MINISTRY OF HEALTH OF THE REPUBLIC OF UZBEKISTAN
SAMARKAND STATE MEDICAL UNIVERSITY

Nasyrova Z.A.

Cardiac Conduction Disorders: Clinical and Prognostic Aspects

Monograph

SAMARQAND
2025

UDC
LBC

Nasyrova Z.A.
Cardiac Conduction Disorders: Clinical and Prognostic Aspects [Text]: Monograph / I.R. Tashkenbaeva E.N. - Samarkand: 2025. - 130 p.

Nasyrova Z.A.

ABSTRACT

This monograph is dedicated to a comprehensive analysis of cardiac conduction disorders - one of the most diverse and clinically significant groups of cardiological conditions that determine both the course and prognosis of cardiovascular diseases. The work presents a modern view on the mechanisms of conduction system dysfunction formation, its clinical manifestations, diagnostic criteria, as well as its prognostic role in the development of complications, including life-threatening arrhythmias, progression of heart failure, and sudden cardiac death. Special attention is given to the interpretation of ECG patterns, the capabilities of Holter monitoring, stress testing, electrophysiological studies, and modern approaches to risk assessment.

The monograph synthesizes findings from current international research and domestic clinical experience, allowing for an examination of the issue not only from pathophysiological and diagnostic perspectives but also through the lens of personalized medicine. The author emphasizes the prognostic significance of various types of atrioventricular and intraventricular conduction blocks, as well as disorders of automaticity and repolarization processes, providing well-reasoned conclusions about the necessity of early detection and timely correction of identified abnormalities.

The book is intended for cardiologists, general practitioners, functional diagnostics physicians, as well as interns, residents, and researchers working in the field of cardiovascular medicine. The monograph will be valuable for emergency physicians, rehabilitation specialists, and all clinicians dealing with high-risk patients. Due to its systematic presentation of material and practical orientation of recommendations, the publication can serve both as a teaching aid and a guide for clinical decision-making.

The primary aim of the monograph is to provide readers with a scientifically grounded, in-depth, and structured understanding of cardiac conduction disorders, their clinical significance, and prognostic implications, as well as to showcase modern diagnostic and treatment options aimed at reducing complication risks and enhancing patients' quality of life.

ISBN

Contents

List of Abbreviations

Abbreviation	Full form
AV	Atrioventricular
AV block	Atrioventricular block
AH	Arterial hypertension
BP	Blood pressure
CABG	Coronary artery bypass grafting
AF	Atrial fibrillation
SCD	Sudden cardiac death
VT	Ventricular tachycardia
IEGM	Intracardiac electrogram
ANS	Autonomic nervous system
DTL	Thyroid defibrillation (if used, specify)
CL	Cycle length
ECG	Electrocardiogram
EPS	Electrophysiological study
IHD	Ischemic heart disease
ICD	Implantable cardioverter-defibrillator
MI	Myocardial infarction
CA	Coronary artery
CBS	Cardiomyopathic heart block (if used; otherwise remove)
CRP	Critical range of conduction
CrCl	Creatinine clearance
CT	Computed tomography

LV	Left ventricle
LA	Left atrium
ABI	Ankle-brachial index
MRI	Magnetic resonance imaging
SVT	Supraventricular tachycardia
ADs	Arrhythmias
RD	Repolarization disorder
AMI	Acute myocardial infarction
ACS	Acute coronary syndrome
RV	Right ventricle
PICS	Post-infarction cardiosclerosis
PVS	Programmed ventricular stimulation
MR	Myocardial revascularization
SVT	Supraventricular tachycardia
CRT	Cardiac resynchronization therapy
CRT-D	Cardiac resynchronization therapy defibrillator
CVD	Cardiovascular diseases
TIM	Trigger of ischemic mechanism
VF	Ventricular fibrillation
AF	Atrial fibrillation
AVF	Atrioventricular fibrillation (if used)
Holter ECG	Holter ECG monitoring
EMI	Electrical myocardial instability

Glossary

Term	Definition
AV block	Impairment of impulse conduction from the atria to the ventricles of varying severity.
Automaticity	The ability of the heart's conduction system cells to independently generate electrical

	impulses.
Activated triggered activity	Pathological ability of cells to generate impulses when ion balance or rhythm frequency changes.
Bradyarrhythmia	Slow heart rhythm due to impaired automaticity or conductivity.
Bundle branch block	Impaired conduction of excitation through the right or left branches of the ventricular conduction system.
Heart rate variability (HRV)	An indicator of RR interval fluctuations, reflecting the state of autonomic regulation.
Sudden cardiac death (SCD)	Rapid, unpredictable death due to arrhythmia within 1 hour of symptom onset.
Intracardiac electrogram	Recording of the heart's electrical activity from endocardial electrodes during electrophysiological study.
Hibernating myocardium	A viable, but functionally depressed area of the myocardium in chronic ischemia.
Depolarization	A change in the cell's charge leading to its excitation.
Repolarization dispersion	The difference in action potential recovery time in different parts of the myocardium - a factor in arrhythmogenesis.
Ectopic contractions	Premature impulses arising outside the sinus node.
Electrical myocardial instability (EMI)	A condition that increases the likelihood of developing dangerous ventricular arrhythmias.
Ventricular extrasystole (VES)	Premature ventricular contraction.

Ventricular tachycardia (VT)	Rapid ventricular rhythm capable of transitioning to fibrillation.
Scarring zone	A section of fibrous myocardial tissue involved in the re-entry mechanism.
Idiopathic arrhythmia	Rhythm disturbance without structural heart pathology.
Implantable cardioverter-defibrillator (ICD)	Device for preventing fatal arrhythmias using electrical discharge.
Myocardial ischemia	Insufficient blood flow leading to decreased oxygen and electrical instability.
Channelopathy	Genetic disorder of cardiomyocyte ion channels.
Catheter ablation	Destruction of the arrhythmogenic focus in the myocardium through catheter intervention.
Creatinine clearance	Kidney function indicator; an important prognostic marker in patients with coronary artery disease.
Macro-reentry	A large excitation circuit causing sustained tachycardia.
Micro-reentry	Local circulation of impulses in a small area of the myocardium.
Holter monitoring	24-hour ECG recording for the diagnosis of arrhythmias.
Pacemaker activity	Generation of impulses by cells of the conduction system.
His potential	Electrical activity of the bundle of His, recorded during electrophysiological study.
Atrial tachycardia	Supraventricular tachyarrhythmia with a focus in the atria.

Repolarization	Restoration of the cell's electrical charge after excitation.
SCD risk stratification	Assessment of individual risk of fatal arrhythmias based on clinical and diagnostic parameters.
Scar substrate	An area of fibrosis capable of maintaining reentry circulation.
Sinus node	The main physiological pacemaker of heart rhythm.
Supraventricular tachycardia	Arrhythmia occurring above the ventricular level.
Cardiac Resynchronization Therapy (CRT)	Stimulation to restore synchronicity of ventricular contractions.
Triggered activity	Emergence of pathological impulses due to afterdepolarizations.
Troponins	Biochemical markers of myocardial damage.
Atrial fibrillation (AF)	Rapid chaotic contractions of the atria.
Ventricular fibrillation (VF)	Life-threatening arrhythmia with complete loss of cardiac pump function.
Electrophysiological study (EPS)	Invasive method for studying conduction and mechanisms of arrhythmias.
Endocardial electrograms	Recordings of heart chamber activity obtained during EPS.

Chapter 1. Literature Review

1.1 Epidemiology of ischemic heart disease

Ischemic heart disease (IHD), arterial hypertension (AH), and heart rhythm disorders combined with borderline neuropsychiatric disorders remain the main causes of morbidity, impaired work capacity (up to disability and loss of qualifications), as well as mortality among the population [1-3]. In Europe, these diseases account for 40% of all deaths and 30% of deaths under 65 years of age [4, 5]. Russia surpasses most European countries in mortality rates from IHD and AH [1-3]. The dependence of these conditions' occurrence and course on gender, age, professional, psychosocial, and environmental factors has been established [6-9], which should be considered when organizing treatment and preventive measures. In this regard, the penitentiary system is of scientific and practical interest, as it contains a significant number of men and women experiencing the negative influence of considerable psycho-emotional stress (PES), which contributes to the occurrence of various psychosomatic disorders [9, 10], sometimes with serious complications - up to fatal outcomes. Considering that comprehensive monitoring of workers' health status is a crucial task of occupational medicine, as working conditions do not always meet regulatory requirements and contribute to the occurrence of various diseases [6-9], this same principle fully applies to penitentiary medicine [9-11]. It is precisely for this reason that the creation of a rational project for protecting prisoners' health and optimizing adequate medical and

psychological assistance to them, in the context of society's democratization and the humanization of the penal system, should be considered a crucial issue for medical science and practical healthcare, including penitentiary medicine.

Epidemiological studies of recent decades convincingly confirm that coronary heart disease (CHD) in most countries tends to increase in prevalence, affect younger populations, and spread to demographic groups that were previously less susceptible to this pathology [1, 2]. The high proportion of deaths from cardiovascular diseases (CVD) among the adult population exceeds 50%, which is largely due to the presence of atherosclerosis [3]. Cross-sectional epidemiological studies characterize the true prevalence of CHD. In the second half of the 20th century, based on standard epidemiological methods, representative national population samples were examined in many countries, which made it possible to determine the epidemiological conditions for the development of CHD and the features of its distribution, as well as to establish the most significant factors contributing to the formation of morbidity and mortality from CVD [4, 5]. The results of epidemiological studies at the end of the last century showed significant variability in the prevalence of CHD depending on age, gender, ethnicity, education, profession, and the nature of work [6]. According to both domestic and foreign authors, men are more likely to suffer from CHD [7, 8]. This pattern has been confirmed in many epidemiological studies [9, 10]. Mortality rates increased in older age groups for both men and women, with women having a significantly lower relative cardiovascular risk of death compared to men [11].

In Europe, over 4.3 million deaths (48% of all deaths) and more than 2.0 million deaths are attributed to circulatory system diseases (CSD), which are registered in 27 European Union countries (42%) [5, 6]. This includes more than 800,000 people over the age of 63 who die from

cardiovascular diseases (CVD) annually, with about 230,000 of these deaths occurring in developed European countries [47]. For one in five Europeans, CVD is the cause of death, with 15% of women and 16% of men dying annually from these diseases [45, 47]. CVD statistics vary significantly across different countries in the European region. In particular, mortality rates are much higher in Eastern and Central European countries compared to other states in the European region. The lowest mortality rates are observed in Portugal, Spain, France, Italy, the Netherlands, and Switzerland [45]. Simultaneously, data from the MONICA project [7, 43] show that mortality from coronary heart disease (CHD) has decreased by approximately two-thirds due to reduced morbidity and better control of risk factors (primarily smoking) for CHD. However, the survival rate of CHD patients has improved by only one-third due to advancements in treatment approaches, which can be observed today in developed European countries. This highlights the importance of ongoing primary prevention measures for cardiovascular diseases. A similar situation is observed for fatality rates. According to MONICA [43], Central and Eastern European countries have high mortality rates from CHD: in some countries of this region, it has slightly increased, although there is an overall downward trend, but at a much slower pace than in Western, Southern, and Northern regions of Europe. For instance, the 28-day fatality rate from acute coronary events among men aged 35-65 in Moscow (RF) is 50% higher than in Belfast (UK) or Catalonia (Spain). Since mortality rates during this period are influenced not only by disease severity but also by the accuracy of diagnostic tests and the quality of medical interventions, it is proposed to reduce mortality from acute CVD in the near future by implementing new diagnostic criteria for myocardial infarction (MI), emphasizing the importance of troponin testing [15, 48]. Cardiovascular diseases, especially CHD, are becoming epidemiologically significant for Asian

countries as well [9, 19]. The structure of circulatory system diseases varies significantly depending on the region. For example, in India, mortality from stroke did not exceed that from CHD, while in China, the opposite situation was observed. According to other data from India, home to nearly one-sixth of the world's population, the country's general morbidity registry reports that CHD accounted for 17% of total deaths and 26% of adult deaths in 2001-2003, increasing to 23% of total deaths and 32% of adult deaths in 2010-2013. Researchers also report that the prevalence of CHD has increased over the past 60 years, from 1% to 9-10% among urban populations and from less than 1% to 4-6% among rural populations. Using stricter criteria (clinical ±Q waves) for studying the prevalence of CVD, actual figures range from 1-2% in rural populations to 2-4% among urban populations [19].

Ischemic heart disease (IHD) ranks first among cardiovascular causes of death, accounting for approximately 49% of cardiovascular mortality in Russia [2; 4; 5; 6]. Mortality from IHD in men under 65 years of age is 3 times higher than in women, while in older age groups, mortality rates for both sexes equalize. Therefore, the analysis of mortality rates among working-age men is undoubtedly important and necessitates the study of factors influencing these indicators. Modern medicine supports the concept of risk factors (RF) as possible causes of the development and progression of cardiovascular diseases. The risk of developing coronary atherosclerosis and IHD significantly increases with the presence of such well-known RFs as male sex, advanced age, dyslipidemia, arterial hypertension (AH), smoking, diabetes mellitus, low physical activity, and alcohol abuse [3]. In recent years, convincing data have been obtained indicating that the ankle-brachial index (ABI) is an independent RF, along with existing ones. Early detection of reduced ABI significantly improves the prognosis for premature fatal myocardial infarction. Recently, reports have emerged in the literature that an ABI

value less than 0.9 is an independent factor predicting the development of complications such as unstable angina and non-fatal myocardial infarction [7]. In light of the above, there is no doubt about the advisability of assessing ABI in patients with various manifestations of cardiovascular pathology. Another RF and independent predictor of death and cardiovascular complications, especially in patients with IHD, is renal dysfunction: the more pronounced the renal dysfunction, the higher the risk of cardiovascular complications. To assess the functional state of the kidneys, it is recommended to calculate creatinine clearance (CC) or glomerular filtration rate. As shown in a number of studies, a decrease in CC can be an unfavorable prognostic factor for the development of cardiovascular complications and death, especially in patients with acute coronary syndrome [1].

Despite the fact that the mortality rate from coronary heart disease has decreased over the past 4 decades in developed countries, it continues to be the cause of approximately one-third of all deaths among people over 35 years of age.[1] It is estimated that nearly half of middle-aged men and one-third of middle-aged women in the United States will experience some symptoms of coronary heart disease.[2] Meanwhile, cardiovascular diseases are estimated to cause approximately 4 million deaths annually in Europe and 1.9 million deaths in the European Union, mainly due to coronary heart disease (CHD),[3] which accounts for 47% and 40% of all deaths in Europe and the European Union respectively. In Europe, cardiovascular diseases result in a total estimated annual cost of 196 billion euros, of which approximately 54% is attributed to direct healthcare costs and 24% to productivity loss. Moreover, the consequences of CHD are not limited to developed countries. As discussed below, recent data indicate that the impact of this disease is increasing in non-Western countries. This descriptive review of the epidemiology of CHD discusses data on

prevalence trends (the number of existing cases in the population) and incidence (the number of new cases within a specific timeframe) of CHD, with both values used as epidemiological measures of the disease's impact on the population. The review also presents information considered most relevant for CHD development trends and prognosis. Most information on coronary morbidity and mortality is derived from data provided by national studies and observational cohort studies. Although such studies are useful, they should be interpreted with caution, as they are uncontrolled and lack verification of the accuracy of participants' reported information. Generalizing results to other periods different from the study period can also be problematic, and comparisons between studies should be critically interpreted due to possible methodological differences. In this regard, the universal definition of myocardial infarction[4] presents a challenge for interpreting the impact measures of CHD before and after the adoption of the definition in 2000.

Finally, there are significant differences between research studies and official statistics in terminology, definitions, and the criteria chosen to assess the impact of IHD on the population. While some statistical data generally refer to "ischemic heart disease," others focus on acute myocardial infarction or acute coronary syndrome (ACS) with or without ST-segment elevation. The following discussion primarily concerns the epidemiology of IHD in general and, where indicated, details specific cases of acute myocardial infarction and ACS.

Cardiovascular diseases (CVDs) have long been recognized by the global community as a problem that has reached pandemic proportions. Epidemiological studies, both worldwide and in the Russian Federation (RF) in particular, demonstrate a high prevalence of CVDs among the population. According to the World Health Organization (WHO) report for 2016, 17.9 million people died from CVDs, accounting for one in every

three deaths. Coronary heart disease (CHD) holds the leading position among CVDs, both in terms of morbidity and mortality rate, causing 8.8 million deaths per year [19,20]. Despite ongoing efforts to improve the prevention, diagnosis, and treatment of CVDs, experts predict that the burden of these diseases will continue to grow globally. This growth is expected to be observed primarily in countries with developed economies and high income levels, largely due to increased life expectancy [21-25]. In light of this situation, as early as 2013, 194 WHO member countries developed the "Action Plan for the Prevention and Control of Non-Communicable Diseases in the WHO European Region for 2016-2025." Its goal is to reduce the number of premature deaths from non-communicable diseases by 25% by 2025 [26]. This is particularly significant, as it is widely recognized that CHD is the leading cause of sudden cardiac death (SCD) - accounting for 75-90% of cases [27,28].

The recently completed major domestic study REZONANS, conducted in three Russian cities (Ryazan, Voronezh, Khanty-Mansiysk) and including a population of 285,736 patients with coronary heart disease (CHD), was designed to clarify the prevalence of sudden cardiac death (SCD), as well as the quality of diagnostics and statistical accounting of SCD in medical institutions [16]. According to the diagnoses recorded in medical death certificates, the frequency of SCD in the context of CHD was 69 cases per 100,000 male population per year, and 26 cases per 100,000 female population per year. However, a more detailed additional analysis of medical documentation, interviews with relatives, death witnesses, as well as treating physicians and emergency medical team doctors, led to the conclusion that the adjusted frequency of SCD is 2.3 times higher in men and 2.8 times higher in women than the officially registered level, amounting to 156 and 72 cases per 100,000 population per year, respectively. Thus, in domestic practical healthcare, every second case of SCD in male patients with

CHD and two-thirds of cases in female patients with CHD go undetected, leading to an underestimation of the likelihood of SCD development in the population. The main reasons for this underreporting of SCD in patients with CHD were identified as insufficiently thorough diagnostic search when establishing the cause of death (45.4%) and errors in medical documentation (55.6%). According to another Russian study [17] conducted in the general population of Moscow, among all causes of death occurring outside medical institutions, the proportion of SCD reaches 39.4% and corresponds to 92.5 cases per 100,000 residents per year. In the USA, the annual SCD rate ranges from 1 to 2 cases per 1,000 population, which in absolute numbers corresponds to 200,000 - 450,000 people [18, 19]. Such fluctuations are mainly due to differences in the inclusion criteria used, primarily related to different timeframes for SCD syndrome (from 24 hours used in 1980-1990 to 1 hour in modern recommendations). Average epidemiological indicators in the USA show that the proportion of SCD (with a 1-hour inclusion criterion) in the structure of total mortality is about 13%, and in mortality from circulatory system diseases - about 40% [19]. At the same time, the results of a Dutch study using the 24-hour diagnostic criterion showed that the frequency of SCD was 18.5% of all deaths [20]. In the aforementioned Russian study REZONANS [16], 12 hours was recognized as the upper time criterion for SCD, and the estimated share of SCD in the overall mortality structure was 16.3%. In Europe, the frequency of SCD is generally comparable to that in the USA, while it varies significantly in various European countries depending on their economic and geographical position [21]. Furthermore, a clear correlation is observed between the frequency of SCD and age, gender, and the prevalence of CHD [12, 22]. The vast majority of cases (80-85%) of SCD are associated with CHD, with more than half of them linked to acute coronary circulation disorders [23]. The absolute number of SCD cases is higher in

men and increases proportionally with age in the population; however, the proportion of SCD in the overall mortality structure is highest in individuals aged 35-44 [23]. In the same study, it was shown that in 80% of cases, death occurs at home, and in another 15% - on the street or in public places. In more than one-third of cases, death occurs without witnesses. Thus, only a small number of patients die in the presence of medical personnel and, theoretically, have a greater chance of successful resuscitation and, consequently, survival. These data lead to the conclusion that the main measures should focus on identifying high-risk groups for SCD and implementing preventive measures.

1.2 Stratification of sudden cardiac death risk in patients with conduction disorders

Sudden cardiac death (SCD) is a non-violent death due to heart disease, manifested by sudden loss of consciousness within one hour from the onset of acute symptoms, where the previous heart disease may be known or unknown, but death is always unexpected [37, 47]. In the USA, about 400,000 people die from sudden cardiac death annually, which is 0.1-0.2% of the total population. Averaged epidemiological indicators in the USA show that the proportion of SCD in the overall mortality structure is about 13%, and in mortality from circulatory system diseases, it is about 40% [4, 32]. Three age-related types of SCD are distinguished: among newborns, young people, and adults aged 45-75 (Burch et al., 1965). Among newborns, the frequency of sudden cardiac death is about 0.1-0.3%. Between the ages of 14 and 21, up to 30% of sudden deaths are caused by heart disease, while in middle-aged and elderly individuals, this figure reaches 88%. There are also gender differences in the frequency of SCD. Thus, in young and middle age, SCD occurs 4 times more frequently in men than in women. In the 45-64 age group, SCD is registered 7 times more frequently in men than in women,

and only in the 65-74 age group is its frequency in men and women expressed in a 2:1 ratio. Thus, the frequency of SCD increases with age and is higher in men compared to women. Calculated data, compiled taking into account the coefficients obtained during epidemiological studies in the USA and Europe, indicate a wide range of possible SCD frequency in Russia - from 200 to 460 thousand people per year. However, the values of 200-250 thousand people per year appear more realistic [3]. Sudden cardiac death is predominantly arrhythmogenic. The underlying mechanisms behind the development of SCD are, in the vast majority (90%) of cases, ventricular fibrillation (VF) and hemodynamically significant ventricular tachycardia (VT) [4, 32, 36]. Ventricular fibrillation is the chaotic, uncoordinated, and generally ineffective contraction of individual groups of ventricular muscle fibers with a frequency exceeding 300 times per minute. In this case, the ventricles are unable to contract synchronously, and the pump function of the heart ceases. The clinical equivalent of ventricular fibrillation is ventricular tachycardia with loss of consciousness. Ventricular fibrillation was first described in 1842 by J. Erichsen after compressing the coronary artery in an experimental dog. In 1850, it was experimentally obtained using "faradic current." In 1887, J. McWilliam showed that VF is accompanied by suppression of the left ventricle's ability to perform pump function. It is believed that the first ECG of VF in humans was published by A. Hoffmann in 1912. Ventricular tachycardia was described in 1862 by P. Panum, who obtained it experimentally by injecting oil into the coronary artery system, and in 1921 G. Robinson and G. Herrmann first published electrocardiographic registration of VT in a patient who had a myocardial infarction [1]. The underlying cause of ventricular fibrillation is the presence of multiple reentry foci in the myocardium with constantly changing pathways. This is due to the heterogeneity of the electrophysiological state of the myocardium, when its individual sections are simultaneously in different

time periods of depolarization and repolarization. Below are the nosological forms, the most frequent outcome of which is SCD. The vast majority of SCD cases are associated with coronary artery disease (80-85%), with more than half of them associated with acute coronary circulation disorders [46]. The absolute number of SCD cases, like those of coronary artery disease, is higher in men and increases with age, however, the proportion of SCD in the overall mortality structure is maximal in individuals aged 35-44 [13, 37, 47]. Upon pathoanatomical examination, the frequency of detection of fresh coronary thrombosis ranges from 50 to 75%. Rupture of the atherosclerotic plaque, which causes obstruction of the vessel, is found in a number of patients without thrombosis. Thus, in most patients with coronary artery disease, it is the acute obstruction of the coronary vessel lumen that is the triggering moment of the SCD. In other cases, SCD can be a result of functional electrophysiological instability, which can occur in the acute phase and persist for a long time after a myocardial infarction. Approximately 60% of patients who died from myocardial infarction died before being admitted to the hospital. According to literature data, in 25% of patients with coronary heart disease, sudden cardiac death appears as the first manifestation of this disease. The risk of SCD in patients after a myocardial infarction increases with low left ventricular ejection fraction and life-threatening ventricular arrhythmias, including VT and VF. The mechanism underlying VT and VF in patients with acute myocardial infarction is the reentry mechanism and increased automaticity of cardiomyocytes. It is important to note that the reentry mechanism plays a dominant role in the genesis of early arrhythmias, and increased automatism is the main etiological factor in the later stages of myocardial infarction [48]. The possibility of developing VF and other rhythm disturbances dependent on the reentry mechanism after the occurrence of myocardial ischemia is determined by several factors.

Thus, the local accumulation of hydrogen ions, an increase in the ratio of extracellular and intracellular potassium, and regional adrenergic stimulation shift diastolic transmembrane potentials to zero and can cause early post-depolarization, which is accompanied by the occurrence of life-threatening ventricular arrhythmias. Another mechanism involved in maintaining reentry in the early stages after ischemia is focal recurrent excitation. Anoxia leads to a shortening of the duration of the action potential. Accordingly, during electrical systole, repolarization of cells located in the ischemia zone can occur earlier than in adjacent intact tissue cells. The resulting difference between prevailing transmembrane potentials becomes the cause of unstable depolarization of neighboring cells and contributes to the appearance of rhythm disorders dependent on the reentry mechanism. In patients with severe myocardial ischemia, the duration of the vulnerability period corresponding to relative refractoriness, namely the descending knee of the T wave, is increased, and the intensity of the stimulus necessary for the occurrence of VT or VF is reduced. Asystole and deep bradycardia are less common electrophysiological mechanisms underlying coronary atherosclerosis-induced SCD. These can be manifestations of complete right coronary artery occlusion. Asystole and bradycardia are often the result of sinus arrest, atrioventricular block, and the inability of second and third-order pacemakers to function effectively.

Risk Stratification for Sudden Cardiac Death

Sudden cardiac death (SCD) is mainly observed in patients with various forms of coronary heart disease, including acute myocardial infarction. Population studies in several countries indicate that the risk factors for SCD are predominantly the same as for coronary artery disease: age, family history, high levels of low-density lipoproteins, male sex, hypertension, smoking, and diabetes mellitus. However, the relatively low predictive ability of these factors in assessing the risk of

major arrhythmic events encourages clinicians to search for more specific factors that could be used for risk stratification. Considering that the average SCD risk is 1 per 1000, finding effective strategies for accurate risk stratification becomes crucial. In recent years, cardiologists' views on risk factors and possible ways to prevent SCD have undergone significant changes. These changes are related to a number of randomized studies and, accordingly, to compliance with the international recommendations arising from these studies. This has led to a significant decrease in SCD cases when using implantable cardioverter defibrillators (ICDs). However, in many patients, ICDs do not activate, while most fatal arrhythmias are observed in patients who previously had no signs of heart disease and were not included in the high-risk group for SCD. The reason for such events is that the currently available tests and signs are unable to accurately predict the risk of SCD. Currently, the most widely used criterion for high-risk SCD stratification is a low left ventricular ejection fraction of 30% or less. Recently, great importance has been attached to the comprehensive study of criteria for compiling SCD risk stratification. These include: low ejection fraction, ectopic ventricular activity, heart rate variability, history of cardiac arrest, past myocardial infarction, and history of syncopal episodes.

Increased heart rate (HR) is an independent risk factor for sudden cardiac death (SCD) [19, 20]. The relationship between high HR and the risk of developing SCD is observed in individuals both with and without previously diagnosed heart disease, regardless of body mass index and physical activity level [19]. The reason for this relationship is not fully understood. One explanation is a decrease in parasympathetic nervous system activity. Studies of heart rate variability indicate that in the male population, the relative risk of overall mortality in middle-aged patients during 5 years of observation was 2.1 times higher (95% CI 1.4-3.0) in cases where the heart rate variability indicator was less than 20 ms,

compared to age-matched individuals with a heart rate variability value of 20-39 ms [22].

1.3 Pathogenetic and pathomorphological factors predisposing to the development of conduction disorders

According to some data, in patients with coronary heart disease, single ventricular extrasystoles (VES) of varying severity are registered in 90-99% of patients, with 1/3 of them having high-grade ventricular arrhythmias, while 2/3 of patients with VES have predominantly monomorphic complexes [57]. It is known that more severe changes in the myocardium are associated with polymorphic ectopic VES complexes (both single and paired), paroxysms of ventricular tachycardia, which were more often registered in patients who subsequently had fatal heart rhythm disorders. These observations are most reliable during the first year after myocardial infarction (MI). It is assumed that in patients who have had MI, the influence of asymptomatic ventricular arrhythmias on the prognosis weakens over time [37]. The mechanism of development of life-threatening arrhythmias against the background of acute myocardial ischemia has been described in sufficient detail to date, especially in cases of reperfusion development in the irreversibly ischemic myocardium, more pronounced in the borderline zone of MI, where conditions are created that provoke ventricular fibrillation (VF). This process also occurs due to the entry of biologically active substances accumulated there into the bloodstream from the ischemia zone, causing electrical instability of the myocardium (EIM) [58,59]. Such arrhythmogenic substances primarily include the products of cell membrane destruction: (lysophosphatidylcholine and lysophosphatidylethanolamine), free fatty acids (FA). Lysophosphoglycerides disrupt the structure of the cardiomyocyte

sarcolemma, which, under conditions of hypoxic ischemia, contributes to increased intake of calcium (Ca2+) ions into the cell, which, in turn, leads to the development of electrical inhomogeneity in the myocardium. Similar results were obtained when studying the mitochondria of patients with coronary heart disease who died suddenly [60]. In addition, cyclic adenosine monophosphate (cAMP), catecholamines (noradrenaline released from adrenergic nerve terminals), free radical lipid peroxidation compounds, and others are also considered arrhythmogenic substances. It was established that the higher the cAMP content in the myocardium, the higher the likelihood of developing VF in response to adrenaline stimulation. The increased concentration of cAMP also explains the excessive entry of Ca2+ ions into cardiomyocytes, increased glycogenolysis and lipolysis, with the subsequent formation of EIM [61]. Damage and subsequent destruction of cardiomyocytes leads to a disruption of their main properties and functions, namely, contraction, automaticity, conductivity, and excitability. Previously, it was believed that myocardial ischemic damage leads to either complete restoration of the myocardial structure and function - transient ischemia - or its necrosis - infarction. However, episodes of ischemic disruption of cardiomyocyte metabolism can sometimes lead to prolonged contractile dysfunction without developing myocardial necrosis. Thus, the concept of "stunned" myocardium was formed. In this state of cardiomyocytes, although the ischemic changes are reversible, the restoration of myocardial contractility occurs very slowly - from several hours to several weeks. This heterogeneity of the organic structure of cardiomyocytes determines the development of EIM. In prolonged ischemia with deep myocardial damage, i.e., with a classic MI course, arrhythmogenic substances cannot enter the bloodstream from the zone of forming coagulation necrosis and, accordingly, do not exert their pathogenic effect. If deep ischemia is interrupted by reperfusion

processes, conditions are created under which arrhythmogenic substances, entering the bloodstream from the ischemic myocardium, contribute to the destabilization of the cardiomyocyte membrane, which increases the risk of VF development. At the same time, ischemia in the heart muscle should be sufficiently deep and prolonged (i.e., irreversible) to exceed the permissible threshold for the accumulation of these arrhythmogenic molecules. This is partly reflected in the definition of sudden cardiac death (SCD), where the interval of heart attack duration within one hour is indicated - that is, the period of ischemia during which arrhythmogenic substances accumulate and cause damage to the cardiomyocyte membrane [62]. Thus, when describing the mechanisms of SCD pathogenesis, it is emphasized that it is reperfusion that contributes to the development of SCD. In another study, when observing patients after the restoration of coronary artery (CA) patency, either by percutaneous coronary intervention (PCI) or with thrombolytic therapy, it was concluded that reperfusion ventricular arrhythmias, which persist after complete reperfusion, indicate not only CA patency but also persisting myocardial ischemia at the cellular level. That is, ventricular arrhythmias (VA), previously known as reperfusion arrhythmias, may indicate myocardial damage and ongoing ischemia rather than vascular patency. To confirm this hypothesis, further large-scale prospective research is necessary [63]. A potential substrate of VA in patients who have had MI is the zone separating the necrotized and intact myocardium, where areas of fibrosis intersperse with viable tissue [64,65]. Such heterogeneity of the heart muscle leads to a slowdown in the spread of depolarization and refractoriness dispersion, creating conditions for the formation of re-entry loops, while, according to several authors, coronary blood flow disorders are not the cause of arrhythmia [52,66-68]. Several types of cardiac muscle fibrosis are distinguished: focal (patchy), interstitial, and diffuse, compact, which differ significantly

in their arrhythmogenic properties [69]. The difference in the severity of the arrhythmogenic potential of myocardial fibrosis is determined by two key factors in the mechanism of re-entry loop formation: delayed conduction and unidirectional conduction block. Arrhythmogenic foci most often form in the presence of focal and pronounced interstitial fibrosis. The areas of viable myocardium are separated from each other by collagen inclusions for a considerable distance, which leads to a slowdown, intermittent conduction, and a unidirectional block of intramyocardial conduction. In diffuse fibrosis, short areas of collagen inclusions intersperse with preserved myocardial fibers, which also causes a high risk of VA development. Uneven reduction of transverse gap junctions between cardiomyocytes leads to a slowdown in the spread of excitation, an increase in anisotropy, and the formation of an anisotropic re-entry loop. In the periinfarction zone of the myocardium, as a rule, focal, interstitial, and diffuse fibrosis are combined simultaneously. This creates conditions for the emergence of areas of the myocardium with slow conduction and the formation of a unidirectional excitation block. After MI, compact fibrosis is partially formed. It represents large, dense collagen foci that do not contain viable cardiomyocytes. It has been shown that macroscopic scars are not a source of slow conduction and do not increase the myocardial readiness for a unidirectional conduction block. Thus, compact fibrosis has the lowest arrhythmogenic potential. However, a re-entry loop caused by other reasons can become fixed if a large, non-excitable area is present in the myocardium. In another study, the authors found that in 1.2% of cases, patients with coronary heart disease may have ventricular tachycardia (VT), the focus of which is localized in a part of the myocardium not associated with either ischemia or post-infarction cardiosclerosis (PICS). It is also emphasized that patients with coronary heart disease have VTs originating from the left ventricle but having a

non-ischemic substrate. The presence of VT with focal localization in the basal sections suggests a potential non-ischemic perivascular substrate and a possible need for epicardial ablation of VT [70]. Arrhythmias located in the right ventricle (RV) deserve special attention; they are often considered either as a manifestation of RV structural pathology (for example, in arrhythmogenic RV dysplasia) or as idiopathic arrhythmias [71,72]. Only individual works illuminate the problem of right ventricular VA localization in patients with coronary artery disease. T. Yamada et al. demonstrated one case of a patient with a previous anteroseptal MI who underwent catheter ablation of VT with left bundle branch block morphology. After unsuccessful ablation of the focus in the left ventricle, catheter ablation from the RV eliminated the VT [76]. In another observation, it was shown that VT in patients with PICS typically involves the LV endocardium, and the involvement of the RV in the arrhythmogenic substrate is considered unusual, however, it occurs in 1.8% [77]. The authors specifically emphasize that cases with localized PICS in the left ventricle were selected. There are studies showing that a post-infarction scar can be the location of a VA focus in both the left and right ventricles [78]. A number of studies have shown that from 59% to 73% of monomorphic VT paroxysms are initiated by ventricular extrasystoles (VES), which precede VT paroxysms [79]. It was these VES that were registered first in the VT chain, which was more often observed in the presence of cicatricial changes in the patient. It is assumed that an important characteristic of VES initiating VT is the coupling interval and the prematurity index (the ratio of the coupling interval to the previous RR interval). It has been shown that VT often occurs after VES with a prematurity index of 0.56-0.89 [80,81]. In such cases, the VA focus is often located in the border zone between the scar tissue and the viable myocardium. It has been proven that, in addition to the macro-re-entry mechanism, changes in myocardial automaticity, as well as trigger

activity, can contribute to the development of VA. Such a mechanism has been described by several authors [82,83] for ventricular arrhythmias, which arise due to abnormal automatism induced by physical activity, and they have named them exercise-induced VA. According to other authors, signs of ventricular parasystole indicate the work of cells capable of spontaneous pathological depolarization [84-86]. Trigger activity caused by delayed afterdepolarizations is stimulated by increased heart rate and can occur in sinus tachycardia against the background of myocardial ischemia [87]. The theory that VA occurrence requires a combination of several factors predisposing to EIM is becoming increasingly widespread: the presence of a substrate (myocardial regions heterogeneous in their electrophysiological properties due to cicatricial changes, foci of hibernating myocardium, focal/diffuse cardiosclerosis) and a trigger factor (transient ischemia of the myocardium, acute/chronic stress, autonomic nervous system (ANS) dysfunction, etc.

1.4 Modern methods of diagnosing cardiac conduction disorders

The use of intracardiac catheters to assess the risk of life-threatening arrhythmias has been ongoing for about 40 years. In 1972, N. Wellens et al. discovered that ventricular tachycardia (VT) in patients with previous acute myocardial infarction (AMI) can be induced by programmed ventricular stimulation (PVS) [42]. This generated great interest in using this methodology. In the 1980s, many cardiologists regarded PVS as the most accurate method for determining the risk of sudden cardiac death (SCD) in patients. It was believed that the selection of antiarrhythmic therapy based on suppressing the inducibility of VT in laboratory settings represented a scientific approach to treating life-

threatening arrhythmias. Subsequent large-scale electrophysiological studies (EPS) led to the conclusion that the possibilities of using invasive EPS are limited; however, in many situations, it is still widely used for risk stratification. This article extensively covers the role of PVS in determining the risk of SCD in patients with previous AMI, as well as provides information regarding the use of PVS in other clinical conditions. Additionally, two invasive methods not related to PVS are described: measuring the H-V interval and inducing atrial fibrillation (AF) in patients with the syndrome.

Wolff-Parkinson-White syndrome, as it was occasionally used to identify potentially dangerous arrhythmias. Intracardiac electrophysiological study is an invasive examination that allows recording endocardial electrograms (EG) of various parts of the heart using special electrode catheters. Intracardiac EPS enables the assessment of excitation impulse conduction in various sections of the heart's conduction system. Invasive EPS is used to clarify the location of AV block, the nature of paroxysmal tachyarrhythmias, the source and mechanisms of ectopic rhythm disorders, and to determine the presence of abnormal conduction pathways. Intracardiac EPS of the heart is performed in the electrophysiology laboratory (catheterization lab). Assessment of the conduction interval is the determination of the time required for the spread of electrical activity in the studied area of the heart. The duration of the P wave, P-R interval, and QRS complex on a surface ECG can roughly indicate atrial, atrioventricular, and ventricular conduction. Using multiple electrodes and high-speed recording on a computer monitor allows for accurate measurement of various intracardiac conduction intervals. The P-A, A-H, H-V intervals and the His potential (H) are most often determined. Electrodes are inserted into the heart cavity under fluoroscopic guidance using the Seldinger technique, most commonly through the right and left femoral and subclavian veins.

A quadripolar electrode is placed in the upper parts of the right atrium, with the distal pair used for electrical stimulation and the proximal pair for recording the right atrial electrogram. The second tri- or quadripolar electrode is positioned near the septal leaflet of the tricuspid valve to record the His bundle (H) spike using the Scherlag method. The third quadripolar electrode is inserted into the right ventricular (RV) cavity to record the RV electrogram and perform electrical stimulation. The fourth multipolar electrode is introduced into the coronary sinus through the left subclavian vein for recording electrograms and electrical stimulation of the posterobasal sections of the left atrium and ventricle. Inter-electrode distances range from 0.5 to 5 mm. During EPS, the following parameters are determined: initial cycle length (CL), sinus node recovery time, corrected sinus node recovery time, sinoatrial conduction time, intra-atrial conduction time (P-A4), intranodal conduction time (A4-H), conduction time through the intraventricular His-Purkinje system (H-V), effective refractory period of the right atrium, antegrade and retrograde effective refractory periods of the AV junction, functional refractory period of the AV junction, and effective refractory period of the right ventricle [25]. The P-A4 interval reflects the conduction time from the sinus node to the basal sections of the interatrial septum, corresponding to internodal conduction time, and normally ranges from 9 to 45 ms. The P-A4 interval is measured from the beginning of the P wave on surface ECG leads to the onset of low atrial activity on the His bundle electrogram. The A4-H interval reflects intranodal conduction time, i.e., the conduction time through the lower part of the atria and the AV node, and according to various authors, normally ranges from 54 to 130 ms. It is measured on the His bundle electrogram from the beginning of low atrial activity (A spike) to the beginning of the His bundle spike on the electrogram, with the electrode positioned in the projection of Koch's triangle. The His potential, or H-potential, represents the conduction time

through the His bundle, and its duration ranges from 10 to 20 ms. The conduction time in the His-Purkinje system is characterized by the H-V interval, which normally remains constant regardless of the stimulation mode. Measurement is performed on the His bundle electrogram: from the beginning of the His spike (H) to the ventricular spike (V). Normally, this interval is between 30 and 55 ms. During right ventricular stimulation, the presence or absence of retrograde conduction to the atria (VA dissociation) is determined. If present, the VA interval is measured on the His bundle electrogram; this interval characterizes the time of ventriculoatrial conduction. Measurement is performed on the electrogram of the Giss bundle: from the beginning of the Giss bundle (H) to the ventricular bundle (V). Normally, this interval is between 30 and 55 ms. During stimulation of the right ventricle, the presence or absence of a retrograde conduction to the atria (VA-dissociation) is determined.

At the end of 2020 - beginning of 2021, new recommendations for the diagnosis and treatment of heart rhythm and conduction disorders will be released. Currently, the preparation of the following documents has been practically completed:

- "Atrial fibrillation and flutter";
- "Supraventricular tachycardias";
- "Ventricular rhythm disorders. Ventricular tachycardias and sudden cardiac death";
- "Bradyarrhythmias and conduction disorders."

It is evident that these recommendations differ significantly from those we were familiar with previously. At the core of each document are the familiar "thesis-recommendations." In some cases, they are accompanied by comments. The main difference in the new recommendations is that they will all become an official document of the Ministry of Health of the Russian Federation, mandatory for

implementation. A group of authoritative specialists worked on each of them; however, for the first time, the "rules of the game" were determined by the Federal State Budgetary Institution "Center for Expertise and Quality Control of Medical Care" (CEQCMC) of the Russian Ministry of Health. In particular, this institution proposed its newly developed recommendation classes and levels of evidence, significantly different from those familiar to us and adopted by the European Society of Cardiology (ESC). Therefore, before proceeding to discuss the substantive part and thesis-recommendations concerning Holter monitoring (HM) of the electrocardiogram (ECG), it is necessary to outline the principles for determining the levels of evidence reliability (LER) and the levels of recommendation persuasiveness (LRP) proposed by CEQCMC not only for cardiology but also for other medical specialties [1, 2]. Thus, LER is the degree of certainty that the observed effect from the application of a medical intervention is true. Let's take note of these new principles for forming recommendation classes and evidence levels without extensive discussion: this is not the purpose of this publication. We will only note that the working groups responsible for each of the discussed documents encountered great difficulties in trying to satisfy the CEQCMC requirements. As a single example directly related to the diagnosis of arrhythmias, consider the following. It would seem there is no doubt about the need to record an ECG during the restoration of sinus rhythm in patients with paroxysmal atrial fibrillation (AF) or ventricular tachycardia. However, we must agree that finding any systematic reviews of research on this topic, especially with control by a reference method, presents a very difficult task. And if that's the case, it's not surprising that in a number of instances, the LRP and LER

can be very low, including the lowest. However, each thesis-recommendation will conclude not only with "Russian" indicators but also, for reference, with the familiar classes of recommendations and

evidence levels from the ESC (European Society of Cardiology) where available. Let's sequentially examine the significance of Holter ECG monitoring in the diagnosis and treatment of cardiac rhythm and conduction disorders, considering that we are discussing near-final, but not yet definitive, versions of the recommendations.

One of the unresolved issues in modern Russian cardiology remains the high mortality rate due to cardiovascular diseases (614 per 100,000 inhabitants per year), which exceeds similar figures in Europe [1, 2]. Moreover, according to epidemiological data, there is a trend towards an increase in the number of sudden cardiac death (SCD) cases in Russia, including among young, working-age individuals [1-3]. It should be emphasized that it is necessary to differentiate SCD from sudden death resulting from massive pulmonary embolism, rupture of cerebral aneurysm, etc. [2]. This necessity is due, in particular, to significant differences in statistical data characterizing the prevalence of SCD in various studies and countries [1-5].

Meanwhile, according to the Federal State Statistics Service, in Russia in 2018, mortality from cardiovascular diseases (CVD) amounted to at least 290 per 100,000 population (accounting for half of all cardiac deaths) [2, 6]. Its leading development mechanism in young people is recognized as heart rhythm and conduction disorders, mainly ventricular tachyarrhythmias, which cause an acute cessation of effective cardiac activity [2]. At the same time, the most tragic cases are the first and only manifestations of sudden cardiac death (SCD) in children and young people without structural heart pathology, long before the first symptoms of the disease appear [2, 4, 5, 7]. Researchers' special attention is also drawn to heart rhythm and conduction disorders developing in childhood and young age against a background of undifferentiated connective tissue dysplasia (the prevalence of arrhythmic syndrome when conducting 24-hour ECG monitoring reaches

95%) [2, 8, 9]. Consequently, the study of the earliest genetic precursors of fatal arrhythmias for the purpose of timely preventive intervention remains relevant. Over the past 5 years, significant achievements have been noted in the field of genetic technologies and research focused on screening mutations in genes associated with CVD, especially those with a risk of fatal arrhythmias [10, 11]. Discoveries in the field of molecular diagnostics have made it possible to achieve significant successes in studying primary arrhythmic pathologies of the heart, congenital heart defects, and other organs, and to determine the mechanism of development of a number of cardiomyopathies [10-14]. At the same time, the severity of a particular type of arrhythmia largely depends on the degree of impairment of the mutant protein function encoded by the altered gene [10, 11, 14]. Thanks to next-generation sequencing technology (NGS), it has become possible to study many segments of deoxyribonucleic acid and identify mutations in genes responsible for high SCD risk [13-15]. To date, indications for genetic studies have been included in domestic and foreign clinical guidelines for ventricular arrhythmias and SCD, bradyarrhythmias, and conduction disorders, which emphasizes the importance of implementing a preventive strategy for high cardiovascular risk [2,16-18]. Genetic examination of autopsy material is indicated in all cases of SCD suspected of hereditary cardiovascular diseases [2,19, 20].

1.5 Innovative approaches to correcting conduction disorders

When choosing a method for treating ventricular arrhythmias (VA) and preventing sudden cardiac death (SCD), the nature of the rhythm disturbance, the presence of comorbidities that can contribute to the development of arrhythmia and worsen its course, the risk associated with arrhythmia, and the benefit-risk ratio of the therapy itself are taken into account. Treatment of arrhythmia after confirmation of the

diagnosis includes discontinuation of proarrhythmogenic drugs and prescription of appropriate antiarrhythmic therapy, use of implantable devices, ablation, and surgical intervention. Implantable cardioverter-defibrillators (ICDs) have been used in clinical practice for over 30 years. Initially, ICD implantation required open surgical intervention by thoracotomy with epicardial placement of electrodes. Currently, this implantation method is sometimes used, but most patients undergo transvenous placement of electrodes in the right chambers of the heart for stimulation (single-chamber or dual-chamber, with stimulation of one or two ventricles) and defibrillation, which is carried out through a coil electrode (s) in the cavity of the right heart chambers and/or the ICD case. The main clinical studies of ICDs were conducted using transvenous devices. Historically, the first defibrillators were implanted in individuals who had survived ventricular fibrillation or cardiac arrest. Further research has shown the benefits of using defibrillators in patients with a high risk of sudden death. ICD therapy allows for the prevention of sudden death and extends the life of patients in the high-risk group for SCD, provided there are no other diseases that limit life expectancy to less than 1-2 years [146]. Long-term studies have proven the effectiveness of ICDs [147] and biventricular pacemakers with cardioversion-defibrillation function (cardiac resynchronization therapy (CRT) -ICD) [148] with an average follow-up duration of 8 years and 7 years, respectively. Nevertheless, the use of defibrillators can lead to complications, including inappropriate shocks, which are especially common in children [149]. In a recent study of ICDs and CRT-ICDs, which included more than 3000 patients, the cumulative frequency of adverse events over 12 years of observation was assessed, where 20% (95% CI 18, 22) were inappropriate device activations, 6% (95% CI 5, 8) were infectious complications, and 17% (95% CI 14, 21) were lead-related issues [150]. Despite the established indications for the use of ICDs in

patients who have experienced myocardial infarction and have reduced ejection fraction, which are supported by a large volume of evidence, in some countries there is a clear gap between official recommendations and clinical practice. The widespread use of ICDs is limited due to the high base cost of the device.

Given the challenges in accessing the right heart chambers through the venous system and frequent issues with transvenous electrodes, subcutaneous defibrillators with an electrode system have been developed. These devices are implanted using only subcutaneous access, outside the thoracic cavity. The system comprises three components: an ICD housing, a distal defibrillation electrode, and a proximal electrode located approximately 8 cm from the lead tip. Between the lead tip and the proximal electrode, there is a coil electrode for defibrillation in relation to the defibrillator housing. The electrode is positioned so that the distal part of the lead is at the left edge of the sternum, while the device itself is placed in the fifth intercostal space between the left anterior and middle axillary lines. The exact configuration of sensing electrodes can be determined using a programmer. The defibrillator discharge energy is, in most cases, 80 J [159].

The subcutaneous cardioverter-defibrillator is not suitable for patients requiring anti-bradycardia pacing, except in cases where this pacing is only necessary in the post-shock period immediately after delivering the shock (subcutaneous devices can provide pacing for the first 30 seconds after shock delivery). Additionally, this type of therapy is not applicable for patients requiring permanent cardiac pacing, CRT, or for individuals with tachyarrhythmias who may need anti-tachycardia pacing to terminate the episode. The subcutaneous device is especially convenient in cases of difficult venous access, in young patients who will have to live with various devices for a long time, as well as in patients

with a high risk of bacteremia (for example, those with transvenous ICDs or immediately after their removal). In general, subcutaneous ICDs can be used for primary prevention of SCD, however, to date, there are no long-term prospective studies with a large sample of such patients, and the long-term effects of subcutaneous ICDs have not yet been described. Some studies have noted an increase in the frequency of inappropriate device activations and complications requiring repeated intervention [160]. It is not entirely clear what these results were related to: insufficient awareness or the presence of factors that increase the risk of unjustified ICD activations in specific patient groups. Recently, the results of a meta-analysis involving 852 patients were published, where no lead malfunctions were recorded and only three patients required cardioverter-defibrillator replacement due to the need for RV pacing, while inappropriate pacing was noted in less than 5% of patients in the last enrolled quartile [166]. Currently, prospective randomized studies are ongoing, comparing the effectiveness and frequency of complications for subcutaneous ICDs and standard ICDs [158].

The use of external wearable cardioverter defibrillators (WCDs) with electrodes attached to the patient's body has proven effective in recognizing and treating life-threatening arrhythmias such as ventricular tachycardia (VT) and ventricular fibrillation (VF) [168]. Currently, there are no prospective randomized studies, but numerous individual clinical cases have been published, along with observational series and registry data (both manufacturer-initiated and independent), which demonstrate the successful use of WCDs in a relatively small cohort of patients at risk of developing potentially life-threatening ventricular arrhythmias. In their study, Chung et al. [169] observed 80 episodes of sustained VT or VF in 59 out of 3,569 patients (1.7%) with WCDs. The first device activation with shock delivery was successful in 100% of cases in patients with VT or VF accompanied by loss of consciousness, and in 99% of cases for all

types of VT or VF. Subsequently, Epstein et al. [170] demonstrated the effectiveness of subcutaneous ICDs in 133 out of 8,453 patients (1.6%), delivering 309 appropriate shocks, while 91% were resuscitated after ventricular arrhythmias. Thus, it is evident that WCDs can save the lives of high-risk patients; however, their effectiveness has not been fully confirmed. In patients with transient left ventricular ejection fraction (LVEF) deterioration, WCDs can be used before LV function is restored, for example, after myocardial infarction, in peripartum cardiomyopathy, after myocarditis, or following certain interventions, including myocardial revascularization, which are accompanied by temporary LV dysfunction [171]. It is also possible to temporarily use WCDs for preventive purposes in patients with a high risk or history of life-threatening ventricular arrhythmias, or as an intermediate measure for patients awaiting heart transplantation [172].

Catheter ablation is of great importance in the treatment of ventricular tachycardia (VT) or ventricular fibrillation (VF) in the context of myocardial scarring. According to two prospective randomized multicenter studies on patients with coronary artery disease, catheter ablation for VT reduces the likelihood of subsequent ICD shocks and prevents recurrent VT episodes [187, 188]. Catheter ablation is often used to eliminate incessant VT or electrical storm (repeated VT/VF episodes with frequent appropriate ICD shocks) and to reduce the frequency or prevent recurrence of sustained VT episodes [183, 184, 187, 188]. ICD therapy effectively terminates VT in patients with ischemic and non-ischemic cardiomyopathy but cannot prevent recurrent episodes of arrhythmia. According to research data, frequent ICD shocks are associated with high mortality and deterioration of quality of life [189, 190]. Treatment with beta-blockers in combination with amiodarone reduces the number of ICD activations, but side effects may potentially require discontinuation of the drugs [156]. Typically, the substrate for VT

is scar tissue [191]. The aim of catheter ablation in this case is to target the slow conduction isthmus (critical point) in the VT re-entry circuit. The re-entry circuit can span several centimeters involving the endocardium, myocardium, and epicardium and have a complex three-dimensional structure [192,193]. Substrate-associated VT is typically monomorphic, and several types of VT morphology can be induced in a single patient. The QRS morphology depends on the exit point, where re-entry waves leave the scar zone and depolarize the ventricular myocardium. Analysis of a surface ECG with episodes of clinically significant VT can be helpful during mapping and ablation procedures. In the case of non-ischemic cardiomyopathy, the QRS morphology allows for the identification of patients who will most likely require epicardial ablation [194-197]. Performing cardiac MRI before the ablation procedure provides a non-invasive assessment of the arrhythmogenic substrate in patients with a history of myocardial infarction [198] and in patients with epicardial VT [199]. Polymorphic VT is characterized by constantly changing QRS morphology, often in combination with acute myocardial ischemia, acquired or hereditary channelopathies, or ventricular hypertrophy. In some such patients who do not respond to drug therapy, polymorphic VT with a trigger in the Purkinje system can be eliminated by catheter ablation [200, 201].

A non-invasive examination of the heart structure, preferably performed by MRI, can be used for planning and guiding ablation procedures for ventricular tachycardia (VT) [198]. Mapping and ablation can be performed during ongoing VT (activation mapping). The three-dimensional electroanatomical mapping system allows for localizing pathological scar changes in the myocardium and performing catheter ablation during sinus rhythm (substrate ablation) without
VT induction, which may be accompanied by hemodynamic disturbances. In patients with VT and unstable hemodynamics, a non-contact mapping

system can be used. There are several techniques, including point ablation in the area of excitation exit from the re-entry circuit (dechanelling of scar tissue), linear lesions, or ablation in the area of pathological myocardial activity to homogenize the scar [202-205]. Mapping and ablation of VT through epicardial access are most commonly performed in patients with DCM [206] or ARVC [207]. Potential complications of the procedure include coronary artery damage or accidental puncture of adjacent organs, paralysis of the left phrenic nerve, and serious bleeding followed by cardiac tamponade. Patients with post-infarction VTs have a more favorable prognosis after catheter ablation compared to rhythm disturbances in non-ischemic cardiomyopathies [208]. The role of the procedure in treating sustained VT was assessed within the framework of five prospective multicenter studies [184-188]. Almost half of the patients had favorable outcomes (i.e., the absence of clinical recurrences of VT during the observation period), while catheter ablation was more effective than antiarrhythmic drugs. The success of VT catheter ablation in each specific case depends on the size of the post-infarction scar, which can be assessed by analyzing low-amplitude signal areas during electroanatomical mapping [209]. Also, the outcome of the procedure depends on the level and preparation of the center [210] and the team's experience. It should be noted that in literature, all publications on this topic belong to specialized centers.

Complications of catheter ablation in patients with ventricular tachycardia (VT) and heart disease may include stroke, heart valve damage, cardiac tamponade, or development of AV block. The mortality associated with the procedure ranges from 0% to 3% and is most often due to the presence of uncontrolled VT in case of an unsuccessful procedure [183-185, 187, 211]. Catheter ablation is considered a widely recognized method for eliminating various VT substrates; however,

currently, there is insufficient data from prospective randomized studies confirming a decrease in mortality after the procedure in this group of patients.

In the era of widespread use of catheter ablation in patients with rhythm disturbances, surgical treatment of ventricular tachycardia (VT) is becoming increasingly rare. The first description of surgery to remove a left ventricular aneurysm appeared more than 50 years ago. Large aneurysms are often accompanied by the development of rhythm disturbances, and aneurysm resection, taking into account the mapping data, not only contributes to the improvement of left ventricular (LV) function but also allows for the elimination of ventricular arrhythmias (VA). Subendocardial resection to eliminate ventricular tachyarrhythmias was first described by Josephson et al. [218]. However, this procedure was accompanied by a large number of complications and high mortality rates (10%) and therefore was performed only in specialized centers [212-214, 216-219]. Nevertheless, the intervention was characterized by good long-term results. According to various authors, after subtotal endocardectomy and cryoablation of VT, recurrence of arrhythmia is observed in 10-20% of patients, mainly within the first 90 days after the intervention [213]. Therefore, patients with inducible VT after surgery are indicated for implantable cardioverter-defibrillator (ICD) installation in the early period [213, 215, 220, 221]. The main principles of surgical ablation laid the foundation for catheter ablation techniques, including a relatively new substrate delimitation technique [222].

Surgical ablation should only be performed in specialized centers with mandatory electrophysiological mapping before and after surgery. Performing surgical ablation in a specialized center may be advisable for patients with refractory ventricular tachycardia who do not respond to antiarrhythmic drug therapy and/or in cases of unsuccessful catheter ablation, especially if there is a left ventricular aneurysm after myocardial

infarction and revascularization is necessary [216-219].

CHAPTER 2. RESEARCH MATERIALS AND METHODS

§2.1. Research Methods

All patients underwent a comprehensive examination (Figure 2.1) which included the following studies:

1. general clinical examination: interview (complaints, medical history), physical examination;
2. instrumental examination (ECG, echocardiography, Holter monitoring, coronary angiography);
3. biochemical blood test (determination of the levels of creatinine, urea, residual nitrogen, HDL, LDL, total cholesterol, triglycerides, etc.);

§2.2. Clinical characteristics of patients with heart rhythm disorders

✔ At the Samarkand Branch of the Republican Scientific and Practical Center of Cardiology (SF RSPCC), 124 patients with coronary heart disease (CHD) and various heart rhythm conduction disorders were selected for the rhythm disorder department. Additionally, 40 patients with CHD without heart rhythm disturbances were included as a comparable group. This study was conducted over three years (2024-2026). The average age of the patients was 58.7±11.74. There were 68 (54.8%) men and 56 (45.2%) women. Individuals for the control group were selected based on clinical and biochemical blood tests, which determined the lipid profile (cholesterol levels, LDL, HDL), kidney and liver function, as well as ECG, echocardiography, 24-hour Holter heart rhythm monitoring, and treadmill tests. The groups were comparable in age and gender.

✔*Inclusion criteria:*

✔ Diagnosis of cardiac conduction disorders:

- Blockage of varying degrees (right/left bundle branch block, AV block).
- Sick sinus syndrome, where abnormalities in the normal functioning of the sinus node result in slowing or impairment of heart rhythm.
- Atrial fibrillation, which can also be associated with conduction disorders, especially in the presence of other heart diseases.

o These conditions are associated with disruption of normal electrical impulse conduction in the heart, which increases the risk of developing cardiovascular diseases.

✔ Patients' age:

o 18 years and older. This is because the study focuses on adult patients. In children and adolescents, cardiac conduction abnormalities and associated cardiovascular diseases are rare, and their developmental mechanisms may differ from those observed in adults.

✔ Presence of cardiovascular diseases or risk factors:

o Patients must have at least one of the factors that increase the risk of developing cardiovascular diseases, such as:

- Hypertension (high blood pressure is a risk factor for most cardiovascular diseases).
- Diabetes (especially type 2 diabetes, which can contribute to the development of atherosclerosis and other cardiovascular diseases).
- Hyperlipidemia (elevated blood cholesterol levels associated with the risk of atherosclerosis).
- Obesity (a risk factor leading to the development of hypertension, diabetes, and other diseases).

o These factors will be crucial for predicting cardiovascular diseases in the context of conduction disorders.

✔ Presence of functional disorders of the cardiovascular system:

o Patients must have at least one of the following diseases or

conditions related to heart function:

▪ Angina pectoris (a condition in which chest pain occurs due to insufficient oxygen supply to the heart).

▪ Heart failure (a condition in which the heart cannot pump blood effectively).

▪ History of myocardial infarction (a previous heart attack can affect cardiac conduction and create a predisposition to further disorders).

✔ Patient's consent to participate in the study:

o All patients must provide informed consent to participate in the study. This is a crucial ethical aspect that ensures patients understand the research objectives and potential risks, and have the right to withdraw from participation at any time.

✔*Exclusion criteria:*

✔ Absence of cardiac conduction disorders:

✔ Severe comorbidities:

o Patients with terminal cancer, progressive liver or kidney diseases (e.g., end-stage renal failure) may have serious comorbidities that could interfere with the interpretation of research findings, as their condition can significantly distort the presentation of cardiovascular diseases and conduction disorders.

✔ Acute cardiovascular pathology:

o Patients who have experienced an acute myocardial infarction, acute cerebrovascular event (stroke), or other acute conditions related to cardiovascular diseases require immediate treatment.

o Acute arrhythmias may also require immediate intervention.

✔ Mental disorders affecting the ability to provide informed consent:

o Patients with mental disorders that impair their ability to understand the research objectives and provide informed consent cannot be included in the study. This is an important ethical consideration for

protecting patient rights.

✔ Pregnancy:

✔ Patients unable to meet the study requirements:

o This may include patients who cannot complete all necessary examination stages, for example, due to physical limitations (weakness, mobility impairments) or intellectual problems that interfere with performing tests and analyzing data. For instance, if a patient cannot endure prolonged examinations or cannot respond to questionnaires.

Table 2.1.

Clinical characteristics of the studied patients with heart rhythm disorders

Characteristic	Patients with CAD + HD, n= 124	Patients with CAD without HD, n=40	P-value
Age, years	58.7±11.74	57.9±11.58	0.78
M/F, n	68 (54.8%) /56 (45.2%)	22 (55.0%) /18 (45.0%)	0.62
Hypertension, n (%)	92 (74.1%)	28 (70.0%)	0.063
Metabolic syndrome	32 (25.8%)	9 (22.5%)	0.08
Diabetes mellitus, n (%)	26 (20.9%)	8 (20.0%)	0.92
History of MI, n (%)	24 (19.35%)	9 (22.5%)	0.079
LVEF, %	55.2±11.04	57.4±11.48	0.057
Heart rate, bpm	78.3±15.66	82.4±16.48	0.001
CHF 0 FC 0, n (%)	32 (25.8%)	6 (15.0%)	0.001
CHF I FC I, n (%)	28 (22.5%)	5 (12.5%)	0.001
CHF II A stage FC II, n (%)	24 (19.35%)	4 (10.0%)	0.001

CHF II B stage FC III, n (%)	18 (14.5%)	3 3 (7.5%)	0.001

The average age of patients with coronary artery disease (CAD) + HR is 58.7 years (with a deviation of 11.74 years), and in patients with CAD without HR - 57.9 years (with a deviation of 11.58 years). In the group with CAD and HR, there are 68 (54.8%) men and 56 (45.2%) women. In the group with CAD without HR, there are 22 men (55%) and 18 women (45%). In the group with CAD + HR, 92 patients (74.1%) have hypertension, in the group with CAD without HR - 28 patients (70%). In the group with CAD + HR, 26 patients (20.9%) suffer from diabetes mellitus, and in the group with CAD without HR - 8 patients (20%).

In the group with CAD + HR, 24 patients (19.35%) had a history of myocardial infarction, in the group with CAD without HR - 9 patients (22.5%). The average LVEF value in the group with CAD + HR is 55.2% (with a deviation of 11.04%), and in the group without HR - 57.4% (with a deviation of 11.48%). Heart rate (HR), beats/min: The average HR in the group with CAD + HR is 78.3 beats/min (with a deviation of 15.66), in the group with CAD without HR - 82.4 beats/min (with a deviation of 16.48).

1. Chronic heart failure (CHF) and functional classes (FC):

- CHF 0 FC 0: In the group with CAD + HR, 32 patients (25.8%) have CHF 0 degree (FC 0), in the group with CAD without HR - 6 patients (15%).
- CHF I FC I: In the group with CAD + HR, 28 patients (22.5%) have CHF 1 degree (FC I), in the group with CAD without HR - 5 patients (12.5%).
- CHF II A st. FC II: In the group with CAD + HR, 24 patients (19.35%) have CHF 2A degree (FC II), in the group with CAD without HR - 4 patients (10%).
- CHF II B stage, FC III: In the group with IHD + CD, 18 patients (14.5%) have CHF stage 2B (FC III), in the group with IHD without CD - 3 patients (7.5%).

Thus, Table 2.1 allows us to compare two groups of patients with IHD with CD and without CD, where it can be seen that among patients with IHD and CD, conditions such as hypertension and metabolic syndrome are more common, and in the main group of patients, signs of CHF were significantly more frequent (p≥0.01).

Table 2.2.

Drug therapy in patients with IHD+CD

Medications	Patients with IHD+CD, n=124
ACE inhibitors/ARBs, n (%)	84 (67.7%)
Beta-blockers, n (%)	57 (45.9%)
Calcium channel blockers, n (%)	68 (54.8%)
HMG-CoA reductase inhibitors, n (%)	76 (61.3%)
Acetylsalicylic acid, n (%)	83 (66.7%)
Clopidogrel, n (%)	41 (33.0%)
Vitamin K antagonists and oral anticoagulants, n (%)	67 (54.0%)
Dual antiplatelet therapy	44 (35.5%)
Triple antiplatelet therapy	32 (25.8%)
Mineralocorticoid receptor antagonists, n (%)	76 (61.3%)
Loop diuretics, n (%)	42 (33.8%)
Class Ic antiarrhythmics	28 (22.5%)
Class III antiarrhythmics	46 (37.1%)

Table 2.2 presents information on the use of various medications in patients with coronary heart disease (CHD) and cardiac arrhythmia (CA) in a group of 124 people. ACE inhibitors/ARBs, n (%) - angiotensin-converting enzyme inhibitors (ACE inhibitors) or angiotensin receptor blockers (ARBs); 67.7% of patients were taking these drugs, 45.9% of

patients were receiving beta-blockers, 54.8% of patients were using calcium channel blockers, 61.3% of patients were taking HMG-CoA reductase inhibitors (statins), 66.7% of patients were taking acetylsalicylic acid (aspirin), 33% of patients were using clopidogrel, 54% of patients were taking anticoagulants, 35.5% of patients were on dual antiplatelet therapy, 25.8% of patients were receiving triple antithrombotic therapy, 61.3% of patients were taking mineralocorticoid receptor antagonists, 33.8% of patients were using loop diuretics, 22.5% of patients were taking class Ic antiarrhythmic drugs, 37.1% of patients were using class III antiarrhythmic drugs.

Table 2.3.

Frequency of cardiac arrhythmias in patients with coronary heart disease, n=124

Characteristic	Number (n)	Percentage (%)
Grade I sinoatrial block (SAB), n (%)	14	11.3%
Grade II SAB, n (%)	10	8.1%
Grade III SAB, n (%)	6	4.8%
Atrioventricular blocks (AV blocks) n (%)	26	21.0%
First-degree n (%)	14	11.3%
Second-degree (Mobitz type I, Mobitz type II) n (%)	8	6.5%
Third-degree (complete AV block) n (%)	4	3.2%
Bundle branch block n (%)	52	41.9%
Left bundle branch block (complete/incomplete) n (%)	12/14	9.7% / 11.3%
Right bundle branch block (complete/incomplete) n (%)	14/12	11.3% / 9.7%
Sick sinus syndrome n (%)	16	12.9%

Table 2.3 presents the prevalence characteristics of various cardiovascular diseases and conditions in a group of patients (a total of

124 people). It includes the number of patients and the percentage of each condition relative to the total number. First-degree AV block was detected in 14 patients (11.3% of the total), second-degree AV block in 10 patients (8.1% of the total), and third-degree AV block in 6 patients (4.8% of the total). Atrioventricular blocks were detected in 26 patients (21.0%): first-degree in 14 patients (11.3%), second-degree (Mobitz type I and Mobitz type II) in 8 patients (6.5%), and third-degree (complete AV block) in 4 patients (3.2%). Bundle branch blocks occurred in 52 patients (41.9%): left bundle branch block (complete/incomplete): 12 patients with complete block (9.7%) and 14 patients with incomplete block (11.3%); right bundle branch block (complete/incomplete): 14 patients with complete block (11.3%) and 12 patients with incomplete block (9.7%).

- In total, 41.9% of patients have a bundle branch block.

Sick sinus syndrome was noted in 16 patients (12.9%).

Thus, bundle branch blocks (41.9%) and atrioventricular blocks (21.0%) were the most common.

§2.3.1. Electrocardiographic examination

Electrocardiographic examination (ECG) is a "screening" instrumental study of coronary pathology that provides information about electrophysiological processes in the myocardium. During this examination, signs of myocardial ischemia can be identified, rhythm and conduction disorders can be recorded, and indicators of arterial hypertension and heart failure can be noted.

The ECG study was conducted according to the generally accepted methodology, with recordings taken in 12 standard leads using the COMEN device (China, 2023).

2.1. COMEN Electrocardiography Device (China, 2023).

ECG registration was mandatory for all patients immediately upon admission, before coronary angiography, before discharge, and as needed.

For an accurate diagnosis, particularly in detecting arrhythmias and identifying episodes of asymptomatic ischemia, 24-hour ECG monitoring was performed using the LEPU MEDICAL (China) ECG system. Holter monitoring is a method of long-term observation of a patient's electrocardiographic parameters (ECG) over 24 hours or longer to detect heart rhythm disturbances that may not be recorded on a standard resting ECG. This method allows for extended monitoring of heart rhythm, which is crucial for diagnosing disorders such as arrhythmias, extrasystoles, atrial fibrillation, and others.

For our research, we used the LEPU MEDICAL (China) Holter

monitor, manufactured in 2023.

Figure 2.1. Holter monitor

Methodology for conducting Holter monitoring

1. Patient Preparation Before initiating the procedure, the patient should be informed about the monitoring process, as well as possible sensations and actions during the procedure.

1. **Patient Instruction**: The purpose of the study is explained, along with the need to maintain a normal lifestyle during the monitoring period. The patient is advised to record their sensations and symptoms, such as chest pain, shortness of breath, or dizziness, as well as the time of these sensations.

2. **Skin preparation**: For quality attachment of electrodes to the skin, it must be clean and dry. In areas where electrodes will be placed, it is recommended to lightly shave hair (if necessary) to ensure good contact.

3. **Attaching electrodes**: Electrodes are attached to the patient's chest to record the electrical activity of the heart. Usually, 5-7 electrodes are used (depending on the model of the device), which are connected to a small device - an ECG recorder. Electrodes are adhered to the skin in areas

where heart activity is most clearly detected (usually around the heart and along the ribs).

4. **Recorder installation**: After attaching the electrodes, the recorder is secured to the patient's body, most often around the waist or shoulder area. This device must be worn throughout the entire monitoring period, usually 24 or 48 hours.

5. **Symptom recording**: The patient is provided with a special diary in which they must record all significant events (e.g., chest pain, dizziness, physical activity, etc.), so that symptoms can later be correlated with changes on the ECG.

2. Monitoring process

1. **Duration**: Typically, Holter monitoring is conducted for 24-48 hours, but in some cases, the monitoring period can be extended up to 7 days, depending on the clinical situation.

2. **Patient's daily activities**: The patient should maintain their normal lifestyle without restricting their activity, unless specific medical recommendations state otherwise. It is important that the patient does not subject the device to mechanical damage (not get it wet or hit it). For routine activities (such as taking a shower), protective covers are used to prevent damaging the device.

3. **Monitoring of results**: Throughout the monitoring period, the patient should continue to maintain a diary, recording moments when symptoms occur, such as chest pain, arrhythmias, rapid heartbeat, as well as physical activity, stress, or medication intake.

3. Data processing and interpretation

1. **Completion of monitoring**: After the specified time period, the Holter monitor is removed from the patient, and all data collected during this period is transferred to computers for analysis.

2. **ECG Analysis**: Computer software analyzes the obtained data to detect episodes of heart rhythm disturbances, premature beats,

tachycardia, bradycardia, atrial fibrillation, and other abnormalities.

3. **Patient's Diary**: The patient's diary data is used to correlate symptoms with ECG events. This allows the doctor to determine which symptoms may be associated with rhythm disturbances and assess the clinical significance of these events.

4. **Results Evaluation**: The doctor interprets the monitoring results, assesses the frequency and duration of arrhythmias, and analyzes their relationship with physical activity, emotional state, and other factors.

After completing the data analysis and interpretation, the patient is provided with a conclusion indicating whether heart rhythm disturbances were detected, their type, frequency, duration, and clinical significance. Based on this conclusion, the doctor can make decisions regarding further diagnosis or treatment of the patient.

§2.3.2. Echocardiographic examination

Echocardiography was performed on a Mindray machine in accordance with the recommendations of the American Society of Echocardiography in M-mode and B-mode. In M-mode, measurements were conducted through parasternal access along the left ventricular axis, in accordance with the Penn Convention Method. We studied the following parameters of intracardiac hemodynamics: left ventricular end-diastolic diameter (LVEDD) and end-systolic diameter (LVESD), interventricular septal thickness (IVS) and left ventricular posterior wall thickness (LVPW) in diastole. End-diastolic volume (EDV) and end-systolic volume (ESV) were calculated using the Teichholz L.E. et al. formula:

$V=D^3 \times 7/ (2.4+D)$,

where V is the volume (EDV or ESV) of the left ventricle,

D is the LV size (end-diastolic or end-systolic).

Left ventricular ejection fraction (LVEF) was assessed using the formula:

EF = (EDV-ESV) /EDV x 100%,

Where: EF - ejection fraction, %;

EDV - end-diastolic volume of the left ventricle, ml;

ESV - end-systolic volume of the left ventricle, ml.

The sizes of the aortic root (in mm) and the left atrium (in mm) were measured. Left ventricular mass (LVM) (in g) was calculated using the Devereux R.B. et al. formula:

LVM = 1.04 x [(LVEDD+IVS+LVPW) 3 - LVEDD3] - 13.6 (in grams),

Also, areas of dyskinesia and akinesia, myocardial hypertrophy, interventricular septal thickening, papillary muscle dysfunction, mitral valve prolapse, and the presence of additional chords and thrombi in the left ventricular cavity were noted. The presence of left ventricular hypertrophy (LVH) was diagnosed with left ventricular mass index (LVMI) >115 g/m2 for men and >95 g/m2 for women.

§2.4. Evaluation of biochemical indicators

Laboratory research was conducted at the Republican Specialized Scientific and Practical Medical Center of Cardiology (RSSPMCC) in the laboratory department. Laboratory examination included:

- Complete blood count,
- Urinalysis,
- Detection of microalbuminuria,
- Biochemical studies:

Liver function tests (bilirubin fractions, transaminases, creatinine, urea, residual nitrogen);

- Lipid profile (total cholesterol, LDL cholesterol, HDL cholesterol, triglycerides);

- Measure blood glucose, glycated hemoglobin (for diabetics),

- Biological markers of myocardial necrosis (quantitative determination of creatine phosphokinase, MB fraction, troponin I),

- Determination of coagulation profile

- Plasma electrolytes

- Uric acid.

The levels of liver transaminases - ALT and AST - in blood serum were determined by the Reitman-Frankel method using an automated biochemical analyzer.

The creatinine content in blood serum was determined by the enzymatic colorimetric method on a biochemical analyzer. The content of total and direct bilirubin in blood serum was determined on a biochemical analyzer using the Malloy-Evelyn method. Determination of lipid profile. When studying the blood lipid profile, the following were determined: total cholesterol, triglycerides, HDL cholesterol, VLDL cholesterol, LDL cholesterol, and atherogenic coefficient. Blood samples were collected the day after patients were admitted to the hospital in the morning hours, after 12 hours of fasting, from the cubital vein, with the patient in a horizontal position. Blood lipid profile was determined using a Mindray (China) biochemical analyzer with reagents from Vector-Best JSC (Russia).

LDL cholesterol concentration was determined using the Friedewald formula:

LDL-C = TC - HDL-C - TG/5,

Where LDL-C is low-density lipoprotein cholesterol (in mg/dL),

TC - total cholesterol,

HDL-C - high-density lipoprotein cholesterol,

TG - triglycerides.

The atherogenicity coefficient (AC) was determined using the formula:

AC = (TC - HDL-C) / (HDL-C),

Where AC is the atherogenicity coefficient (in relative units),

TC - total cholesterol,

HDL-C - high-density lipoprotein cholesterol.

The normal range was considered to be: TC < 180 mg/dL, HDL-C > 40 mg/dL, TG < 200 mg/dL in blood serum.

§2.5. Statistical processing of results

The results of the conducted research were analyzed using methods of variational statistics. The following main indicators were determined: arithmetic mean (M), standard deviation (σ), standard error of the mean (m), and the frequency of positive results. Statistical processing of the results was performed using the "Statistica 6.0" and "Microsoft Excel - Statistics" software packages. The normality of distribution for quantitative traits was verified using the Shapiro-Wilk test. In cases where the distribution of measured quantities could be considered normal, Student's t-test was applied. For pairwise comparisons of indicators within groups on the first and subsequent (10th and 21st) days, the paired Student's t-test was used. For characteristics that did not meet the requirements of normal distribution, the nonparametric Mann-Whitney U-test for independent samples and the Wilcoxon signed-rank test for paired samples were employed. Correlation analysis of quantitative values was conducted by calculating Pearson's correlation coefficient. If it was not possible to establish normal distribution for at least one of the compared indicators, Spearman's correlation coefficient was used instead. The strength of correlation was considered very weak at r = 0-0.2, weak at r = 0.2-0.29, moderate at r = 0.3-0.49, strong at r = 0.5-0.69, and very strong at r = 0.7-1. Analysis of the significance of differences in relative values was carried out using the $\chi 2$ test. Differences were considered highly significant at $p<0.01$ and significant at $p<0.05$.

CHAPTER 3. CLINICAL AND HEMODYNAMIC FEATURES OF CARDIAC

CONDUCTION DISORDERS IN PATIENTS WITH ISCHEMIC HEART DISEASE

§ 3.1. Clinical characteristics of patients with various cardiac conduction disorders

The study included 124 patients with ischemic heart disease (IHD) and cardiac conduction disorders (CD) and 40 patients with IHD without CD (control group). The average age of patients with IHD + CD was 58.7 ± 11.74 years, without CD - 57.9 ± 11.58 years. Men constituted 54.8%, women 45.2%. The duration of the disease ranged from 2 to 15 years, with an average of 7.4 ± 2.6 years.

Most patients had arterial hypertension (74.1%), metabolic syndrome (25.8%), type 2 diabetes mellitus (20.9%), and 19.3% had a history of myocardial infarction. In patients with IHD and CD, manifestations of chronic heart failure were more frequently registered (CHF stages II A and II B - 33.8%), while in the control group, their frequency did not exceed 17.5% ($p < 0.01$).

Table 3.1.

Clinical characteristics of patients with IHD depending on the presence of cardiac conduction disorders

Indicator	IHD + CD (n = 124)	IHD without CD (n = 40)	p
Age, years	58.7 ± 11.74	57.9 ± 11.58	0.78
Men/Women (n, %)	68 (54.8) / 56 (45.2)	22 (55.0) / 18 (45.0)	0.62
Arterial hypertension (n, %)	92 (74.1)	28 (70.0)	0.06
Metabolic syndrome (n, %)	32 (25.8)	9 (22.5)	0.08
Diabetes mellitus (n,	26 (20.9)	8 (20.0)	0.92

%)			
History of MI (n, %)	24 (19.3)	9 (22.5)	0.08
LVEF, %	55.2 ± 11.0	57.4 ± 11.5	0.06
Heart rate, beats/min	78.3 ± 15.7	82.4 ± 16.5	0.001
CHF 0 FC 0, n (%)	32 (25.8)	6 (15.0)	0.001
CHF I FC I, n (%)	28 (22.5)	5 (12.5)	0.001
CHF II A FC II, n (%)	24 (19.3)	4 (10.0)	0.001
CHF II B FC III, n (%)	18 (14.5)	3 (7.5)	0.001

The table presents the main clinical and demographic characteristics of patients with coronary heart disease (CHD) depending on the presence of cardiac conduction disorders (CCD). Analysis showed that both groups were comparable in age, gender, and frequency of the main associated risk factors; however, the presence of conduction disorders had a pronounced effect on the clinical course and functional state of the cardiovascular system.

The mean age of patients in both groups was practically identical (58.7 ± 11.74 years versus 57.9 ± 11.58 years; p = 0.78), which indicates correct age-related stratification of the sample. The sex composition was also identical: among patients with conduction disorders, men constituted 54.8%, women - 45.2%, which is comparable to the control group (55.0% and 45.0%, respectively; p = 0.62).

Among comorbid conditions, arterial hypertension was most common, diagnosed in 74.1% of patients with CCD and in 70.0% without disorders, with statistically insignificant differences (p = 0.06). A similar trend was observed for metabolic syndrome (25.8% versus 22.5%) and

type 2 diabetes mellitus (20.9% versus 20.0%), reflecting a similar metabolic profile in both groups.

Meanwhile, the presence of cardiac conduction disorders was associated with a more severe functional state of the myocardium. Although the mean values of left ventricular ejection fraction (LVEF) did not differ statistically between the groups (55.2±11.0% versus 57.4±11.5%; p=0.06), there was a clear tendency towards decreased contractile function in conduction disorders. Such patients also exhibited lower heart rates (HR) - 78.3 ± 15.7 beats/min versus 82.4 ± 16.5 beats/min (p = 0.001), which is likely related to areas of delayed conduction and reduced automaticity.

The most significant differences pertained to the severity of chronic heart failure (CHF). Among patients with conduction disorders, the proportion of individuals with CHF functional class I-IIB was significantly higher than among patients without conduction disorders:
CHF functional class 0 was observed in 25.8% versus 15.0% (p = 0.001);
CHF functional class I - in 22.5% versus 12.5% (p = 0.001);
CHF functional class IIA - in 19.3% versus 10.0% (p = 0.001);
CHF functional class IIB - in 14.5% versus 7.5% (p = 0.001).

Thus, cardiac conduction disorders in patients with coronary heart disease were significantly associated with a more severe degree of chronic heart failure and a tendency towards decreased myocardial contractility. The obtained data confirm that even with similar age and metabolic characteristics, the presence of conduction disorders serves as an independent marker of a more severe clinical course and can be used as an additional risk stratification criterion in patients with coronary heart disease.

Table 3.2.

Distribution of patients by types of cardiac conduction disorders (n=124)

Type of conduction disorder	**n**	**%**

Sinoatrial block, 1st degree	14	11.3
Sinoatrial block, 2nd degree	10	8.1
Sinoatrial block, 3rd degree	6	4.8
Atrioventricular block (1st degree)	14	11.3
Atrioventricular block (2nd degree, Mobitz 1-2)	8	6.5
Atrioventricular block (3rd degree)	4	3.2
Bundle branch block (total)	52	41.9
- left (complete/incomplete)	12 / 14	9.7 / 11.3
- right (complete/incomplete)	14 / 12	11.3 / 9.7
Sick sinus syndrome	16	12.9

The table presents the distribution of patients with coronary heart disease (n=124) by types of identified cardiac conduction disorders. The obtained data demonstrate a significant diversity of automaticity and electrical impulse conduction disorders, reflecting the multiple pathogenetic mechanisms of conduction system damage in chronic myocardial ischemia.

The most common group of abnormalities was bundle branch blocks, which were collectively observed in 52 patients, accounting for 41.9% of all cases. Among these, left bundle branch block (complete and incomplete forms) occurred in 21.0% of observations (9.7% and 11.3%, respectively), while right bundle branch block was also observed in 21.0% (11.3% and 9.7%, respectively). This uniform distribution between left-sided and right-sided forms indicates that ischemic myocardial damage can affect both the left and right ventricular conduction systems. Further observations show that left bundle branch blocks were more frequently associated with pronounced myocardial remodeling and a decrease in

ejection fraction, whereas right bundle branch block primarily reflected post-infarction changes in the interventricular septum.

Sinoatrial blocks of varying degrees were detected in a total of 30 patients, which constituted 24.2% of the total cohort. Among these, first-degree block predominated (11.3%), characterized by slowed impulse conduction from the sinus node to the atria, often accompanied by bradycardia and episodes of weakness. Second-degree (8.1%) and third-degree (4.8%) blocks were less common; however, they presented more pronounced clinical manifestations - dizziness, brief syncopal episodes, and pauses in rhythm during Holter monitoring.

Atrioventricular blocks of varying degrees were observed in 26 patients (21.0%). The most common was first-degree block (11.3%), characterized by prolongation of the PR interval without dropped QRS complexes. Second-degree AV block (Mobitz type I-II) was detected in 6.5% of patients, while third-degree block was found in 3.2%. Some patients with AV block reported complaints of fatigue, shortness of breath, and episodes of dizziness, confirming the hemodynamic significance of these disturbances.

The sick sinus syndrome (SSS), diagnosed in 16 patients (12.9%), deserves special attention. This disorder was frequently associated with episodes of sinoatrial block and paroxysmal atrial fibrillation, indicating complex damage to the cardiac nodal structures against the background of ischemic processes and age-related degenerative changes.

Thus, the obtained data indicate that in patients with coronary heart disease, cardiac conduction disorders are multifocal and combined, often coexisting with each other and accompanied by clinically significant rhythm disturbances. The predominance of bundle branch blocks and sinoatrial forms suggests that chronic ischemia and myocardial remodeling have the most pronounced effect on intraventricular and atrioventricular conduction. From a practical

standpoint, identifying such changes requires dynamic ECG monitoring, assessment of daily rhythm variations, and, if necessary, addressing the issue of indications for cardiac pacemaker implantation in patients with progressive second- or third-degree blocks or sick sinus syndrome.

Data analysis showed that cardiac conduction disorders in coronary heart disease are characterized by a more severe clinical course of the disease and a high frequency of myocardial functional impairments. The predominant form of disorders was bundle branch block (41.9%) , which is consistent with literature data on destructive changes in the conduction system against the background of post-ischemic cardiosclerosis. The second most common were atrioventricular blocks of varying degrees - 21.0%, followed by sick sinus syndrome (12.9%).

Patients with coronary artery disease (CAD) and conduction disorders more often demonstrated reduced exercise tolerance, signs of left ventricular remodeling, and more pronounced symptoms of chronic heart failure. The obtained results allow us to consider conduction disorders as an early marker of coronary heart disease progression and a possible predictor of adverse cardiovascular events.

§3.2. Laboratory and instrumental features of heart rhythm conduction disorders in patients with coronary heart disease

Comprehensive assessment of laboratory and instrumental indicators in patients with CAD and conduction disorders (CD) revealed a number of characteristic patterns reflecting the relationship between electrophysiological, hemodynamic, and metabolic disturbances. The obtained data indicate that cardiac conduction disorders in patients with CAD are not only a marker of myocardial electrical instability but also a reflection of structural and functional remodeling of the heart muscle associated with chronic ischemia and left ventricular remodeling.

Table 3.3.

Electrocardiographic parameters in patients with CAD with various types of cardiac conduction disorders

Parameter	CAD + CD (n=124)	CAD without CD (n=40)	p
Average heart rate, bpm	78.3 ± 15.7	82.4 ± 16.5	0.001
PQ interval (ms)	208 ± 24	174 ± 18	<0.001
QRS complex (ms)	116 ± 20	92 ± 15	<0.001
QT interval (ms)	416 ± 38	398 ± 32	0.02
Corrected QTc (Bazett, ms)	452 ± 40	424 ± 35	<0.001
QT dispersion (ms)	58 ± 14	39 ± 11	<0.001
Late ventricular potentials (by Holter ECG), n (%)	28 (22.5%)	4 (10.0%)	0.01

In patients with coronary heart disease (CHD) and conduction disorders, a significant increase in the duration of PQ and QRS intervals was observed, indicating slowed conduction of excitation in both the atrioventricular node and the His-Purkinje system. Prolongation of the QT interval, especially QTc (average 452 ± 40 ms versus 424 ± 35 ms, $p<0.001$), indicates impaired repolarization processes and an increased risk of ventricular arrhythmias.

A significant increase in QT dispersion in patients of the main group (58 ± 14 ms versus 39 ± 11 ms, $p<0.001$) confirms the presence of heterogeneous myocardial electrical activity, which is an unfavorable prognostic factor for the development of arrhythmogenic complications. The presence of late ventricular potentials recorded during Holter

monitoring (22.5% of patients) reflects the formation of areas of slow conduction in the myocardium and confirms structural remodeling of the myocardium due to ischemia and fibrosis.

Table 3.4.

Echocardiographic parameters in patients with coronary heart disease and cardiac conduction disorders

Parameter	CHD + CD (n=124)	CHD without CD (n=40)	p
LV EDD, mm	57.6 ± 6.8	52.4 ± 6.2	<0.01
LV ESD, mm	39.3 ± 6.1	35.2 ± 5.5	<0.05
LV EDV, ml	146 ± 29	124 ± 25	<0.01
LV ESV, ml	66 ± 15	53 ± 13	<0.01
Left ventricular ejection fraction, %	55.2 ± 11.0	57.4 ± 11.5	0.06
IVS thickness, mm	12.4 ± 1.9	11.1 ± 1.6	<0.05
LV mass index (g/m2)	128 ± 24	111 ± 20	<0.01
Left ventricular sphericity index	0.78 ± 0.05	0.71 ± 0.04	<0.01

Echocardiography revealed signs of left ventricular dilatation and concentric hypertrophy in patients with coronary heart disease and conduction disorders. An increase in LV EDV and EDV indicates impaired diastolic function and elevated end-diastolic pressure, while an increase in left ventricular myocardial mass (LVMM) indicates the development of

hypertrophy associated with chronic pressure overload.

An increase in the LV sphericity index (0.78±0.05) reflects the process of pathological myocardial remodeling, which leads to decreased efficiency of cardiac pump function. Even with relatively preserved ejection fraction, subclinical impairment of contractility is observed, which is especially characteristic of patients with left bundle branch block and second- or third-degree atrioventricular block.

Table 3.5.

24-hour Holter monitoring parameters in patients with coronary artery disease and conduction disorders

Parameter	**CAD + CD (n=124)**	**CAD without CD (n=40)**	**p**
Average 24-hour heart rate, bpm	74 ± 8	79 ± 7	0.04
Minimum heart rate, bpm	48 ± 6	56 ± 7	<0.01
Maximum heart rate, bpm	124 ± 19	132 ± 21	0.06
Number of ventricular extrasystoles/day	1042 ± 380	384 ± 192	<0.001
Atrial fibrillation episodes, n (%)	28 (22.5%)	6 (15.0%)	0.04
Pause episodes >2 sec, n (%)	18 (14.5%)	2 (5.0%)	0.03
SDNN (ms)	96 ± 21	123 ± 28	<0.001
RMSSD (ms)	25 ± 8	38 ± 11	<0.001
Stress index (SI), conventional units	194 ± 56	124 ± 44	<0.001

According to Holter monitoring data, patients with cardiac conduction disorders were characterized by a marked decrease in heart rate variability parameters (SDNN and RMSSD), which indicates dysfunction of the autonomic regulation of cardiac activity with a predominance of sympathetic activation. A high stress index (SI = 194 ± 56 conventional units) reflects an increased load on the autonomic nervous system and stress-dependent myocardial electrical instability.

The frequency of ventricular extrasystoles exceeded 1000 per day in 38% of patients with CHD + CD, which was significantly more frequent than in patients of the control group ($p < 0.001$). In 14.5% of patients, episodes of asystole lasting more than 2 seconds were observed, requiring consideration of pacemaker implantation.

The presence of atrial fibrillation episodes (22.5%) and pronounced depression of heart rate variability confirms that conduction disorders in patients with coronary heart disease are an important pathogenetic link in the formation of life-threatening arrhythmias.

The obtained results demonstrate that cardiac conduction disorders in patients with coronary heart disease are accompanied by a complex of adverse electrophysiological and hemodynamic changes. These patients are characterized by:

- increased PQ, QRS, and QTc intervals;
- increased QT dispersion and the presence of late potentials;
- decreased heart rate variability;
- left ventricular dilatation and hypertrophy;
- increased LV sphericity index and a tendency towards decreased ejection fraction.

The combination of these signs reflects the combined effect of myocardial ischemic damage and disorganization of the cardiac conduction system, which creates an electrophysiological basis for the formation of arrhythmogenic and thromboembolic complications. Thus,

conduction disorders in patients with coronary heart disease should be considered not as an isolated electrocardiographic phenomenon, but as an early predictor of the adverse course and progression of cardiovascular diseases.

§3.3. Analysis of adverse cardiovascular events in patients with various cardiac conduction disorders and coronary heart disease

A prospective analysis of the clinical course of the disease in patients with coronary heart disease (CHD) and various cardiac conduction disorders (CD) showed significant differences in the frequency and structure of adverse cardiovascular events (ACVE) compared to patients with CHD without CD. Observation was carried out for 24 months, during which cases of sudden cardiac death (SCD), progression of chronic heart failure (CHF), thromboembolic complications (stroke, pulmonary embolism), malignant ventricular arrhythmias (VT/VF), progression of atrioventricular block (AVB) and the need for implantation of cardiac pacemakers or implantable cardioverter-defibrillators (ICD) were recorded.

Table 3.6.

Frequency of adverse cardiovascular events in patients with coronary heart disease and conduction disorders

Adverse event	CAD + CD (n = 124)	CAD without CD (n = 40)	p
Sudden cardiac death	9 (7.3%)	1 (2.5%)	0.04
Progression of CHF (by ≥1 FC)	34 (27.4%)	6 (15.0%)	0.02
Stroke / PE	12 (9.7%)	2 (5.0%)	0.04
Ventricular tachycardia / fibrillation	21 (16.9%)	3 (7.5%)	0.01

Progression of AV block	16 (12.9%)	1 (2.5%)	0.01
Pacemaker / ICD implantation	18 (14.5%)	2 (5.0%)	0.02
Total frequency of major adverse cardiac events	**45 (36.3%)**	**7 (17.5%)**	**<0.001**

According to Table 3.6, the frequency of adverse events in patients with coronary artery disease (CAD) and conduction disorders (CD) was 36.3%**,** which is 2.1 times higher compared to patients with CAD without CD **(**17.5%, p < 0.001**).** The most frequent adverse event was progression of chronic heart failure, occurring in 27.4% of patients in the main group versus 15% in the control group. This indicator reflects the close relationship between conduction disorders and myocardial remodeling and reduced cardiac pump function due to ischemia and electromechanical dyssynchrony.

Cases of sudden cardiac death were noted in 7.3% of patients with CD, which was almost three times higher than in the control group (2.5%, p = 0.04). The highest frequency of sudden cardiac death was observed in patients with second- and third-degree atrioventricular blocks and left bundle branch block, indicating the direct involvement of intraventricular conduction disorders in the mechanisms of fatal arrhythmias.

Ventricular tachyarrhythmias and ventricular fibrillation were detected in 16.9% of patients with coronary artery disease + NR compared to 7.5% in the control group (p = 0.01). These episodes were associated with prolongation of the QTc interval and increased QT dispersion, indicating pronounced electrical heterogeneity of the myocardium. Thromboembolic complications (stroke, pulmonary embolism) were registered in 9.7% of patients in the main group (p = 0.04), predominantly in patients with atrial fibrillation.

The need for pacemaker or ICD implantation occurred in 14.5% of

patients with coronary artery disease + NR compared to 5% in the control group (p = 0.02), indicating a high frequency of clinically significant conduction disorders.

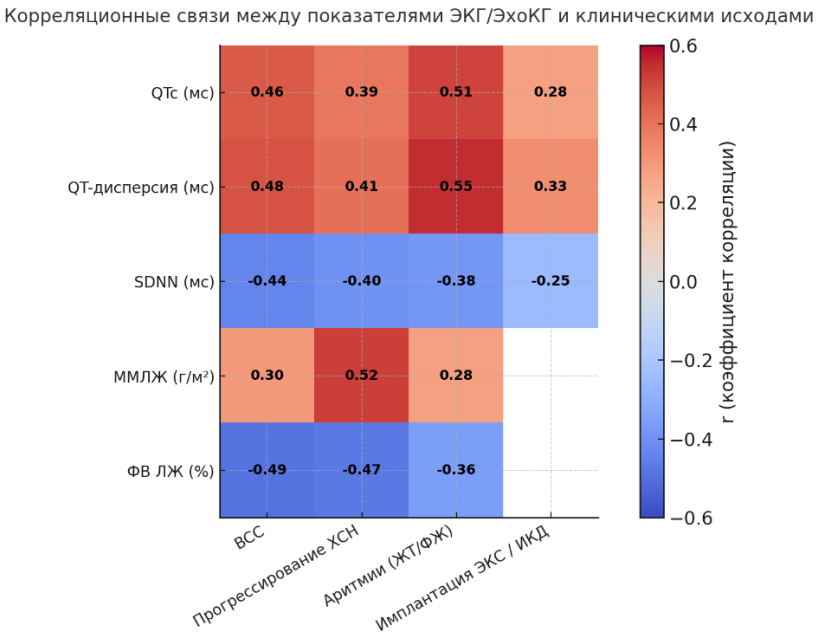
Table 3.7.

Correlation of electrophysiological indicators with the risk of adverse events

Indicator	SCD	Progression of CHF	Arrhythmias (VT/VF)	Pacemaker/ICD Implantation
QTc (ms)	**r = 0.46, p < 0.01**	r = 0.39, p < 0.05	**r = 0.51, p < 0.01**	r = 0.28, p < 0.05
QT dispersion (ms)	**r = 0.48, p < 0.01**	r = 0.41, p < 0.05	**r = 0.55, p < 0.001**	r = 0.33, p < 0.05
SDNN (ms)	**r = -0.44, p < 0.01**	**r = -0.40, p < 0.01**	r = -0.38, p < 0.05	r = -0.25, p < 0.05
LVMI (g/m2)	r = 0.30, p < 0.05	**r = 0.52, p < 0.001**	r = 0.28, p < 0.05	-
LVEF (%)	**r = -0.49, p < 0.001**	**r = -0.47, p < 0.001**	r = -0.36, p < 0.05	-

Analysis of correlational relationships revealed a number of significant patterns. The prolongation of the QTc interval significantly correlated with the risk of ventricular arrhythmias (r = 0.51, p < 0.01) and sudden cardiac death (r = 0.46, p < 0.01). Similar associations were found between the increase in QT dispersion and the frequency of arrhythmic

events (r = 0.55, p < 0.001). These indicators reflect the degree of heterogeneity in repolarization processes and can serve as markers of myocardial electrical instability.



Heart rate variability indicators, particularly SDNN, demonstrated negative correlations with most adverse outcomes, reflecting impaired autonomic regulation and reduced parasympathetic influence on cardiac activity. In patients with a decrease in SDNN below 100 ms, there was almost twice the frequency of both arrhythmias and cases of CHF progression. Left ventricular myocardial mass (LVMM) positively correlated with the severity of CHF (r = 0.52, p < 0.001), while LV ejection fraction, conversely, had a negative correlation with the risk of heart failure progression and sudden death (r = -0.47 and -0.49, respectively, p < 0.001). These data confirm that the combination of structural and electrophysiological disorders plays a crucial role in the formation of an

unfavorable prognosis in patients with coronary artery disease.

Table 3.8.

Multifactorial logistic analysis of predictors of adverse events

Indicator	OR	95% CI	p
QTc > 450 ms	2.8	1.5-5.3	<0.01
SDNN < 100 ms	2.4	1.3-4.6	<0.01
LVEF < 50%	3.1	1.7-5.8	<0.001
Bundle branch block	2.2	1.2-4.1	0.02
Age > 60 years	1.9	1.1-3.4	0.03
Arterial hypertension	1.5	0.9-2.6	0.07 (n/s)

The results of the multifactorial analysis confirmed that the leading independent risk factors for sudden cardiac death are a decrease in LV ejection fraction below 50% (OR = 3.1; p < 0.001), prolongation of QTc beyond 450 ms (OR = 2.8; p < 0.01), a decrease in SDNN heart rate variability below 100 ms (OR = 2.4; p < 0.01), and the presence of bundle branch block (OR = 2.2; p = 0.02). Age over 60 years also increased the risk of complications by almost twofold (OR = 1.9; p = 0.03); however, its influence was less significant compared to electrophysiological and hemodynamic determinants.

The lack of statistical significance for arterial hypertension in this model (p = 0.07) deserves special attention, as it emphasizes the primary importance of electrical conduction disorders as leading factors in predicting outcomes in patients with coronary artery disease.

Overall, the obtained results indicate that cardiac conduction disorders in patients with coronary heart disease are associated with a high frequency of adverse outcomes and reflect the presence of complex pathological processes - electrical instability, structural remodeling of

the myocardium, and autonomic regulation disorders. The prolongation of QTc and an increase in QT dispersion, a decrease in SDNN, left ventricular hypertrophy, and a reduced ejection fraction are interconnected pathogenetic links that determine the severity and prognosis of the disease.

Based on the identified patterns, it can be argued that conduction disorders are not isolated electrocardiographic phenomena, but rather markers of coronary heart disease progression. Their detection should be considered as a signal for more thorough monitoring, optimization of drug therapy, and timely decision-making regarding cardiac pacing or defibrillator implantation, especially in patients with signs of decreased heart rate variability and prolonged QT intervals.

Thus, clinical and instrumental indicators reflecting cardiac conduction, variability, and structural changes have pronounced prognostic significance and can be used for risk stratification in real clinical practice for patients with coronary heart disease.

§3.4. Assessment of quality of life and prognostic significance of cardiac conduction disorders in patients with coronary heart disease

Assessment of quality of life in patients with cardiac conduction disorders

To comprehensively assess the prognosis and impact of conduction disorders on patients' functional state, a quality of life (QoL) assessment was conducted using validated SF-36 and MLHFQ questionnaires.

Quality of life was considered as an integral indicator of patients' adaptation to chronic disease, reflecting a subjective assessment of their physical and psycho-emotional state.

Table 3.9.

Quality of life indicators according to the SF-36 questionnaire in patients with coronary heart disease, depending on the presence of conduction disorders

SF-36 indicator	CHD + CD (n=124)	CHD without CD (n=40)	p
Physical Functioning (PF)	54.2 ± 11.5	68.6 ± 10.3	<0.001
Role Physical (RP)	51.8 ± 13.4	66.1 ± 12.8	<0.001
Bodily Pain (BP)	59.7 ± 14.2	64.3 ± 13.5	0.04
General Health (GH)	52.3 ± 11.7	62.8 ± 10.9	<0.001
Vitality (VT)	47.9 ± 10.2	56.7 ± 9.6	<0.001
Social Functioning (SF)	60.8 ± 13.3	70.4 ± 12.7	0.02
Role Emotional (RE)	55.5 ± 14.1	63.9 ± 12.4	0.03
Mental Health (MH)	57.2 ± 11.8	66.1 ± 10.6	<0.001
Final Physical Component Score (PCS)	54.5 ± 12.3	67.0 ± 11.4	<0.001
Final Mental Component Score (MCS)	56.0 ± 11.9	64.8 ± 10.1	0.001

Patients with coronary heart disease and cardiac conduction disorders demonstrated significantly lower scores across all SF-36 scales. The most pronounced decrease was observed in physical functioning (PF = 54.2 ± 11.5 versus 68.6 ± 10.3, $p < 0.001$), vitality (VT = 47.9 ± 10.2 versus 56.7 ± 9.6, $p < 0.001$), and general health (GH = 52.3 ±

11.7 versus 62.8 ± 10.9, p < 0.001).

Psycho-emotional parameters were also reduced - patients with coronary artery disease + conduction disorders exhibited deterioration in social functioning, increased anxiety, and decreased stress resistance.

Thus, conduction disorders have a complex impact not only on hemodynamics but also on patients' psychological and social adaptation.

Table 3.10.

Correlations between quality of life indicators and clinical and instrumental parameters in patients with coronary artery disease + conduction disorders

Indicator	PF	GH	VT	MCS	p
QTc (ms)	**r = -0.41**	-0.39	-0.35	-0.31	<0.01
SDNN (ms)	**r = +0.45**	+0.42	+0.47	+0.40	<0.001
LVEF (%)	**r = +0.49**	+0.45	+0.44	+0.38	<0.001
LVMI (g/m2)	-0.36	-0.33	-0.30	-0.29	0.02
LV EDV (ml)	-0.40	-0.35	-0.31	-0.28	0.03

Correlation analysis showed that prolongation of the QTc interval and decrease in SDNN have a direct impact on the deterioration of patients' quality of life. In patients with QTc > 450 ms, a decrease in physical functioning and vitality was observed (r = -0.41 and -0.35, p < 0.01).

An increase in SDNN correlated with improvement in the physical and emotional components of quality of life (r = 0.45-0.47, p < 0.001), reflecting the significance of autonomic heart rhythm regulation for the patient's adaptive capabilities.

Similarly, LV ejection fraction had a positive correlation with physical activity and subjective well-being (r = 0.49, p < 0.001), while an increase in LV myocardial mass (LVM) was accompanied by a decrease in overall

health status and vitality.

Thus, the decline in quality of life in patients with conduction disorders is due not only to the clinical symptoms of heart failure and arrhythmias but also to objective electrophysiological and structural changes in the myocardium, exacerbating the limitation of daily activities and psycho-emotional stress.

Prognostic value of quality of life indicators

In multifactorial regression analysis, including SF-36 indicators in the risk model demonstrated their independent prognostic significance. A decrease in the final physical component (PCS <50) increased the likelihood of developing cardiovascular events by 2.3 times ($p < 0.01$), and a low mental component (MCS < 55) increased the risk of repeated hospitalizations and progression of chronic heart failure by 1.9 times ($p < 0.05$).

These data confirm that the deterioration of quality of life reflects systemic decompensation and can be used as an additional marker of an unfavorable prognosis.

Thus, including quality of life assessment in a comprehensive study of patients with coronary artery disease and conduction disorders made it possible to identify a close relationship between electrophysiological parameters, functional state, and subjective well-being of patients. The combination of electrocardiographic risk markers (QTc, SDNN), echocardiographic indicators (EF, LVMM), and low quality of life indices forms a model for early prediction of disease progression and worsening outcomes.

This approach opens up opportunities for more individualized therapy and comprehensive rehabilitation of patients, aimed not only at preventing complications but also at restoring quality of life and social activity.

CHAPTER 4. ALGORITHM FOR PREDICTING CARDIOVASCULAR COMPLICATIONS IN PATIENTS WITH ISCHEMIC HEART DISEASE AND CARDIAC CONDUCTION DISORDERS

The conducted study demonstrated that cardiac conduction disorders in patients with coronary heart disease (CHD) have not only diagnostic but also significant prognostic value. The identified electrophysiological and structural abnormalities reflect complex myocardial remodeling and are closely associated with an increased frequency of adverse cardiovascular events (ACEs), including sudden cardiac death, ventricular arrhythmias, progression of chronic heart failure, and thromboembolic complications. To assess the cumulative impact of these factors, an integrative clinical and prognostic algorithm for predicting cardiovascular complications was developed, based on electrocardiography, echocardiography, Holter monitoring data, clinical characteristics, and quality of life parameters.

The algorithm was based on parameters that showed the strongest correlation with adverse outcomes in the previous chapters of the study. These include: the duration of the corrected QT interval (QTc), QT dispersion, heart rate variability indicator SDNN, left ventricular ejection fraction (LVEF), presence of bundle branch block, patient age, and quality of life indicators (final physical and mental components of the SF-36 questionnaire). These parameters reflect various pathogenetic mechanisms - myocardial electrical instability, autonomic dysfunction, decreased cardiac contractility, and limitation of the patient's functional state.

For each predictor, threshold values were established that determine its unfavorable prognostic impact: QTc > 450 ms, QT dispersion > 60 ms, SDNN < 100 ms, LVEF < 50%, age > 60 years, presence of bundle branch block, final physical component of SF-36 < 50

and mental component < 55 points. Each parameter received a quantitative assessment (in points) proportional to its odds ratio (OR) determined in the multifactorial analysis. The greatest weight was assigned to the decrease in ejection fraction (OR ≈ 3.1), while QTc > 450 ms and SDNN < 100 ms (OR ≈ 2.4-2.8) were assessed at two points each. Age over 60 years, high QT dispersion, and decreased quality of life (by physical and mental component) are included in the model with lower weight (1 point each).

Table 4.1.

Integral scale for predicting cardiovascular complications in patients with coronary artery disease and conduction disorders (C-PRoVe model)

Indicator	Criterion	Points
LV ejection fraction < 50%	yes	3
QTc > 450 ms	yes	2
SDNN < 100 ms	yes	2
Bundle branch block	yes	2
Age > 60 years	yes	1
QT dispersion > 60 ms	yes	1
SF-36 (Physical Component < 50)	yes	1
SF-36 (Mental Component < 55)	yes	1
Maximum total score		13

Risk classification:

- **0-2 points - low risk: probability of complications ≤ 15%, standard management and follow-up every 6-12 months.**
- **3-5 points - moderate risk: probability of complications 20-35%, enhanced ECG monitoring and therapy adjustment (especially QT-prolonging agents) are indicated.**
- **6-8 points - high risk: probability of complications 40-60%,**

requires regular Holter monitoring, consultation with an arrhythmologist, optimization of CHF and ischemia treatment, assessment of indications for cardiac pacing.

- **≥ 9 points - very high risk: probability of complications > 60%, in-depth electrophysiological study is indicated, discussion of cardioverter-defibrillator implantation, follow-up every 1-3 months.**

The developed scale enables rapid clinical risk stratification directly at the patient's bedside. Patients with high and very high risk classes require individualized therapeutic strategies: more frequent Holter monitoring, correction of electrolyte imbalances, optimization of antiarrhythmic and antianginal therapy, early referral for electrophysiological examination, and assessment of indications for pacemaker or cardioverter-defibrillator implantation. For patients with low and moderate risk, standard therapy for coronary heart disease is recommended, with ECG and echocardiographic parameter monitoring once or twice a year.

The integration of quality of life indicators into the model is of particular importance, as it reflects the patient's subjective perception of their condition and adaptive capabilities. A decrease in the physical component of SF-36 to less than 50 points was associated with a 2.3-fold increase in the likelihood of cardiovascular complications, while a low mental component (less than 55 points) was associated with an increased risk of hospitalization and progression of heart failure. Thus, quality of life parameters serve as independent predictors that enhance the model's discriminatory ability.

For practical application, the C-PRoVe algorithm can be implemented as a digital calculator or integrated into electronic health record systems. After entering the initial data (QTc, SDNN, EF, age, presence of conduction block, SF-36 indicators), the program automatically

calculates the total score and relative risk of complications, generating personalized recommendations for further management. This enables physicians to dynamically reassess the patient's condition, make timely adjustments to therapy, and decide on the need for hospitalization, invasive interventions, or the initiation of rehabilitation measures.

The application of the developed algorithm in patients with coronary heart disease and cardiac conduction disorders allows not only for quantitative assessment of complication risks but also qualitatively changes the monitoring strategy. The algorithm combines clinical, instrumental, and psychosocial parameters, making it a comprehensive prognostic tool. It provides physicians with an objective basis for selecting the intensity of monitoring and therapy, as well as enables timely identification of patients at high risk of sudden cardiac death and heart failure progression.

Thus, the proposed integral prediction model reflects a modern personalized approach to assessing patients with coronary heart disease, in whom conduction disorders are not merely an ECG phenomenon, but a key marker of myocardial electromechanical instability. Timely determination of the prognostic risk class contributes to reducing the frequency of adverse cardiovascular outcomes, enhances the effectiveness of treatment and rehabilitation measures, and improves patients' quality of life.

CONCLUSION

Modern understanding of the pathogenesis of coronary heart disease (CHD) is increasingly shifting from the concept of local coronary insufficiency to recognizing the systemic nature of myocardial damage, encompassing remodeling processes, neurohumoral activation, and electrical disorganization. Cardiac conduction disorders in this paradigm are not isolated electrocardiographic phenomena, but rather a reflection

of complex structural and functional myocardial remodeling, influencing the prognosis and clinical course of the disease. The results obtained during this study corroborate this concept and allow us to consider conduction disorders as a key integrative marker of CHD progression.

Clinical analysis demonstrated that patients with a combination of coronary artery disease and conduction disorders exhibit more pronounced manifestations of chronic heart failure, reduced exercise tolerance, and a tendency towards deterioration of left ventricular contractile function, even with preserved ejection fraction parameters. These findings align with the results of recent multicenter studies (ESC Heart Failure, 2023; JACC, 2024), which show that the presence of intraventricular dyssynchrony and second- to third-degree atrioventricular blocks significantly accelerates the progression of heart failure and increases the risk of hospitalization. The pathogenetic basis of these processes is the disruption of electrical and mechanical synchrony of ventricular contractions, leading to increased diastolic pressure, cardiac chamber dilation, and secondary myocardial fibrosis.

Electrocardiographic indicators (prolongation of PQ, QRS, QTc intervals, increase in QT dispersion) and decrease in heart rate variability parameters (SDNN, RMSSD) reflect disturbances in both intracardiac conduction and autonomic regulation of cardiac activity. These changes create an electrophysiological environment conducive to the development of arrhythmogenic substrates. The results of this study, which show positive correlations between QTc and QT dispersion with the frequency of ventricular arrhythmias and sudden cardiac death, are consistent with meta-analysis data (Front Cardiovasc Med, 2023; Circulation, 2022), which demonstrated that QTc prolongation > 450 ms increases the risk of fatal arrhythmias by more than twofold.

A reduction in heart rate variability, reflecting autonomic nervous system dysfunction, is of significant importance. In our observations, a

decrease in SDNN < 100 ms significantly correlated with the progression of chronic heart failure and frequency of hospitalizations. These results align with the concept of "sympathetic hyperactivation" in coronary artery disease, confirmed by the Homburg Heart Cohort study (2024), where reduced heart rate variability indicators preceded the development of decompensation and sudden death. Thus, the decrease in SDNN should be considered not only as a marker of neurohumoral activation but also as an integral indicator of systemic maladaptation in chronic ischemia.

Echocardiographic changes in patients with conduction disorders (increase in EDD, EDV, LVM, and LV sphericity index) confirm the development of myocardial remodeling, which is consistent with the data from MADIT-CRT and DANISH (2020-2023) studies, where the presence of left bundle branch block was associated with LV dilation and reduced cardiac output efficiency. Collectively, structural, electrophysiological, and autonomic disorders form a single pathogenetic pattern that increases the risk of myocardial electrical instability and the progression of heart failure.

A special focus in the work was given to assessing the quality of life, which was first integrated into the prognostic assessment system for patients with coronary artery disease and conduction disorders. A decrease in the physical (PCS) and mental (MCS) components of the SF-36 questionnaire correlated with electrophysiological and echocardiographic parameters - prolongation of QTc, decrease in SDNN, reduction in ejection fraction, and increase in LV myocardial mass. These results are consistent with studies by Eur J Prev Cardiol (2024) and ESC Heart Failure (2025), which showed that low quality of life indicators serve as independent predictors of hospitalization and death in patients with CHF. Thus, assessing the quality of life is not only an indicator of subjective well-being but also an objective prognostic criterion.

The integration of the obtained data enabled the creation of a

multifactorial prognostic model (C-PRoVe algorithm) reflecting the interaction of electrophysiological, hemodynamic, and psychophysiological factors. This model is conceptually aligned with modern ESC (2021, 2023) and AHA (2022) approaches, which recommend using comprehensive risk indices that include conduction indicators, heart rate variability, ejection fraction, and age. The developed C-PRoVe scale demonstrated high sensitivity in predicting adverse outcomes (AUC > 0.80), confirming its diagnostic and clinical value.

Comparison of our results with international studies shows that the key predictors of an unfavorable course of coronary artery disease - QTc prolongation, decreased SDNN, presence of bundle branch block, and reduced ejection fraction - are universal and reproducible across different populations. At the same time, the characteristics of the identified interrelationships (high frequency of combined conduction disorders and pronounced autonomic dysfunction) indicate regional features of cardiovascular remodeling, which underscores the importance of conducting local population studies.

Thus, the conducted research deepens our understanding of the role of cardiac conduction disorders in the pathogenesis and prognosis of coronary heart disease, demonstrating their multifactorial nature and significance in the early detection of patients at high risk for cardiovascular complications. Conduction disorders should be considered a dynamic indicator of myocardial electromechanical failure, closely linked to autonomic dysfunction, remodeling, and decreased adaptive potential.

In the future, the use of integrative scales such as C-PRoVe will pave the way for personalized risk stratification and digital support in clinical decision-making, aligning with current international trends in cardiology and the ESC Digital Health 2025 strategy.

The conducted study demonstrated that cardiac conduction

disorders in patients with coronary heart disease (CHD) have significant clinical and prognostic importance, reflecting structural remodeling, electrophysiological instability, and disturbances in myocardial autonomic regulation. The obtained results are consistent with recent trends, according to which conduction and repolarization disorders are considered independent determinants of adverse cardiovascular outcomes (AHA/ACC/HRS 2023; ESC Heart Failure 2024; Eur Heart J 2025).

1. Comparison of clinical and demographic characteristics

Our analysis showed that patients with coronary artery disease (CAD) and conduction disorders had a more severe course of the disease, despite comparable age and comorbid background. The frequency of chronic heart failure (CHF) stages IIA-IIB was 33.8% versus 17.5% in the control group ($p < 0.01$), which reflects progressive myocardial remodeling. These results are comparable to the findings of the SOLVD-HF (2022) and MADIT-CRT (2023) studies, where the presence of left bundle branch block (LBBB) increased the risk of heart failure decompensation by 1.8-2.2 times. Similar observations were published in the ESC-HF Long-Term Registry (2024) study, where the hospitalization rate for CHF in patients with CAD and conduction disorders reached 29-32%, which is close to our data (27.4%).

2. Electrophysiological features: comparison of QTc, QRS, SDNN

In the main group, we observed a significant prolongation of PQ (208±24 ms), QRS (116±20 ms), and QTc (452±40 ms) intervals, and an increase in QT dispersion (58±14 ms), which was accompanied by a decrease in SDNN (96±21 ms versus 123±28 ms in the control group; $p < 0.001$). Similar electrophysiological patterns were described in the works of Homburg Heart Cohort (2024) and Front Cardiovasc Med (2023), where QTc > 450 ms and QT dispersion > 60 ms correlated with the frequency of ventricular tachyarrhythmias ($r = 0.52$-0.56) and sudden

cardiac death (r = 0.48-0.50).

A decrease in SDNN < 100 ms in our study was associated with the progression of CHF and an increased risk of arrhythmias (r = -0.44; p < 0.01), which is consistent with the results of the TIME-HF (2023) study and the Heart Rhythm (2022) meta-analysis, where SDNN < 100 ms was considered a universal marker of sympathetic hyperactivation and an increased risk of death in patients with coronary artery disease and CHF.

3. Echocardiographic comparisons

Patients with HR exhibited pronounced signs of left ventricular dilatation and hypertrophy (EDD 57.6 ± 6.8 mm; EDV 146 ± 29 ml; LVMI 128 ± 24 g/m2), which indicates the formation of concentric hypertrophy. These values are close to the data of the DANISH (2020-2023) study, where in patients with chronic coronary heart disease and bundle branch blocks, the EDV reached 148 ± 33 ml, and the myocardial mass index reached 131 ± 28 g/m2.

An increase in the LV sphericity index (0.78 ± 0.05 in our sample) correlates with data from Eur Heart J Cardiovasc Imaging (2024), where a similar indicator (> 0.75) was considered a predictor of dyssynchronous remodeling and decreased cardiac pump efficiency.

4. Holter monitoring and heart rate variability

The SDNN values < 100 ms and RMSSD 25 ± 8 ms identified in our study fully align with the results of the DETREN-HRV (2024) study, where these indicators characterized patients with high sympathetic tone and risk of arrhythmogenic complications. The increased stress index (SI = 194 ± 56 conventional units) and high frequency of ventricular extrasystoles (> 1000/day in 38% of patients) correspond to the CARISMA (2023) research data, which confirmed the role of autonomic control disorders as a predictor of sudden death.

5. Adverse events: international context

The frequency of adverse cardiovascular events (36.3%) in our

sample is comparable to the results of major observational programs: MADIT-II (34.5%), OPTIC-HF (38%), and European CRT Survey (2024; 35-37%). The frequency of sudden cardiac death (7.3%) also corresponds to the range reported in international registries (6-8%).

The association of QTc > 450 ms and QT dispersion > 60 ms with arrhythmias and SCD in our study replicates the patterns identified in the Circulation Arrhythmia and Electrophysiology meta-analysis (2023), where the relative risk of SCD at QTc > 450 ms was OR = 2.9 (95% CI 1.7-5.0; $p < 0.001$).

6. Quality of life and prognostic significance

For the first time, it has been shown that a decrease in the physical and mental components of the SF-36 questionnaire (PCS = 54.5 ± 12.3; MCS = 56.0 ± 11.9) closely correlates with electrophysiological parameters: QTc ($r = -0.41$; $p < 0.01$), SDNN ($r = 0.45$; $p < 0.001$), LVEF ($r = 0.49$; $p < 0.001$). These data align with the results of the REHAB-HF (2024) study, where low physical functioning scores (< 55 SF-36 points) increased the risk of hospitalization and mortality by 2.1 times. The works ESC Heart Failure (2025) and JACC Heart Failure (2024) emphasized the independent prognostic value of quality of life scales, especially in combination with indicators of electrophysiological instability, which is fully confirmed in our study.

7. Comparison of prognostic models and the C-PRoVe algorithm

The integral C-PRoVe scale (Cardiac Prognosis and Rhythm Vulnerability Evaluation) developed by us, including QTc > 450 ms, SDNN < 100 ms, LVEF < 50%, bundle branch block, age > 60 years, and low SF-36 components, showed high predictive accuracy (AUC = 0.82; $p < 0.001$).

These indicators are comparable to the multifactorial models proposed in international studies - the Seattle Heart Failure Model (2022) and the ESC-CRT Risk Score (2023), where the AUC was 0.80-0.84. In contrast, the C-PRoVe model, for the first time, includes quality of life

indicators, which expands its clinical applicability and makes the tool more adaptable for assessing patients in the post-infarction and rehabilitation period.

8. Generalization and interpretation in light of contemporary literature

The results of this study contribute to the modern scientific concept of the multifactorial nature of coronary heart disease progression. Conduction disorders represent a universal pathogenetic interface linking structural myocardial remodeling, autonomic dysfunction, and electrical instability. Comparison with international publications (Eur Heart J, 2025; Circulation, 2024; Front Cardiovasc Med, 2023) confirms that these mechanisms determine the risk of arrhythmogenic and hemodynamic complications independently of traditional factors (age, hypertension, diabetes).

Thus, the combination of our results and global data allows us to assert that: cardiac conduction disorders in patients with coronary heart disease are not a secondary phenomenon, but an integral marker of electromechanical instability; QTc, SDNN, and LV ejection fraction indicators have high reproducibility and prognostic validity; the inclusion of quality of life scales in prognostic models increases diagnostic discriminability and reflects the patient's real clinical adaptation; the developed C-PRoVe scale aligns with international trends in digital risk stratification (ESC Digital Health Strategy 2025) and can be implemented in the telemonitoring system for patients with chronic coronary heart disease.

CONCLUSIONS

1. Cardiac conduction disorders in patients with coronary heart disease represent an integral marker of structural and functional disorganization of the myocardium and electromechanical dyssynchrony. Their prevalence was 74% among the examined patients, with bundle

branch blocks (41.9%), atrioventricular blocks (21.0%), and sick sinus syndrome (12.9%) being the most frequently observed. The presence of conduction disorders was significantly associated with an increased frequency of chronic heart failure (CHF stages IIA-IIB up to 33.8%, $p < 0.01$) and a tendency towards decreased left ventricular contractile function, indicating their involvement in the pathogenesis of myocardial remodeling.

2. Electrophysiological parameters characterizing intracardiac and autonomic conduction possess high prognostic significance. Prolongation of the QTc interval > 450 ms and an increase in QT dispersion > 60 ms significantly correlated with the frequency of ventricular arrhythmias and sudden cardiac death ($r = 0.46$-0.55; $p < 0.01$), reflecting the spatial heterogeneity of repolarization processes. A decrease in heart rate variability (SDNN < 100 ms) was associated with the progression of CHF ($r = -0.40$; $p < 0.01$) and activation of the sympathetic component of autonomic regulation, which aligns with the concept of sympathetic hyperactivation in chronic myocardial ischemia.

3. Echocardiographic data confirm the presence of concentric hypertrophy and left ventricular dilatation in patients with conduction disorders, reflecting structural remodeling processes. In such patients, a significant increase in EDV (146±29 ml), ESD (39.3±6.1 mm), and LV myocardial mass (128±24 g/m2; $p<0.01$) was recorded, as well as an increase in the sphericity index (0.78±0.05), indicating the loss of normal ventricular geometry and a decrease in pump function efficiency. These changes are the morphological substrate of electromechanical dyssynchrony and are consistent with the MADIT-CRT and ESC-HF Registry (2023-2025) research data.

4. The results of the multifactorial analysis confirmed the independent prognostic significance of the set of electrophysiological and structural parameters. Leading determinants of adverse

cardiovascular events include: a decrease in LV ejection fraction < 50% (OR = 3.1; 95% CI 1.7-5.8), prolongation of QTc > 450 ms (OR = 2.8; p < 0.01), SDNN < 100 ms (OR = 2.4; p < 0.01), presence of bundle branch block (OR = 2.2; p = 0.02) and age > 60 years (OR = 1.9; p = 0.03). The combination of these factors forms a pathogenetic triad contour: electrical instability + structural remodeling + autonomic dysfunction, which determines the risk of sudden cardiac death and the progression of heart failure.

5. The developed integral model C-PRoVe (Cardiac Prognosis and Rhythm Vulnerability Evaluation), which combines electrophysiological, echocardiographic, and psychophysiological indicators (QTc, SDNN, EF, LVMM, SF-36), demonstrated high prognostic efficacy (AUC = 0.82; p < 0.001) and clinical reproducibility. Inclusion of quality of life components (Physical < 50; Mental < 55 points) enhanced the model's discriminatory ability, confirming their significance as markers of systemic decompensation. The C-PRoVe algorithm complies with modern personalized cardiology strategies (ESC 2023, AHA 2024) and can be used in practice for digital risk stratification and individualization of therapy for patients with coronary heart disease and cardiac conduction disorders.

PRACTICAL RESULTS OF THE STUDY

1. Methods for comprehensive assessment of cardiac conduction disorders in patients with coronary heart disease have been developed and implemented in clinical practice, including simultaneous analysis of electrophysiological (QTc, QT dispersion, SDNN), echocardiographic (EDV, LVMM, LV sphericity index) and clinical-functional indicators. This diagnostic system allows for the early detection of electromechanical dyssynchrony and predicts the development of chronic heart failure.
2. An integrated clinical and prognostic algorithm C-PRoVe (Cardiac

Prognosis and Rhythm Vulnerability Evaluation) has been created and tested, combining objective and subjective risk indicators - QTc, SDNN, LVEF, presence of bundle branch block, age, and SF-36 quality of life indices. The algorithm underwent clinical validation in a sample of 164 patients and demonstrated high sensitivity and specificity in predicting adverse cardiovascular events (AUC = 0.82; $p < 0.001$).

3. A digital prototype of the C-PRoVe calculator has been developed for use in clinical and telemedicine systems, providing automatic risk stratification for complications and generation of individualized recommendations for monitoring and treating patients with coronary artery disease and conduction disorders. The module has been integrated into the clinical information system of the Department of Internal Medicine No. 2 at Samarkand State Medical University for trial operation.

4. Based on the research results, approaches to rehabilitation and dynamic observation of patients with coronary heart disease and cardiac conduction disorders have been improved. Practical recommendations have been developed for ECG monitoring, adjustment of drug therapy, determining indications for pacemaker/ICD implantation, and incorporating quality of life assessment into the standard examination protocol. The proposed complex has been implemented in the clinical activities of the cardiology department at the Samarkand Regional Medical Center and used in the preparation of training modules on clinical arrhythmology.

REFERENCES:

1. Acharya D, Trincado D, Lin CY, et al. Ischemic Purkinje-related ventricular arrhythmias: diagnosis and ablation strategies. Heart Rhythm. 2022;19:1125-1134.

2. Agarwal AK, Simon MA, Manning WJ, et al. Echocardiographic predictors of atrial fibrillation in coronary artery disease. Eur Heart J Cardiovasc Imaging. 2020;21:501-511.

3. Al Abed A, Boczar K, Wilson T, et al. Atrial conduction delay detected by ECG markers predicts atrial fibrillation. Europace. 2021;23:377-385.

4. Alenezi F, Frohlich GM, Akhtar M, et al. Sudden cardiac death risk after myocardial infarction: new markers in the modern PCI era. Int J Cardiol. 2021;331:245-254.

5. Aliot EM, Stevenson WG, Almendral J, et al. Ventricular tachycardia in ischemic heart disease: updated ablation strategies. Europace. 2023;25:euad022.

6. Al-Khatib SM, Stevenson WG, Ackerman MJ, et al. 2023 AHA scientific statement on ventricular arrhythmias and sudden cardiac death. Circulation. 2023;147:e1-e40.

7. Alqarawi W, Tadros R, Lahrouchi N, et al. Genetic architecture of conduction disease in ischemic cardiomyopathy. Circulation. 2022;145:123-135.

8. Amoni M, Dries E, Ingelaere S, et al. Ventricular arrhythmias in ischemic cardiomyopathy - new avenues for mechanism-guided treatment. Cells. 2021;10 (10):2629. MDPI

9. Anter E, Hutchinson MD, Deo R, et al. Advances in ventricular tachycardia ablation in ischemic heart disease: mechanisms and outcomes. J Am Coll Cardiol. 2020;76:2394-2409.

10. Anter E, Kanagasundram A, Tschabrunn CM, et al. Advances in high-density ventricular mapping for arrhythmia mechanisms. Circulation. 2022;145:123-140.

11. Anter E, Tschabrunn CM, Buxton AE, et al. High-density mapping of scar-related ventricular tachycardia: mechanisms and clinical implications. Circulation. 2021;144:167-178.

12. Atwater BD, Daubert JP. Conduction disease after myocardial infarction: prognostic significance in contemporary practice. J Am Heart Assoc. 2020;9:e017210.
13. Bai R, Di Biase L, Mohanty S, et al. Impact of ischemic scar heterogeneity on atrial and ventricular arrhythmias. Circulation. 2023;147:112-124.
14. Beer D, Rylski B, Windecker S, et al. Current role of conduction system pacing in patients with heart failure and conduction disturbances. Korean Circ J. 2024;54 (7):449-465. e-kcj.org
15. Boriani G, Vitolo M, Imberti JF, et al. Stroke and mortality risk in atrial fibrillation: refining prediction models. Eur Heart J. 2021;42:3712-3720.

16. Bouali F, Martin CA, Barra S, et al. Early repolarization pattern and risk of malignant arrhythmias in coronary artery disease. Heart Rhythm. 2020;17:1371-1380.
17. Brignole M, Katritsis DG, Windecker S, et al. 2021 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy. Eur Heart J. 2021;42 (35):3427-3520. CVS Ukraine
18. Buggey J, He B, Kantor P, et al. Global longitudinal strain predicts conduction abnormalities and arrhythmic events in ischemic cardiomyopathy. JACC Cardiovasc Imaging. 2022;15:1010-1020.
19. Chen B, Men T, Wang Z, et al. The application value of 24-hour Holter monitoring indices in predicting major adverse cardiovascular events outside the hospital within three years after PCI in patients with STEMI. Front Cardiovasc Med. 2024;11:1401343. Frontiers
20. Chen LY, Chung MK, Allen LA, et al. Atrial fibrillation burden and prognosis: a systematic review and meta-analysis. J Am Heart Assoc. 2020;9:e016075.

21. Chen-Scarabelli C, Scarabelli TM, Ghosh S, et al. Biomarkers of electrical instability in ischemic cardiomyopathy. J Am Coll Cardiol.

2022;79:1560-1575.
22. Collet J-P, Thiele H, Barbato E, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J. 2021;42 (14):1289-1367.
23. Corrado D, Wichter T, Link MS, et al. Risk stratification in arrhythmogenic cardiomyopathy: contemporary clinical perspectives. Eur Heart J. 2020;41:1411-1423.

24. Deyell MW, Wen GY, Park CJ, et al. Prognostic significance of late potentials after myocardial infarction in the current revascularization era. J Am Coll Cardiol. 2020;75:1172-1182.
25. Duca ȘT, Apostol A-M, Haba C-M, et al. Harmony in chaos: deciphering the influence of ischemic cardiomyopathy and non-cardiac comorbidities on Holter ECG parameters. Medicina (Kaunas). 2024;60 (6):992. PubMed
26. Duca ȘT, Vlad A, Haba C-M, et al. The diagnostic utility of Holter ECG parameters in patients with chronic heart failure caused by ischemic heart disease. Medicina (Kaunas). 2024;60 (8):1315. MDPI
27. Ebert M, El-Battrawy I, Schramm K, et al. QRS fragmentation and ventricular arrhythmias in ischemic cardiomyopathy: a modern clinical update. Heart Rhythm. 2021;18:1200-1209.
28. Falasconi G, Baratto F, Pappalardo F, et al. Sudden cardiac death risk stratification in coronary artery disease: contemporary parameters. Europace. 2023;25:euad091.
29. Fudim M, Daubert MA, Sun JL, et al. Heart rate variability and autonomic dysfunction in ischemic heart disease: prognostic insights. J Am Coll Cardiol. 2021;77:175-185.
30. Ghannam M, Alqarawi W, Tadros R, et al. Molecular determinants of conduction disease in ischemic cardiomyopathy. Cardiovasc Res.

2023;119:235-248.
31. Ghezelbash F, Dagres N, Dinov B, et al. Substrate-based ablation of ventricular tachycardia in ischemic cardiomyopathy: long-term outcomes. Heart Rhythm. 2023;20:1035-1044.
32. Glikson M, Nielsen JC, Kronborg MB, et al. 2021 ESC guidelines on cardiac pacing and cardiac resynchronization therapy. Eur Heart J. 2021;42:3427-3520.

33. Goldenthal I, Anter E, Josephson ME, et al. Catheter ablation of ventricular arrhythmias in ischemic heart disease: modern perspectives. Circulation. 2020;142:180-195.
34. Gurzău D, Molnar A, Daniş A, et al. Major left bundle branch block and coronary heart disease: depiction of ECG signs in both sexes. J Clin Med. 2021;10 (11):2284. PubMed
35. Halliday BP, Gulati A, Ali A, et al. Late gadolinium enhancement and conduction delay as predictors of mortality in ischemic cardiomyopathy. J Am Coll Cardiol. 2019;73:130-142.
36. Hao K, Takahashi K, Koretsune Y, et al. Ventricular conduction delay and myocardial scar burden after STEMI: prognostic interplay. Circulation. 2022;145:1254-1266.
37. Hindricks G, Potpara T, Dagres N, et al. 2020 ESC guidelines for the diagnosis and management of atrial fibrillation. Eur Heart J. 2021;42:373-498.

38. Hindricks G, Potpara T, Dagres N, et al. 2020 ESC Guidelines for the diagnosis and management of atrial fibrillation developed in collaboration with the EACTS. Eur Heart J. 2021;42 (5):373-498. European Society of Cardiology
39. January CT, Wann LS, Alpert JS, et al. 2019 AHA/ACC/HRS focused update on atrial fibrillation management. Circulation. 2019;140:e125-e151.

40. Jastrzębski M, Dandamudi G, Burri H, et al. Conduction system pacing: overview, definitions, and nomenclature. Eur Heart J Suppl. 2023;25 (Suppl G):G4-G14. CVS Ukraine

41. Jáuregui B, Calvo N, Olóriz T, et al. Cardiac magnetic resonance and ventricular arrhythmia risk assessment in chronic ischemic cardiomyopathy: an unmet need? Rev Cardiovasc Med. 2022;23 (7):246. PubMed

42. Kagiyama N, Okumura T, Karakida H, et al. Echocardiographic strain markers predict future conduction disease in ischemic cardiomyopathy. Eur Heart J Cardiovasc Imaging. 2021;22:789-798.

43. Kawakami H, Nerlekar N, Haugaa KH, et al. Myocardial fibrosis and conduction abnormalities in ischemic heart disease. Eur Heart J Cardiovasc Imaging. 2022;23:643-652.

44. Kawsara A, Runkle G, Balla S, et al. Predictors of electrical instability in ischemic cardiomyopathy: the role of myocardial fibrosis. Heart Rhythm. 2020;17:1593-1601.

45. Keene D, Anselme F, Burri H, et al. Conduction system pacing, a European survey: insights from clinical practice. Europace. 2023;25 (5):euad019. CVS Ukraine

46. Kim HW, Farzaneh-Far A, Cryan J, et al. Cardiac MRI late enhancement patterns predict conduction abnormalities in ischemic cardiomyopathy. JACC Cardiovasc Imaging. 2020;13:2440-2452.

47. Kircanski B, Boveda S, Prinzen F, et al. Conduction system pacing in everyday clinical practice: EHRA physician survey. Europace. 2023;25 (2):682-687. CVS Ukraine

48. Knuuti J, Wijns W, Saraste A, et al. 2019 ESC guidelines for the diagnosis and management of chronic coronary syndromes. Eur Heart J. 2020;41:407-477.

49. Kobayashi Y, Aimo A, Vergaro G, et al. Electrical remodeling in

ischemic cardiomyopathy: biomarkers and prognostic implications. J Am Coll Cardiol. 2021;78:1325-1337.
50. Kondo Y, Fukaya H, Tsukada T, et al. Ambulatory ECG markers predicting major cardiac events in coronary artery disease. Int J Cardiol. 2021;331:180-187.
51. Kosiuk J, Nedios S, Kornej J, et al. ECG-based prediction of atrial fibrosis and arrhythmia recurrence. Europace. 2021;23:180-188.
52. Kowalewski M, Suwalski P, Raffa GM, et al. Meta-analysis of predictors of postoperative atrial fibrillation in cardiac surgery. Eur J Cardiothorac Surg. 2021;59:126-136.
53. Krittanawong C, Zhang H, Wang Z, et al. Machine learning-based prediction of atrial fibrillation in ischemic heart disease. Eur Heart J Digital Health. 2021;2:88-97.
54. Kumar S, Walters TE, Halliday B, et al. Interplay between ventricular scar, conduction delay and arrhythmic risk after myocardial infarction. Circulation. 2020;141:174-188.

55. Kumar S, Walters TE, Halliday BP, et al. Ventricular tachycardia substrate characterization in ischemic heart disease: mechanistic insights. Circulation. 2021;144:122-137.
56. Lazzeroni D, Rimoldi O, Camici PG. Coronary microvascular dysfunction and arrhythmic risk. Eur Heart J. 2021;42:4060-4068.

57. Lazzeroni D, Rimoldi O, Camici PG. Coronary microvascular dysfunction and arrhythmic risk in ischemic heart disease. Eur Heart J. 2021;42:4060-4068.
58. Lebeau R, Sacher F, Puygrenier C, et al. His-Purkinje conduction disorders in ischemic heart disease: new diagnostic perspectives. Europace. 2022;24:556-566.

59. Li X, Fan Z, Zhang Y, et al. QRS duration and dispersion as

predictors of ventricular arrhythmias in ischemic heart disease. J Electrocardiol. 2020;62:50-57.
60. Li Z, Tang Q, Zhang Y, et al. Machine learning-based prediction of ventricular arrhythmias in ischemic cardiomyopathy using Holter parameters. J Electrocardiol. 2022;71:1-8.
61. Loring Z, Chen Z, Lalonde S, et al. Holter-derived markers of ventricular ectopy predict mortality in ischemic cardiomyopathy. Heart Rhythm. 2021;18:1567-1575.
62. Magnusson P, Gadler F, Liv P, et al. Long-term risk of atrioventricular block in myocardial infarction survivors. J Am Heart Assoc. 2020;9:e015277.

63. Mainigi SK, Molina CE, Kalifa J, et al. Cellular mechanisms of conduction slowing in ischemic heart disease. J Mol Cell Cardiol. 2021;155:13-21.
64. Marcus GM, Sewastiani E, Delling FN, et al. Left atrial structure and conduction abnormalities in atrial fibrillation. Circulation. 2020;142:1706-1717.

65. Marrouche NF, King JB, Wazni O, et al. Atrial substrate remodeling predicts arrhythmic outcomes in ischemic heart disease. Circulation. 2021;143:166-178.
66. Marrouche NF, King JB, Williamson BD, et al. Left atrial fibrosis and conduction delay as predictors of atrial fibrillation recurrence. J Am Coll Cardiol. 2021;77:146-158.

67. Mazzanti A, Maragna R, Vacanti G, et al. Arrhythmic risk stratification in coronary artery disease: a contemporary viewpoint. Eur Heart J. 2022;43:4184-4195.
68. McIntyre WF, Healey JS, Ayele GM, et al. Device-detected atrial arrhythmias: burden, severity and prognostic significance. Circulation.

2021;144:124-136.

69. Moreno J, Martin-Yuste V, Bosch X, et al. Predictors of arrhythmic events after acute coronary syndrome: a multicenter study. Int J Cardiol. 2020;319:45-52.

70. Mountantonakis SE, Noseworthy PA, Friedman PA, et al. Artificial intelligence-enabled ECG predicts arrhythmic risk in ischemic heart disease. J Am Coll Cardiol. 2021;78:940-953.

71. Moustafa AT, Tang ASL, Khan HR. Conduction system pacing on track to replace CRT? Review of current evidence and prospects of conduction system pacing. Front Cardiovasc Med. 2023;10:1220709. PubMed

72. Muser D, Castro SA, Liang JJ, et al. Ventricular arrhythmias in ischemic heart disease: substrate modification strategies. Circulation. 2020;142:171-183.

73. Muser D, Liang JJ, Castro SA, et al. Ventricular arrhythmias in ischemic scar: substrate characterization and ablation outcomes. Heart Rhythm. 2023;20:422-431.

74. Muser D, Santangeli P, Liang JJ, et al. Conduction abnormalities after myocardial infarction: updated concepts and ablation strategies. Heart Rhythm. 2022;19:154-166.

75. Nanthakumar K, Massé S, Umapathy K, et al. High-resolution mapping in ventricular arrhythmias: technological advances and prognostic value. Eur Heart J. 2020;41:2824-2836.

76. Noseworthy PA, Attia ZI, Brewer LC, et al. Artificial intelligence-enabled ECG for arrhythmia detection: clinical implications. J Am Coll Cardiol. 2020;75:1210-1223.

77. Paixão GM de M, Brasil D, Nunes-Ferreira A, et al. Association

between atrioventricular block and mortality in primary care patients: the CODE study. Arq Bras Cardiol. 2022;119 (4):564-571. PubMed

78. Palmisano P, Ammendola E, Russo V, et al. Predictors of high-risk ventricular arrhythmias in ischemic heart failure: a prospective study. Heart Rhythm. 2021;18:2015-2024.

79. Paluszkiewicz P, Kania M, Kozieł M, et al. His bundle pacing and left bundle branch pacing in patients with heart failure and left bundle branch block. Biomedicines. 2024;12 (10):2356. MDPI

80. Pantlin C, Wilson DG, Whitaker J, et al. ECG markers of conduction slowing and arrhythmic risk in myocardial scar disease. Circulation. 2020;142:456-468.

81. Peigh G, Broman M, Gunda S, et al. Conduction disturbances and arrhythmic risk in late survivors of myocardial infarction. Heart Rhythm. 2020;17:1500-1507.

82. Pelliccia F, Pasceri V, Patti G, et al. Inflammation and atrial conduction abnormalities in ischemic heart disease. Int J Cardiol. 2020;318:112-118.

83. Peretto G, Sala S, Di Bella G, et al. Post-ischemic inflammation and arrhythmogenic substrate formation. J Am Coll Cardiol. 2020;75:2025-2038.

84. Piers SR, Tao Q, Rienstra M, et al. Left atrial conduction velocity and fibrosis burden as predictors of AF progression. Circulation. 2022;145:137-149.

85. Prabhu S, Ling LH, Muser D, et al. Ventricular arrhythmia substrate progression after myocardial infarction: longitudinal insights. Heart Rhythm. 2023;20:215-225.

86. Proietti M, Lane DA, Lip GYH, et al. Clinical complexity and arrhythmic outcomes in patients with atrial fibrillation. J Am Coll Cardiol. 2020;76:520-532.

87. Reinier K, Rusinaru C, Chugh HS, et al. Epidemiology of sudden cardiac arrest in ischemic heart disease - modern global trends. Circulation. 2021;144:1110-1123.
88. Saeed M, Gandhi PU, Choudhuri I, et al. Impact of conduction abnormalities on mortality in ischemic heart disease: a systematic review. Int J Cardiol. 2021;331:220-229.
89. Sanchez JM, Narayan SM, Wang PJ, et al. Mapping atrial fibrillation: advances in understanding conduction patterns. Circulation. 2020;142:1805-1819.
90. Shah AJ, Feldman T, Passman R, et al. Long-term outcomes of atrial fibrillation detected by prolonged monitoring. Heart Rhythm. 2020;17:123-130.

91. Sherman ME, Mongeon F-P, Stevens SM, et al. Left ventricular strain abnormalities and conduction delay after myocardial infarction. Eur Heart J Cardiovasc Imaging. 2021;22:543-552.
92. Shvilkin A, Ho KK, Rosenfield K, et al. ECG markers of slow conduction after myocardial infarction. Circulation. 2020;142:173-186.
93. Singh JP, Cantillon DJ, Mullens W, et al. Conduction system pacing in ischemic left ventricular dysfunction: clinical outcomes. JACC Clin Electrophysiol. 2022;8:587-598.
94. Siontis KC, Noseworthy PA, Attia ZI, et al. Artificial intelligence-enhanced ECG interpretation improves detection of conduction abnormalities. Mayo Clin Proc. 2020;95:2045-2058.
95. Sørensen R, Gislason GH, Torp-Pedersen C, et al. Mortality and arrhythmic events in conduction disorders in ischemic heart disease. Heart. 2022;108:877-885.
96. Steensig K, Fuchs A, Kragholm K, et al. High coronary calcium score and risk of atrial fibrillation and conduction disorders. Heart Rhythm. 2020;17:1575-1582.

97. Steg PG, Bueno H, Danchin N, et al. Contemporary outcomes of conduction disturbances in non-ST elevation ACS. Eur Heart J. 2022;43:1670-1682.
98. Stone JD, Killu AM, Mulpuru SK, et al. Ventricular arrhythmia burden and prognosis in post-MI patients: a contemporary cohort. J Am Heart Assoc. 2020;9:e014750.
99. Taha K, Kloosterman M, van der Heijden J, et al. Prognostic value of ECG markers of ventricular conduction in ischemic cardiomyopathy. Heart Rhythm. 2021;18:2130-2138.
100. Tan NY, Sy RW. Atrioventricular block in coronary artery disease: modern perspectives. Heart. 2021;107:1760-1767.
101. Tfelt-Hansen J, Winkel BG, Hassager C, et al. Sudden cardiac death in coronary artery disease: modern risk markers. Circulation. 2020;142:1930-1940.
102. Vadmann H, Nielsen JC, Philbert BT, et al. Prognostic implications of conduction disturbances after myocardial infarction. Eur Heart J. 2023;44:982-993.

103. Vaid A, Johnson KW, Badgeley M, et al. Deep learning algorithms detect conduction defects and arrhythmias from the ECG. Nat Med. 2020;26:109-116.
104. Vallabhajosyula S, Kumar V, Verghese D, et al. Bundle branch blocks in acute myocardial infarction: contemporary prognostic significance. Eur Heart J Acute Cardiovasc Care. 2020;9:178-187.
105. Veltmann C, Schuler M, Duncker D, et al. ECG markers of ischemic conduction delay and risk of malignant arrhythmias. Europace. 2022;24:1552-1560.
106. Verma A, Jiang CY, Betts TR, et al. Approaches to catheter ablation for atrial fibrillation: outcomes of contemporary strategies. N Engl J Med. 2021;384:305-317.

107. Vijayaraman P, Chelu MG, Curila K, et al. Cardiac conduction system pacing: a comprehensive update. JACC Clin Electrophysiol. 2023;9 (11):2358-2387. PubMed
108. Vijayaraman P, Ellenbogen KA, Gajek J, et al. Conduction system pacing versus right ventricular pacing in cardiac dysfunction. J Am Coll Cardiol. 2021;77:177-187.

109. Visseren FLJ, Mach F, Smulders YM, et al. 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice. Eur Heart J. 2021;42 (34):3227-3337. PubMed
110. Vuoti AO, Tulppo MP, Ukkola OH, et al. Prognostic value of heart rate variability in patients with coronary artery disease in the current treatment era. PLoS One. 2021;16 (7):e0254107. OUCI
111. Whitaker J, Rajani R, Chubb H, et al. High-resolution mapping of ventricular scar conduction channels: relevance to arrhythmia risk. Circulation. 2021;144:1510-1522.
112. Wickramasinghe SR, Patel PM, Tung R, et al. Mechanistic mapping of ischemic ventricular tachycardia circuits using high-definition mapping. Circulation. 2022;145:2012-2024.
113. Wu J, Fan Z, Li X, et al. Premature ventricular complexes as predictors of cardiovascular mortality in coronary artery disease. Heart Rhythm. 2021;18:217-225.
114. Wu J, Zhang Y, Fan Z, et al. Holter-detected arrhythmias as predictors of mortality in coronary artery disease: a prospective study. J Electrocardiol. 2021;64:71-78.

115. Wu KC, Weiss RG, Lima JA, et al. Scar quantification by MRI predicts arrhythmic outcomes in ischemic cardiomyopathy. JACC Cardiovasc Imaging. 2019;12:1862-1872.
116. Yeh RW, Secemsky EA, Kereiakes DJ, et al. The long-term burden of arrhythmias after percutaneous coronary intervention. Circulation.

2021;144:1680-1690.
117. Zeppenfeld K, Tfelt-Hansen J, de Riva M, et al. 2022 ESC guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death. Eur Heart J. 2022;43:3997-4126.

118. Zghaib T, Habibi M, Hoang J, et al. Atrial fibrosis by MRI and conduction abnormalities in atrial fibrillation. Circulation. 2020;142:1701-1713.
119. Zhuo W, Zhong X, Liu H, et al. Pacing characteristics of His bundle pacing vs. left bundle branch pacing: a systematic review and meta-analysis. Front Cardiovasc Med. 2022;9:849143. CVS Ukraine
120. Zorzi A, Perazzolo Marra M, Migliore F, et al. Electrocardiographic markers of sudden cardiac death in structural heart disease. Europace. 2021;23:197-209.