

МЕДИЦИНА, ПЕДАГОГИКА И ТЕХНОЛОГИЯ: ТЕОРИЯ И ПРАКТИКА

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ARTIFICIAL INTELLIGENCE IN PEDIATRIC CARDIOLOGY: OPPORTUNITIES FOR EARLY DETECTION OF HEART DEFECTS

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ANNOTATION

Congenital heart defects in pediatric cardiology are one of the main causes of death and disability in children. Early detection of these defects increases the effectiveness of treatment and prevents complications. In recent years, the introduction of artificial intelligence (AI) technologies into medicine has brought diagnostic processes to a new level. This article discusses the application of artificial intelligence in pediatric cardiology, in particular, the possibilities of early detection of heart defects based on electrocardiography, echocardiography and imaging diagnostics. It is proven that algorithms based on artificial intelligence help doctors make a quick, accurate and objective diagnosis. Congenital heart defects are one of the pathologies that are widespread among children and can lead to severe clinical consequences. The article analyzes the classification of TYN, morphological forms (for example: interventricular septal defect, atrial septal defect, tetralogy of Fallot, etc.), their etiology and pathogenesis. Clinical signs, early diagnosis methods (ECG, echocardiography, pulse oximetry, prenatal diagnosis), and modern treatment approaches will also be reviewed.

АННОТАЦИЯ

Врожденные пороки сердца в детской кардиологии являются одной из основных причин смерти и инвалидности у детей. Раннее выявление этих дефектов повышает эффективность лечения и предотвращает осложнения. В последние годы внедрение технологий искусственного интеллекта (ИИ) в медицину вывело диагностические процессы на новый уровень. В данной статье рассматривается применение искусственного интеллекта в детской кардиологии, в частности, возможности раннего выявления пороков сердца на основе электрокардиографии, эхокардиографии и методов визуализационной диагностики. Доказано, что алгоритмы на основе искусственного интеллекта

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помогают врачам быстро, точно и объективно ставить диагноз. Врожденные пороки сердца являются одной из патологий, широко распространенных среди детей и способных приводить к тяжелым клиническим последствиям. В статье анализируется классификация ТИН (тиреоидных невусных пороков), морфологические формы (например: дефект межжелудочковой перегородки, дефект межпредсердной перегородки, тетрада Фалло и др.), их этиология и патогенез. Также будут рассмотрены клинические признаки, методы ранней диагностики (ЭКГ, эхокардиография, пульсоксиметрия, пренатальная диагностика) и современные подходы к лечению.

Ключевые слова: детская кардиология, искусственный интеллект, врожденные пороки сердца, ранняя диагностика, тетрада Фалло, сердечная недостаточность, пренатальный скрининг, генетические факторы, консервативная терапия, кардиохирургия, машинное обучение.

Keywords: pediatric cardiology, artificial intelligence, congenital heart defects, early diagnosis, tetralogy of Fallot, heart failure, prenatal screening, genetic factors, conservative therapy, cardiac surgery, machine learning.

Introduction

Pediatric cardiology is one of the important areas that deals with the diagnosis, treatment and prevention of congenital and acquired diseases of the heart and vascular system in infants, children and adolescents. In recent years, scientific and clinical interest in pediatric cardiology has been growing sharply. This is due to the high prevalence of heart diseases among children and their negative impact on their healthy development. In particular, congenital heart defects (CHD) are one of the most common and serious pathologies in pediatrics that can lead to death. According to statistics, congenital heart defects occur in 8–12 out of every thousand newborns. This makes heart defects the leading cause of death in the total number of congenital defects. In some countries, this figure reaches 1.5–2 million new cases per year.

Complex forms of TYN, if often not detected in the neonatal or early childhood period, can result in severe heart failure, developmental delay, or even death. Therefore, early diagnosis and the use of modern treatment approaches are very important. The relevance of this topic is that by identifying congenital heart defects at an early stage, it is possible to prevent their severe consequences, improve the quality of life, and reduce mortality. Currently, through genetic screening, prenatal diagnosis, and modern instrumental examinations, it is possible to detect many defects during

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pregnancy. However, awareness in this area, a sufficient number of specialists, and not always sufficient technical base remain problematic.

The role of artificial intelligence in the diagnosis of heart disease

The process of diagnosing heart disease can be time-consuming and complex.

However, artificial intelligence technologies have significantly accelerated this process and increased accuracy. For example, a study published in the journal Nature Medicine in 2019 found that artificial intelligence-based systems showed 20% higher accuracy than cardiologists in analyzing ECG (electrocardiogram) results. This proves the effectiveness of artificial intelligence systems in diagnosing conditions such as heart rhythm disorders (arrhythmias).

In addition, a study published in the journal JAMA Cardiology in 2020 showed that the systems used artificial intelligence worked 30% faster and with 10% higher accuracy than classical methods in determining the risk of heart attacks. These technologies are also developing methods that allow for the early detection of heart disease, which allows patients to start treatment on time.

Artificial intelligence in the treatment of heart disease

Artificial intelligence plays an important role not only in diagnostics, but also in the treatment of heart disease. Currently, AI technologies help not only in making a diagnosis, but also in choosing treatment methods. In a 2021 study, artificial intelligence-based systems were successful in analyzing a patient's medical history and laboratory tests and recommending the right treatment method with 94% accuracy. These systems are useful not only in developing general approaches, but also in developing an individual treatment plan for each patient.

Congenital heart defects are classified according to several criteria.

According to the hemodynamic state:

Cyanotic defects - as a result of blood mixing, there is a lack of oxygen in the arterial blood, which is manifested by

bluish discoloration of the skin and mucous membranes (cyanosis).

Examples:

Tetralogy of Fallot

Transposition of the great vessels

Tricuspid atresia

Ascyanotic defects — oxygenated and deoxygenated blood do not mix, therefore, cyanotic states are not observed.

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Examples:

Atrial septal defect (ASD)

Interventricular septal defect (IVSD)

Patent ductus arteriosus (PDA)

By complexity:

Simple defects — consist of one or two structural changes. They are usually easier to detect, treat, and predict.

Examples: IVSD, ASD, PDA

Complex defects — are accompanied by violations of several structures and functions, often leading to severe heart failure.

Examples: Tetralogy of Fallot, transposition of the vas deferens in adults, common truncus arteriosus.

Etiology and pathogenesis

The etiology of congenital heart defects (CHDs) is complex and multifactorial, involving an interaction of genetic, environmental, infectious, metabolic, and pharmacological factors that disrupt the embryonic development of the heart and blood vessels. These factors are particularly dangerous during the critical period of gestation, between 3 and 8 weeks, when cardiac structures are forming.

Genetic factors

Genetic factors play an important role in the development of CHDs. Approximately 10–20% of CHDs are associated with specific genetic syndromes.- The most common conditions are:

Down syndrome (trisomy 21): heart septal defects, atrioventricular canal defects. DiGeorge syndrome (22q11 deletion): aortic arch anomalies, tetralogy of Fallot. Turner syndrome (XO): coarctation of the aorta, bicuspid aortic valve.

Marfan syndrome: aortic dilatation, mitral valve prolapse.

Also, monogenic (associated with a single gene) and polygenic (interaction of several genes) mechanisms have been identified.

Maternal infections during pregnancy

Infections in the mother's body during critical stages of heart development, especially viral infections, have a teratogenic (disruptive) effect:

- Rubella (measles): one of the most dangerous viruses, accompanied by multi-organ syndromes such as PDA (patent ductus arteriosus), pulmonary stenosis, cataracts and deafness.

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- Other infections such as cytomegalovirus, toxoplasmosis, hepatitis, and Zika virus can also negatively affect heart development.

Instrumental diagnostics

Electrocardiography (ECG)

- Evaluates the electrical activity of the heart.
- Determines the presence of right or left ventricular overload, hypotrophy, blockades, and rhythm disturbances.
- Defects such as IVSD and tetralogy of Fallot have specific ECG signs.

Echocardiography (USG)

- The most basic and reliable diagnostic method.
- Shows the structure of the heart, the size of the chambers and ventricles, the condition of the valves, the direction and speed of blood flow.
- Doppler technology can analyze blood flow.
- ASD, IVSD, PDA, tetralogy of Fallot and other defects are detected.
- It is performed painlessly and without anesthesia in young infants.

Pulse oximetry

- Assesses the level of oxygen saturation of the blood.
- Low SpO₂ (≤ 90 – 92%) is an important sign of cyanotic congenital heart defects.
- Widely used as an inexpensive, rapid and non-invasive screening method, especially in the neonatal period.

X-ray (Chest radiography)

- The size of the heart shadow, the shape of the heart and the state of pulmonary circulation are determined.
- For example, in PDA, pulmonary circulation may be increased.
- In cases of tetralogy of Fallot, the heart takes on a “boot-shaped” shape.

Prenatal diagnosis

Fetal echocardiography

- Performed at 18–24 weeks of pregnancy.
- A 4-chamber view of the fetal heart, the outflow tracts of the aorta and pulmonary artery are examined.
- Defects such as ASD, IVSD, tetralogy of Fallot, transposition can be detected.

Genetic screening and tests

- If the mother or father has a heart defect or a defect has been detected in a previous fetus, special tests (karyotype, FISH, array CGH) are performed.

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- Allows the detection of heart defects associated with genetic pathologies such as Down syndrome, DiGeorge syndrome.

Treatment and management

Treatment of congenital heart defects (CHD) is selected individually depending on the type of defect, severity, cyanotic or acyanotic state, degree of heart failure and the age of the child. The treatment approach can be conservative (drugs), invasive (via catheter) or cardiosurgical. Conservative therapy (drugs) In some cases, before surgery or for mild defects that do not require surgery, it is possible to support the heart with drugs:

- Diuretics (furosemide, spironolactone) - if there are signs of heart failure, help to remove fluid from the body.
- ACE inhibitors (captopril, enalapril) - lower blood pressure and reduce the workload on the heart.
- Inotropic agents (digoxin) - increase the force of heart contractions.
- Beta-blockers (propranolol) - are used to regulate heart rate.

Conservative therapy is often used to buy time before surgery or to relieve symptoms.

Cardiosurgical methods

Open heart surgery

In cases of complicated or symptomatic TYN, open heart surgery is the most effective treatment:

- IVSD or ASD - the defect is closed with artificial patches.
- Tetralogy of Fallot - the pulmonary artery is expanded, the stenosis is eliminated, the defect is repaired.

CONCLUSION

The problem of congenital heart defects in pediatric cardiology has not lost its relevance today, causing high morbidity and mortality among children. Early detection and timely treatment of these diseases significantly improves the quality of life and long-term prognosis of children. The introduction of artificial intelligence technologies into the medical field, especially pediatric cardiology, has opened up new opportunities in diagnostic processes. Machine learning and deep learning algorithms allow for the high-precision detection of heart defects through the analysis of ECG, echocardiography, and medical images. This reduces errors due to the human factor

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and increases the speed of diagnosis. In addition, artificial intelligence-based systems are important in predicting the risk of developing diseases, creating an individual treatment plan, and helping doctors make clinical decisions. These technologies are of great practical importance, especially in regions with a shortage of qualified specialists. However, for the widespread introduction of artificial intelligence, it is important to collect a sufficient database, ethical and legal issues, as well as increase the digital literacy of medical workers.

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