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POTENTIAL OF DIGITAL CARDIOMETRY IN DIAGNOSING CARDIOVASCULAR DISORDERS IN CHILDREN WITH CHRONIC KIDNEY PATHOLOGY

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ABSTRACT

In the past decade, there has been a sharp increase in interest regarding cardiovascular involvement in kidney diseases. The most common cardiovascular disorders include left ventricular hypertrophy and dysfunction, arrhythmias, and abnormalities of the major arteries. Given the importance of timely detection and the ability to predict the development of complications, digital cardiometry plays a particularly significant role. It provides rapid access to information about central and intracardiac hemodynamics. Materials and Methods. A total of 42 children aged 5 to 16 years with chronic kidney disease were examined. The comprehensive laboratory and clinical-instrumental assessment included digital cardiometry, based on measurements of hemodynamics and the phases of the cardiac cycle. Results of the Study. The proposed method of digital cardiometry enables the diagnosis of key hemodynamic parameters along with simultaneous evaluation of all phase functions of the heart. Early detection of cardiovascular complications allows for the timely initiation of cardioprotective therapy, thereby improving the disease prognosis.

KEYWORDS: *Children, Chronic Kidney Disease, Hemodynamics, Cardiovascular System.*

INTRODUCTION

Over the past decade, there has been a marked increase in interest in cardiovascular involvement in kidney diseases. The risk of developing cardiac pathology in patients at various stages of chronic kidney disease (CKD) is significantly higher than in the general population [2, 3]. Myocardial remodeling is observed in 17–23% of children with CKD stages 1–3, and in 69–82% of children at the initiation of dialysis therapy. The spectrum of cardiovascular lesions includes left ventricular hypertrophy and dysfunction, arrhythmias, and abnormalities of large arteries, such as carotid intima-media thickening, early development of cardiomyopathy, and atherosclerosis [1, 4, 5, 6].

Given the importance of timely detection and the ability to predict complications, the development and implementation of modern digital diagnostic equipment becomes particularly relevant. Such tools are capable of providing more comprehensive and detailed information. A digital hemodynamic analyzer offers a new opportunity to rapidly obtain indicators of central and intracardiac hemodynamics, which has significant prognostic value for early-stage diagnosis of pathological processes [7].

The method is based on the synchronous recording of a single-channel electrocardiogram (ECG) and a rheogram from the ascending aorta, with high-precision (up to thousandths of a second) measurement of the phase characteristics of the signals. Using a dynamic model of blood flow through vessels (including a high-flow regime) and a phase analysis of the cardiac cycle, mathematical calculations of blood volume dynamics throughout various parts of the cardiovascular system during one cycle are performed. The results have been verified by comparison with direct measurements of hemodynamic parameters [7].

In this regard, the aim of this study was to assess the potential of various modern diagnostic methods in detecting cardiovascular disorders in patients with chronic kidney disease.

MATERIALS AND METHODS

A total of 42 children aged 5 to 16 years, who were receiving inpatient treatment at the Samarkand Regional Children's Multidisciplinary Medical Center, were examined. The patients were divided into two nosological groups. Among them, 18 children (42%) were diagnosed with chronic pyelonephritis, and 24 children (48%) with chronic glomerulonephritis. The majority of patients were in the younger school-age group (7–12 years) – 45%, while children of preschool age (4–6 years) and older school age (13–17 years) accounted for 22% and 33%, respectively. Across both groups, regardless of age, boys slightly predominated, comprising 62.0% of the sample. All children underwent comprehensive clinical and laboratory-instrumental nephrological and cardiological evaluations. To determine the stage of CKD, glomerular filtration rate (GFR) was assessed using the Schwartz formula. Both groups

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included children with stages 1–3 of the disease. This particular patient category was intentionally selected because, in such cases, the true extent of cardiovascular system involvement in the pathological process is often difficult to detect.

DISCUSSION OF RESULTS

Electrocardiographic (ECG) examination revealed various types of conduction blocks, including incomplete right bundle branch block in 27% of cases and incomplete left bundle branch block in 10% of patients. Among cardiac arrhythmias, sinus tachycardia was the most common, detected in 44% of children with CKD. It was more prevalent in children with chronic glomerulonephritis compared to those with chronic pyelonephritis, occurring in 66% and 44% of cases, respectively. Sinus bradycardia, as a manifestation of autonomic dysfunction, was found in 3% of patients. Signs of left ventricular hypertrophy were identified in 16% of children.

Echocardiographic examination revealed grade 1 valvular insufficiency, predominantly in children with chronic glomerulonephritis. Specifically, tricuspid valve insufficiency was found in 13% of patients, mitral valve insufficiency in 15%, and aortic valve insufficiency in 12%. In contrast, only one patient with chronic pyelonephritis had mitral valve insufficiency. ECG data also confirmed left ventricular enlargement in 36% of the children. Left ventricular volume indicators tended to be higher in children with chronic glomerulonephritis compared to those with pyelonephritis. Signs of exudative pericarditis were detected in 22% of patients, predominantly in the glomerulonephritis group. The extended cardiological evaluation included hemodynamic assessment using a digital hemodynamic analyzer (manufactured in Russia). This device allows for highly accurate and simple detection of cardiovascular changes and monitoring of disease progression. It connects to any computer running a Windows platform.

The analyzer implements a mathematical hemodynamic model, where the ECG serves as the primary signal and the rheogram as an auxiliary one. Synchronous recording of a single-lead ECG and a rheogram from the ascending aorta, combined with phase analysis of the cardiac cycle, enables the assessment of the functional status of the cardiovascular system for early, preclinical diagnosis and evaluation of therapy effectiveness. Key diagnostic parameters based on cardiac cycle phases include: functional characteristics of the cardiovascular system, hemodynamic parameters, and the metabolic status of the heart muscle.

The **functional characteristic** is primarily represented by the cardiac index—defined as the minute cardiac output per body surface area. A decreased cardiac index was observed in 37 children (88%), with an average value of 1.6 L/min/m² (normal: 3–4 L/min/m²). Another functional parameter, the stiffness index—an indicator of reduced vascular elasticity—was elevated in 37 patients (88%). **Hemodynamic parameters** included stroke volume and cardiac output. The stroke volume, representing the volume of blood pumped by the left and right ventricles per unit time, averaged 21.5 mL (normal: 25–60 mL) and was reduced in 22 patients (52%). Cardiac output, indicating the total volume of blood pumped by the heart per minute, averaged 2 L and was reduced in 19 patients (45%) (normal: 2.2–3.5 L/min). In the cardiac cycle, systolic phases are divided into two types: those occurring under **aerobic** conditions and those under **anaerobic** conditions. Aerobic processes, which rely on fatty acid oxidation and are more energy-efficient, are reflected on the ECG in the Q–R and R–S phases. Oxygen, the main indicator of aerobic metabolism, was reduced in 19 patients (45%) and averaged 0.45 units (normal: 0.5–0.85 units).

Following the aerobic phase is the **anaerobic** phase, which relies on carbohydrate breakdown and results in lactate production. This occurs during sustained myocardial tension and increased intracardiac pressure. Lactate levels were elevated in 7 patients (17%), with an average of 7.4 units (normal: 3–6 units).

The **residual state** of the myocardium, reflecting post-contraction tension after pressure is released, corresponds to residual creatine phosphate levels. This parameter was elevated in 14 patients (33%) and averaged 6.74 units (normal: 2–4 units).

CONCLUSION

Thus, the presented diagnostic methods for detecting cardiovascular complications of CKD at early stages allow for a sufficiently comprehensive assessment of cardiovascular system function. The results obtained through various diagnostic approaches are not contradictory, but rather complementary. Well-known techniques such as ECG and echocardiography primarily provide insights into conduction disorders, myocardial contractility, hypertrophy, and the overall functional state of the heart. In our opinion, cardiometry based on hemodynamic parameters and phase analysis of the cardiac cycle successfully enhances the overall understanding of cardiovascular activity. New parameters and diagnostic criteria have been identified, taking into account the compensatory and functional reserves of the heart.

Based on the above, it becomes possible to conduct active monitoring of patients with chronic kidney disease for targeted early diagnosis of cardiovascular pathology. The proposed method of digital cardiometry allows for highly accurate, simple, and rapid detection of changes and monitoring of cardiovascular processes. It enables the identification of pathology at earlier stages than conventional methods. Analysis of ECG and rheogram data provides information about qualitative changes in the condition of the

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heart and vessels. The method of phase analysis of the cardiac cycle enables indirect diagnosis of key hemodynamic parameters and functional phases of cardiac activity, making it suitable for both remote access to cardiology centers and use in personal telemedicine devices. Early detection of cardiovascular complications allows for timely initiation of cardioprotective therapy, thereby improving disease prognosis.

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