Monitoring of the cardiovascular system during chemotherapy in cancer patients

Monitorización del sistema cardiovascular durante la quimioterapia en pacientes con cáncer

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Abstract

Modern cancer treatment protocols often include drugs that can have a negative effect on the functional state of the heart and blood vessels, which increases the risk of cardiotoxicity. The main purpose of the study is to determine the most effective methods of early detection and control of cardiovascular complications in this category of patients.

The work analyzes various approaches to monitoring the state of the cardiovascular system, including the use of echocardiography, cardiomagnetic resonance imaging, biochemical markers (for example, troponins and natriuretic peptides) and other diagnostic tools. Special attention is paid to the role of a personalized approach in the selection of monitoring methods, taking into account the type of chemotherapeutic drugs used, the stage of the disease and the presence of concomitant diseases.

The authors emphasize the importance of interdisciplinary collaboration between oncologists and cardiologists for timely detection and prevention of cardiotoxic effects. Recommendations for the correction of therapy in the event of the first signs of damage to the cardiovascular system are also presented, and modern strategies for the prevention of cardiotoxicity, such as the use of protective drugs (for example, dexrazoxane), are discussed.

The results of the study confirm the need to introduce comprehensive cardiovascular monitoring programs into cancer treatment standards in order to minimize the risks of complications and improve the quality of life of patients.

Keywords: monitoring, cardiotoxicity, chemotherapy, oncology, cardiovascular system, prevention.

Resumen

Los protocolos modernos de tratamiento del cáncer suelen incluir fármacos que pueden afectar negativamente la función cardíaca y vascular, lo que aumenta el riesgo de cardiotoxicidad. El objetivo principal de este estudio es determinar los métodos más eficaces para la detección temprana y el control de las complicaciones cardiovasculares en esta categoría de pacientes.

El trabajo analiza diversos enfoques para la monitorización del estado del sistema cardiovascular, incluyendo el uso de la ecocardiografía, la cardiorresonancia magnética, marcadores bioquímicos (por ejemplo, troponinas y péptidos natriuréticos) y otras herramientas diagnósticas. Se presta especial atención a la importancia de un enfoque personalizado en la selección de los métodos de monitorización, teniendo en cuenta el tipo de fármacos quimioterapéuticos utilizados, el estadio de la enfermedad y la presencia de enfermedades concomitantes.

Los autores enfatizan la importancia de la colaboración interdisciplinaria entre oncólogos y cardiólogos para la detección y prevención oportuna de efectos cardiotóxicos. También se presentan recomendaciones para la corrección del tratamiento ante los primeros signos de daño al sistema cardiovascular, y se discuten estrategias modernas para la prevención de la cardiotoxicidad, como el uso de fármacos protectores (por ejemplo, dexrazoxano).

Los resultados del estudio confirman la necesidad de introducir programas integrales de monitorización cardiovascular en los estándares de tratamiento del cáncer para minimizar el riesgo de complicaciones y mejorar la calidad de vida de los pacientes.

Palabras clave: monitorización, cardiotoxicidad, quimioterapia, oncología, sistema cardiovascular, prevención.

Introduction

Modern oncology has achieved significant success in the development and implementation of effective treatment methods, including chemotherapy, which has significantly increased the survival rate of patients with various forms of cancer[1]. However, despite the high therapeutic efficacy of many chemotherapeutic drugs, their use is often accompanied by the development of serious side effects, including cardiotoxicity. Cardiotoxic complications are one of the most pressing problems in modern oncology, as they can lead to a decrease in the quality of life of patients, limit the possibilities of further treatment, or even lead to fatal outcomes.

Chemotherapeutic agents such as anthracyclines and targeted drugs (e.g. trastuzumab) are known for their negative effects on the cardiovascular system. The pathogenesis of cardiotoxicity is multifaceted and may include oxidative stress, mitochondrial metabolic disorders, sarcoplasmic reticulum dysfunction, cardiomyocyte apoptosis, and other mechanisms. These changes can manifest as both acute and delayed cardiac dysfunction, including a decrease in the left ventricular ejection fraction, the development of heart failure, arrhythmias, hypertension and other diseases.

Regular monitoring of the cardiovascular system in cancer patients receiving chemotherapy is necessary to minimize the risk of cardiotoxic complications. Timely detection of the first signs of heart damage allows you to adjust treatment tactics, use protective drugs and prevent the progression of cardiotoxicity. In this regard, the importance of developing and implementing comprehensive monitoring programs based on modern diagnostic technologies and an individualized approach to each patient is increasing.

Thus, the problem of monitoring the cardiovascular system during chemotherapy requires special attention from the medical community, since solving this problem contributes not only to improving the safety of treatment, but also to improving long-term treatment outcomes in cancer patients.

The disclosure of the problem of organizing comprehensive monitoring of the cardiovascular system during chemotherapy in cancer patients requires an integrated approach, for this reason, an analysis of literary sources has been conducted that comprehensively address the main issues of the study. Thus, a study of current scientific publications, clinical recommendations and guidelines on the cardiotoxicity of chemotherapeutic drugs was conducted based on a review of articles from international databases (PubMed, Cochrane Library, Scopus). Based on the results of the review, the data obtained from various sources was systematized in order to identify common patterns, key problems and modern approaches to monitoring the cardiovascular system in cancer patients, and various methods of diagnosis and monitoring of the cardiovascular system (echocardiography, cardiomagnetic resonance imaging, biochemical markers) in terms of their accuracy, accessibility, and applicability in specific clinical situations.

In addition, logical links were established between the risk factors for cardiotoxicity, the specifics of the applied chemotherapeutic protocols and possible methods for monitoring the state of the cardiovascular system, and promising directions were identified in the development of methods for monitoring and preventing cardiotoxicity, including the use of new technologies (digital monitoring, artificial intelligence for data analysis). The problem of monitoring the cardiovascular system was considered in the context of comprehensive health management for cancer patients, including the interaction of various specialists (oncologists, cardiologists, pharmacologists).

Results

Modern cancer treatment protocols often include drugs that, despite their high therapeutic efficacy, can have a negative impact on the functional state of the heart and blood vessels. This phenomenon is known as cardiotoxicity of chemotherapy and is one of the most serious problems in modern oncology[2]. Cardiotoxic effects can manifest themselves both in an acute form during or immediately after the course of treatment, and in a delayed form several years after the end of therapy[3]. Such complications can significantly reduce the quality of life of patients, limit the possibilities of further treatment, and even lead to the development of progressive diseases of the cardiovascular system, such as heart failure, arrhythmias, hypertension, and myocardial infarction.

Cardiotoxic complications are one of the most serious side effects of modern chemotherapy. The risk of developing them depends on many factors, including the type of drugs used, the dose and duration of treatment, the patient's age, the presence of concomitant diseases and a genetic predisposition. Table 1 shows the main factors of this risk.

As shown in the table, the development of cardiotoxic complications in cancer patients receiving chemotherapy depends on many factors that can be divided into several categories: related to the type and dose of the drug, the clinical characteristics of the patient, concomitant diseases, genetic predisposition and lifestyle.

1. Factors related to the type and dose of chemotherapeutic drugs

1.1. The type of drug. Anthracyclines are among the most effective anticancer drugs, but their cardiotoxicity is well documented. They cause oxidative stress, mitochondrial damage, and cardiomyocyte apoptosis. The frequency of cardiotoxic effects increases with cumulative dose[4]. For example, the risk of heart failure can reach 26% with a cumulative dose of doxorubicin greater than 550 mg/m2.

Trastuzumab, used to treat HER2-positive breast cancer, may cause a reversible decrease in left ventricular ejection fraction (LVEF). The risk is especially high when trastuzumab is combined with anthracyclines, when the incidence of heart failure can reach 27%. Multikinase inhibitors (e.g., sunilatinib, sorafenib) can cause hypertension, microangiopathy, and impaired myocardial perfusion, which increases the risk of cardiovascular complications[5].

1.2 Cumulative dose. Cumulative dose is a key risk factor for cardiotoxicity for many drugs, especially anthracyclines. The higher the total dose, the higher the chance of serious complications. So, with a cumulative dose of

doxorubicin less than 400 mg/ m2, the risk of heart failure is about 1-2%. At doses above 550 mg/m2, this risk increases to 26%.

1.3 Combined treatment. A combination of several chemotherapeutic drugs can enhance the negative effect on the cardiovascular system[6]. For example, the combination of anthracyclines + cisplatin increases the risk of cardiotoxicity due to joint effects on the myocardium, and the anthracyclines + trastuzumab complex significantly increases the risk of LVEF reduction and heart failure.

2. Clinical characteristics of the patient

2.1 Age. Old age is an important risk factor for cardiotoxicity. With age, there is a natural aging of the myocardium, a decrease in its functional reserves and an increase in sensitivity to damage[7]. Thus, in patients over 65 years of age, the risk of cardiotoxicity from doxorubicin increases 2-3 times compared with younger patients. Women are generally more susceptible to cardiotoxic effects than men. This may be due to hormonal characteristics and a higher prevalence of concomitant diseases (for example, hypertension).

2.3 Previous radiation therapy. Radiation therapy of the heart area (for example, in the treatment of lymphomas or chest tumors) can cause long-term changes in the structure and function of the heart, such as myocardial fibrosis and coronary insufficiency. Patients who received radiation therapy have a significantly increased risk of cardiotoxicity with subsequent chemotherapy[8].

3. The presence of concomitant diseases

3.1 Arterial hypertension. Hypertension increases the load on the heart and makes it more vulnerable to damage[9]. Patients with hypertension have an increased risk of cardiotoxicity when using anthracyclines and multikinase inhibitors.

3.2 Coronary artery disease. The presence of coronary heart disease (CHD) significantly increases the risk of cardiotoxicity[10]. In patients with already impaired myocardial blood supply, even minor damage can lead to serious complications such as myocardial infarction or progressive heart failure.

3.3 Diabetes mellitus. Diabetes increases the risk of cardiotoxicity by disrupting myocardial metabolism and increasing susceptibility to oxidative stress. For example, in patients with diabetes, the risk of cardiotoxicity from anthracyclines may be 30-50% higher.

3.4 Chronic renal failure. The kidneys play a key role in the elimination of many chemotherapeutic drugs. With renal insufficiency, the concentration of these drugs in the blood may increase, which increases the risk of cardiotoxicity[11].

4. Genetic predisposition. Genetic variations can affect the metabolism of chemotherapeutic drugs and their toxic effects on the heart[12]. Thus, mutations in the CYP2D6 and ABCB1 genes can alter the rate of drug elimination from the body, increasing their concentration in the blood and increasing the risk of cardiotoxicity. Variants of genes involved in antioxidant protection (e.g., SOD2, GPX1) may reduce the body's ability to withstand oxidative stress caused by chemotherapy.

5. Lifestyle. Smoking has a negative effect on the cardiovascular system, increasing the risk of atherosclerosis, hypertension and coronary heart disease. Patients receiving chemotherapy and smoking have a significantly increased risk of cardiotoxicity[13]. Chronic alcohol consumption can cause alcoholic cardiomyopathy, which increases the risk of myocardial damage during chemotherapy. Obesity is associated with metabolic syndrome, which includes hypertension, diabetes mellitus, and dyslipidemia. All these factors increase the risk of cardiotoxicity. Low physical activity reduces the functional reserves of the cardiovascular system, making it more vulnerable to damage.

Accordingly, the risk of cardiotoxic complications during chemotherapy is a complex phenomenon that depends on many factors[14]. To minimize this risk, it is important to conduct thorough screening of patients before starting treatment, take into account all possible risk factors, and use a personalized approach to choosing medications, dosages, and methods to protect the cardiovascular system. This approach makes it possible to increase the safety of treatment and improve the quality of life of patients.

Table 1. Risk factors for cardiotoxic complications during chemotherapy

The risk factor	Description	Examples of drugs/situations
Type of chemotherapeutic drug	Different drugs have different potential for cardiotoxicity, depending on their mechanism of action.	1.Anthracyclines (doxorubicin, epirubicin): cumulative dose >400-550 mg/m2. 2. Trastuzumab: combination with anthracyclines.
Cumulative dose	The higher the total dose of the drug, the higher the risk of cardiotoxicity.	Doxorubicin: cumulative dose >550 mg/m2 increases the risk of heart failure by up to 26%.
Combined treatment	A combination of several drugs can increase the negative effects on the heart.	Anthracyclines + trastuzumab: the incidence of heart failure reaches 27% in patients with HER2-positive cancer.
Patient's age	Old age increases the sensitivity of the heart to damage.	In patients over 65 years of age, the risk of cardiotoxicity from doxorubicin increases 2-3 times.
The presence of concomitant diseases	Arterial hypertension, diabetes mellitus, and coronary heart disease increase the risk of injury.	Diabetic patients have an increased risk of cardiotoxicity when using anthracyclines.
Genetic predisposition	Some genetic variants may increase sensitivity to cardiotoxicity.	Mutations in the CYP2D6 or ABCB1 genes can affect drug metabolism and increase their toxicity to the heart.
Previous radiation therapy	Radiation therapy of the heart area increases the likelihood of damage to the cardiovascular system.	Patients with chest tumors (for example, lymphoma) who received radiation therapy have a higher risk of cardiotoxicity.
Lifestyle	Smoking, alcohol abuse, obesity and a sedentary lifestyle increase the risk.	Obese patients are more likely to develop cardiotoxicity when using anthracyclines.

Monitoring of the cardiovascular system plays a key role in the prevention and management of cardiotoxicity in patients undergoing chemotherapy. Modern diagnostic methods make it possible to detect changes in the function and structure of the heart in the early stages, when they are not yet clinically manifested[15]. For the convenience of analyzing monitoring approaches that can be used depending on the availability of technology, the clinical situation and the individual characteristics of the patient, they have been summarized and presented in Table 2.

Table 2. Methods of monitoring the state of the cardiovascular system in cancer patients receiving chemotherapy

Diagnostic method	The main parameters of the assessment are	Advantages
Echocardiography (EchoCG)	a) left ventricular ejection fraction (LVEF); b) diastolic function; c)tissue dopplerography; d)global longitudinal deformation (GLD)	- an inexpensive and affordable method; - safe for the patient; - the possibility of repeated holding
Cardiomagnetic resonance imaging (CMRI)	a) left and right ventricular ejection fraction; b)the volume of the chambers of the heart; c) the mass of the myocardium; d) fibrous changes	- high sensitivity and specificity; - the ability to assess structural changes; - without using radiation
Biochemical markers	a)troponins (I, T): myocardial damage; b) natriuretic peptides (BNP/NT-proBNP): cardiac tension; c)galectin-3: myocardial remodeling; d)c-reactive protein (CRP): inflammation	- sensitive to early changes; – easily accessible through a blood test; –allow you to assess the degree of myocardial damage
Electrocardiography (ECG)	a) presence of arrhythmias; b) signs of myocardial ischemia (ST/T segment changes); c) QT and QRS intervals	- fast and inexpensive procedure; – widely available in all medical institutions
Stress tests	a) reserve capacity of the heart under stress; b) detection of hidden disorders of the heart function;	- they help to determine the functional reserves of the heart; – useful for patients with questionable results of basic research;
Genetic testing	c) identification of genetic variations associated with	– helps in personalizing treatment; – prevents the development of cardiotoxicit
Digital monitoring	a)heart rate; b)blood oxygen saturation level (SpO2); c) real-time cardiac activity	- the possibility of constant monitoring; – Ease of use (portable devices)
Artificial intelligence	a)data analysis to predict the development of cardiotoxicity; b)identification of hidden patterns of changes	- high accuracy of forecasting; - automation of the analysis process

Echocardiography (EchoCG) is a continuous, non-invasive method of assessing the function and structure of the heart using ultrasound. This method is widely used for monitoring the cardiovascular system due to its accessibility and safety[16]. EchoCG provides important information about the state of the heart, including the left ventricular ejection fraction (LVEF), which reflects the effectiveness of cardiac contraction. A decrease in LVEF is an important marker of myocardial dysfunction and may indicate the development of cardiotoxicity. In addition, the method allows you to evaluate diastolic function – the ability of the heart to relax between contractions, which is also important when detecting early changes. Tissue dopplerography, which is part of echocardiography, analyzes the movement of the myocardium and helps identify changes that may precede a decrease in LVEF[17]. Another sensitive indicator is global longitudinal deformation (GLD), which makes it possible to detect the initial signs of myocardial damage even before clinical manifestations. The advantages of EchoCG are its relatively low cost, safety for the patient (no radiation), and the ability to conduct multiple studies for dynamic monitoring. However, there are limitations: the quality of the study depends on the skill of the operator, and it may also be difficult with obesity or other factors affecting image quality.

Cardiomagnetic resonance imaging (CMRI) is a high–tech method that provides detailed information about the structure and function of the heart. CMRI makes it possible to evaluate parameters such as the ejection fraction of the left and right ventricles, the volume of the heart chambers, the mass of the myocardium, as well as the localization and volume of fibrous changes using contrast enhancement of late gadolinium retention[18]. In addition, the method allows you to evaluate the myocardial perfusion pattern, which is especially important for detecting blood supply disorders. The high sensitivity and specificity of CMRI make this method indispensable for detecting early changes in the myocardium that may go unnoticed by other methods[19]. It is important to note that CMRI does not use ionizing radiation, which makes it safe for the patient. However, there are certain limitations: the high cost of the study, limited availability in some regions, as well as the presence of contraindications such as metal implants or serious kidney problems.

Biochemical markers are substances whose level in the blood may indicate damage to the heart muscle or other disorders in the functioning of the cardiovascular system[20]. Troponins are proteins that are released into the blood when cardiomyocytes are damaged, and their elevated levels may indicate cardiotoxicity. Such markers are especially valuable for detecting early changes in the myocardium that are not yet clinically apparent. However, it is important to keep in mind that an increase in troponin levels can be caused by other causes, such as infections or ischemia. Natriuretic peptides (BNP/NT-proBNP) are produced by the myocardium in response to its stretching and increase with cardiac dysfunction.

They allow you to assess the degree of heart strain and predict the development of heart failure. However, the level of these peptides can be disrupted by kidney failure or old age. Other biomarkers include galectin-3, which is a marker of myocardial remodeling, and C-reactive protein (CRP), which serves as an indicator of inflammation and may be associated with oxidative stress in cardiotoxicity.

Electrocardiography (ECG) is a method of recording the electrical activity of the heart, which allows detecting rhythm disturbances, conduction, and signs of ischemia[21]. The main assessment parameters are the presence of arrhythmias (for example, ventricular extrasystoles or atrial fibrillation), changes in the ST segment or T wave indicating possible myocardial ischemia, as well as the values of the QT and QRS intervals, which may be increased by exposure to certain chemotherapeutic drugs. The advantages of an ECG are its speed, low cost, and wide availability in any medical facility. However, this method has low sensitivity for detecting subacute or chronic changes in the myocardium.

Stress tests, such as a treadmill test or echocardiography under stress, allow you to assess the function of the heart during exercise. This is especially important, since some hidden disorders can manifest themselves only with an increase in the load on the heart. Stress tests help to determine the reserve capacity of the heart and are useful for patients with questionable results of basic studies[22]. However, these tests are not always applicable to patients with limited physical activity, for example, those who are in serious condition or have severe motor impairments.

Modern technologies open up new possibilities for monitoring the cardiovascular system. Genetic testing allows you to analyze gene variations associated with increased sensitivity to cardiotoxicity, which helps in choosing safe doses of drugs. Digital monitoring using portable devices such as smart watches ensures constant monitoring of parameters such as heart rate, blood oxygen saturation and other indicators. The use of artificial intelligence and machine learning algorithms for data analysis makes it possible to predict the development of cardiotoxicity and take timely measures to prevent it.

The choice of methods for monitoring the cardiovascular system depends on many factors, including the availability of technology, the specifics of treatment protocols, and the patient's health status. The combined use of various approaches (for example, EchoCG to assess function, CMRI for structural changes, and biochemical markers for early detection of damage) provides the most complete picture of the state of the cardiovascular system and helps timely adjust treatment to minimize the risks of cardiotoxicity.

When the first signs of damage to the cardiovascular system occur in cancer patients receiving chemotherapy, it is necessary to adjust treatment tactics in a timely manner to prevent the progression of cardiotoxicity[23]. In addition, an important aspect is the introduction of modern prevention strategies, including the use of protective drugs and the optimization of the treatment regimen.

When the first signs of damage to the cardiovascular system are detected in patients receiving chemotherapy, it is necessary to immediately begin correcting treatment tactics. The first step is to accurately assess the degree of damage to the heart. The key markers of changes are a decrease in the left ventricular ejection fraction (LVEF) by more than 10% from the baseline level or to values below 50%, which indicates myocardial dysfunction. Increased levels of biochemical markers such as troponins and natriuretic peptides (BNP/NT-proBNP) may also indicate damage to the heart muscle. In addition, changes in the electrocardiogram (ECG), such as prolongation of the QT interval or changes in the ST/T segment, require additional examination to rule out progressive damage.

Based on the data obtained, it is possible to proceed with the modification of chemotherapy. One possible option is to reduce the dosage of the drug, which allows you to continue treatment with less risk to the cardiovascular system. Prolonging the intervals between courses of chemotherapy gives the body time to recover. In case of severe cardiotoxicity, replacement of the drug with a less toxic analogue may be considered. In case of severe changes in heart function, temporary or even permanent cessation of the use of cardiotoxic drugs may be required.

Cardioprotectors may be prescribed to support the cardiovascular system at the initial signs of cardiotoxicity. Beta blockers, such as carvedilol, have antioxidant properties and help prevent the progression of myocardial dysfunction. Angiotensin converting enzyme (ACE) inhibitors or angiotensin II receptor blockers (ARB) reduce the load on the heart and help improve its function. Digoxin can be prescribed with the development of heart failure to enhance myocardial contractility. In addition to drug therapy, lifestyle changes are recommended: light physical activity under medical supervision, a low-salt diet for patients at increased risk of hypertension or heart failure, as well as weight control to reduce the burden on the heart.

Modern cardiotoxicity prevention strategies are aimed at minimizing the risks of damage to the cardiovascular system. One of the key directions is the use of protective drugs. Dexrazoxane is an iron–binding substance that prevents the formation of free radicals caused by anthracyclines and significantly reduces the risk of cardiotoxicity. However, it is important to remember that dexrazoxane is not recommended to be used simultaneously with trastuzumab, as this may reduce its antitumor effectiveness. Mexetil, which is an antioxidant, protects the mitochondria of cardiomyocytes from damage, which makes it useful in the treatment of anthracyclines. Curcumin, the active ingredient of turmeric, demonstrates antioxi-

dant and anti-inflammatory properties, which makes it a promising tool for the prevention of cardiotoxicity.

Optimizing the administration of chemotherapeutic drugs also plays an important role. Liposomal forms of anthracyclines, such as dolastatin, reduce the systemic effect of the drug on the heart, while maintaining its antitumor activity. Continuous administration of drugs instead of rapid intravenous administration can reduce peak concentrations in the blood and, consequently, reduce the risk of cardiotoxicity.

Genetic testing opens up new possibilities for individualizing treatment. Screening makes it possible to identify patients with hypersensitivity to cardiotoxicity. For example, the presence of certain variants of the CYP2D6 gene may increase the risk of side effects when using certain chemotherapeutic drugs, which allows you to adjust the dosage in advance or choose alternative treatment regimens.

Finally, the use of digital technologies is becoming increasingly relevant in monitoring the state of the cardiovascular system. Wearing portable devices such as smart watches allows you to constantly monitor parameters such as heart rate, blood oxygen saturation and other indicators. This helps to identify early signs of heart disorders and take the necessary measures in a timely manner.

Thus, correction of therapy and prevention of cardiotoxicity require an integrated approach, including modification of chemotherapy, the use of cardioprotectors, optimization of drug administration, the use of protective equipment and the introduction of modern technologies. This multidisciplinary approach makes it possible to increase the safety of treatment and improve the quality of life of patients.

Conclusions

Cardiotoxicity caused by chemotherapeutic drugs is one of the most significant problems of modern oncology. A negative impact on the cardiovascular system can lead to a decrease in the quality of life of patients, limited opportunities for further treatment, and even fatal outcomes. Anthracyclines, trastuzumab, and multikinase inhibitors, which are often used in modern treatment protocols, are especially dangerous. Regular monitoring of the state of the cardiovascular system is necessary for the timely detection and prevention of cardiotoxicity. Modern diagnostic methods such as echocardiography, cardiomagnetic resonance imaging, biochemical markers (troponins, BNP/NT-proBNP) and electrocardiography make it possible to assess functional and structural changes in the myocardium at an early stage.

A personalized approach plays a key role in the selection of methods for monitoring and preventing cardiotoxicity. It takes into account the type of chemotherapeutic drugs used, the stage of the disease, the patient's age, the presence of concomitant diseases, and other individual characteristics. This approach makes it possible to optimize the use of diagnostic technologies and improve the safety of treatment.

Prevention of cardiotoxicity is no less important than its treatment. The use of protective drugs such as dexrazoxane, liposomal forms of anthracyclines, and antioxidants helps minimize the risk of damage to the cardiovascular system. In addition, genetic testing and optimization of the drug administration regimen also contribute to reducing cardiotoxic effects. Successful management of cardiotoxicity requires close collaboration between oncologists, cardiologists, pharmacologists, and other specialists. The interdisciplinary approach makes it possible to develop individual treatment plans that take into account both anticancer tasks and protection of the cardiovascular system.

The introduction of new technologies such as digital monitoring, artificial intelligence for data analysis, and personalized treatment strategies opens up new opportunities to improve therapy outcomes. Such innovations can significantly improve the effectiveness of monitoring and prevention of cardiotoxicity.

Regular monitoring of the cardiovascular system should be included in the treatment standards for all patients receiving cardiotoxic drugs. When the first signs of heart damage appear, it is necessary to immediately correct treatment tactics using a combination of modification of chemotherapy and the appointment of cardioprotectors.

Thus, ensuring the safety of the cardiovascular system during chemotherapy requires an integrated approach,

including modern diagnostic technologies, personalized monitoring and active use of preventive measures, which will improve the quality of life of patients and improve long-term treatment outcomes.

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