortic or pulmonary stenosis, ventricular septal defect).
- **Edema:** of the limbs, eyelids and the lumbosacral region.
- **Capillary refill time** (return of color after pressing on the nail plate and releasing): normally no more than 2 seconds. Prolongation indicates impaired peripheral circulation.

The normal position of the apex beat changes with age (Table 1).

Table 1. Age-specific position of the apex beat

Age	Position of the apex beat
Under 2 years	4th intercostal space, 1–2 cm lateral to the midclavicular line
2–7 years	5th intercostal space, 0.5–1 cm lateral to the midclavicular line
7–12 years	5th intercostal space, along the midclavicular line
Over 12 years	5th intercostal space, 0.5–1 cm medial to the midclavicular line

4.Percussion

Percussion is used to determine the borders of relative cardiac dullness, which approximately reflect the size of the heart. In children, percussion should be gentle (quiet) and performed by the finger-to-finger method. The right, upper and left borders are determined (Table 2).

Table 2. Upper and left borders of relative cardiac dullness

Age	Upper border	Left border
Under 2 years	2nd rib	1–2 cm lateral to the midclavicular line
2–7 years	2nd intercostal space	1 cm lateral to the midclavicular line
7–12 years	3rd rib	0.5–1 cm lateral to the midclavicular line
Over 12 years	3rd rib	along the midclavicular line

Under 2 years of age the right border lies lateral to the right parasternal line; in older children it lies along this line or slightly medial to it. Widening of the cardiac borders may be a sign of cardiomegaly. However, percussion is an approximate method, so its findings are confirmed by chest radiography and echocardiography.

5. Auscultation

Auscultation is the most important method for assessing heart sounds and murmurs. It is performed in a quiet room while the child is calm, using a stethoscope of a size suitable for the child's age. The heart is auscultated at the following points: the apex (mitral valve), the second intercostal space at the right sternal border (aortic valve), the second intercostal space at the left sternal border (pulmonary valve), the lower part of the sternum (tricuspid valve) and the Botkin–Erb point.

Features specific to children:

- In newborns and infants under one year, the first and second heart sounds are almost equal in intensity and the pauses between them are equal (embryocardia). This makes it difficult to tell the sounds and the location of murmurs apart.
- In childhood, a second sound over the pulmonary artery that is louder than over the aorta (accentuation) is physiological. At about 10–12 years of age they become equal.
- A physiological third heart sound may be heard in some children.
- Respiratory arrhythmia (heart rate accelerating on inspiration and slowing on expiration) occurs in children and adolescents and is considered normal.

Distinguishing functional (innocent) from organic murmurs. Functional murmurs are very common in children and are not dangerous. It is important to distinguish them from pathological murmurs (Table 3).

Table 3. Distinguishing functional and organic murmurs

Feature	Functional murmur	Organic (pathological) murmur
Phase	systolic only	systolic or diastolic
Intensity	soft, low	often loud
Duration	short	often long
Dependence on position and respiration	changes with body position and breathing	practically unchanged

Feature	Functional murmur	Organic (pathological) murmur
Thrill	absent	may be present
Radiation	localized, does not radiate	radiates to other areas
Heart size	unchanged	often enlarged
General condition	child is healthy	complaints and signs may be present

Any diastolic murmur is considered pathological. If a murmur is detected, ECG, echocardiography and radiography are ordered to establish an accurate diagnosis.

6. Examination of the pulse

In young children the pulse is usually palpated over the brachial, femoral or temporal artery, and in older children over the radial artery. Pulse rate, rhythm, fullness and tension are assessed. The pulse should be counted while the child is calm and not crying. Counting for a full minute is more reliable. It is necessary to compare the pulse on both arms: a difference suggests a vascular anomaly. A weak or absent pulse over the femoral artery is characteristic of coarctation of the aorta. Age-specific heart rate (approximate, per minute) is given in Table 4.

Table 4. Age-specific norms of heart rate and respiratory rate (per minute)

Age	Heart rate	Respiratory rate
Newborn	120–140	40–60
1 year	110–125	30–35
3 years	100–105	25–30
5 years	95–100	25
7 years	85–90	20–25
10 years	80–85	20
12–15 years	70–80	16–20

The ratio of pulse rate to respiratory rate is also assessed. It is about 2.5–3:1 in newborns and about 4:1 in older children. A disturbance of this ratio may indicate changes in respiratory or cardiac function.

7. Measurement of arterial blood pressure

To measure BP correctly in children, the cuff width must suit the child's arm: it should cover about two thirds of the length of the upper arm. A cuff that is too narrow overestimates the result, while a cuff that is too wide underestimates it. Measurement is performed with the child calm, sitting or lying, usually on the right arm.

The following formulas are used to estimate BP in children approximately:

- **under 1 year:** systolic BP = 76 + 2 × n (where n is the age in months);
- **over 1 year:** systolic BP = 90 + 2 × n (n is the age in years);
- **diastolic BP** is usually 1/2 to 2/3 of the systolic value (or approximately 60 + n).

For example, in an 8-year-old child the approximate systolic pressure is 90 + 2 × 8 = 106 mm Hg, and the diastolic pressure is close to 60 + 8 = 68 mm Hg. In newborns, systolic pressure is

approximately 60–90 mm Hg. These formulas are approximate; for an accurate assessment, percentile tables based on age, sex and height are used. It is recommended to measure BP several times and take the average value. International guidelines evaluate BP in children on the basis of percentiles.

Additional examination methods

Clinical findings are confirmed by the following methods:

- **ECG:** shows heart rhythm, conduction and signs of hypertrophy. ECG parameters in children are also age-specific.
- **Echocardiography (cardiac ultrasound):** the main method for detecting abnormalities of the chambers and valves and congenital defects.
- **Chest radiography:** assesses heart size and pulmonary circulation.
- **24-hour monitoring (Holter, ambulatory BP monitoring):** detects rhythm disturbances and BP changes.
- **Complete blood count and biochemical tests:** show anemia, inflammation and other changes.

Conclusion

Examination of the cardiovascular system in children requires the consistent use of history taking, inspection, palpation, percussion and auscultation. Because this system changes continually as the child grows, the child's age must always be taken into account when assessing pulse, respiratory rate, arterial blood pressure, cardiac borders and the position of the apex beat. Functional murmurs are common in children, and the ability to distinguish them from organic murmurs prevents unnecessary anxiety and excessive investigations. At the same time, when signs such as a diastolic murmur, cyanosis, edema or growth retardation are found, the child should be referred for further examination. Mastering these methods correctly at the propaedeutic stage lays the foundation for accurate diagnosis in future practice.

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